ROUTLEDGE HANDBOOKS

The Routledge Handbook of Global Sustainability Education and Thinking for the 21st Century

Edited by Michele John

"As a resource for those seeking to foster a culture of humility, and an ethic of restraint and creativity to match our fraught moment in history, this Handbook may prove invaluable."

Tim Winton *AO, Australian author*

"*The Routledge Handbook of Global Sustainability Education and Thinking for the 21st Century* takes on big topics like climate change, mass extinctions, food production, forests, population, energy, and waste, while speaking the language of higher education: faculty support and training, leadership, governance, pedagogies, competencies. May this handbook be the positive tipping point that transforms colleges and universities everywhere into the Noble endeavours we urgently need them to be."

Krista Hiser, *PhD Professor and Senior Lead and Advisor for Sustainability Education; Global Council for Science and the Environment, Washington, D.C.*

"A comprehensive international guide to the big issues facing humankind and what educators can do. A vitally important and timely book for teachers at all levels. Highly recommended."

David W. Orr, *Professor of Practice, Arizona State University and Editor:* Democracy in a Hotter Time (2023)

"Education is the single most important investment that any society makes – and this timely collection of essays underscores the fact that sustainability education must now be our #1 priority if we are to make sense of the emerging market and political dynamics of the Anthropocene epoch in which we now find ourselves."

John Elkington, *Co-founder of Environmental Data Services (ENDS), SustainAbility and Volans, Author:* Green Swans: The Coming Boom in Regenerative Capitalism (2020)

"The current development trajectory is not sustainable. It is no exaggeration to say that our civilisation can only survive if we are educated about the principles of sustainable futures. This Handbook gives educators the tools and examples to fulfill their responsibility to future generations, helping us all to live sustainably."

Ian Lowe, *Emeritus Professor and Author:* Australia on the Brink: Avoiding Environmental Ruin (2023)

"Progress toward sustainable development will require the reconceptualization and reorganization of our colleges and universities. Toward an essential transformation of sustainability education, this timely volume provides invaluable insights and practical guidance. The need to link knowledge with action is self-evident, and toward this end, the contributors provide a wide-ranging overview of the prospects for academic culture to contribute to shaping more sustainable futures."

Michael M. Crow, *President,* Arizona State University

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THE ROUTLEDGE HANDBOOK OF GLOBAL SUSTAINABILITY EDUCATION AND THINKING FOR THE 21ST CENTURY

This Handbook emerges as a pivotal resource in underscoring the important role of sustainability education in catalysing a global shift toward sustainable development. It articulates the need for a profound transformation within institutional leadership and educational frameworks to support the critical global sustainability transition.

This Handbook explores sustainability thinking as a critical paradigm shift in confronting the multifaceted challenges of sustainable development. It presents an urgent case for a systemic overhaul in our approach to education in the 21st century, advocating for multidisciplinary education and holistic systems thinking in order to more successfully navigate the complexities of sustainable development.

The text discusses the foundational elements of modern sustainability thought and management, including the significance of values, ethics, governance, and the pressing issues of environmental degradation and climate change. It offers an extensive trans-disciplinary overview of sustainability discourse, spanning a broad array of perspectives on sustainability management and education.

It provides a comprehensive introduction to the language of sustainability and a detailed examination of sustainability issues, highlighting their implications for education, training, and management development. It addresses urgent global issues such as decarbonisation, resource scarcity, population dynamics, pollution, and land degradation, emphasising the crucial role of educational initiatives in helping to mitigate these challenges.

This seminal work has been developed for a diverse audience, including academics, policymakers, students, and educators, serving as a valuable tool for those wanting to comprehend complex global sustainability challenges and the paramount importance of education in supporting global sustainability in the 21st century.

Michele John is Professor of Sustainability and Director of the Sustainable Engineering Group (SEG), Curtin University, Perth, Western Australia, Australia. Michele has been involved in sustainability education development for the past two decades. This Handbook was developed to fill an urgent need for a comprehensive resource in 21st-century sustainability knowledge and thinking for both education and management.

THE ROUTLEDGE HANDBOOK OF GLOBAL SUSTAINABILITY EDUCATION AND THINKING FOR THE 21ST CENTURY

Edited by Michele John

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"Bees work for man,
and yet they never bruise
Their Master's flower,
but leave it having done,
As fair as ever and as fit to use;
So both the flower doth stay
and honey run."

– George Herbert, from The Temple Providence (1633)

To the book's authors – Thank you for your untiring leadership in sustainability education.

To Annette Gough, Jordi Segalas, Roger Hadgraft, Jonathan Majer, Sonja Kuzich, Rachel Sheffield, Joseli Macedo, Teri Balser, Wahidul Biswas, Anulipt Chandan, Tony Lucey, Anna Torres and Stephen Iredell, for your intellectual leadership, sustainability ethic, and commitment to sustainability education. Your support in the development and review of this Handbook has been invaluable.

To the Achilles Group – A very big thank you for your funding of the Open Access publication of this Handbook. Your dedication and commitment to sustainability will enable the global dissemination of this Handbook and its sustainability wisdom.

To my mother, Patricia Anne Judge (nee Alford), who taught me the vital importance of recycling and resource recovery and waste management from an early age. Thanks, Mum.

To Maxine Prentice, my first teaching mentor, and Jan Wroth, whose art inspires me every day.

And to Mother Nature. Thank you for your innate beauty, wisdom, and support of our lives.

Deo Gratia

Michele John
December 2024

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EDITORIAL PREFACE

Education for the sustainability transition

"The crisis in education, however, runs much deeper and goes beyond the challenge of equity and equality. Study after study, poll after poll, draw the same conclusion: education systems are no longer fit for purpose. Young people and adults alike report that education does not equip them with the knowledge, experience, skills, or values needed to thrive in a rapidly changing world. Learning continues to underplay skills, including problem solving, critical thinking and empathy. . . . Today, millions of learners are denied their fundamental right to quality education, and societies are left ill-prepared to overcome intersecting crises that threaten our collective future – climate disruption, poverty, increasing inequality, cultural and political polarisation, lack of trust, and conflict. All of this can and must change."

(António Guterres, Secretary General, United Nations Transforming Education Summit, New York, September 2022)

Global Sustainability Education and Thinking in the 21st Century establishes the primacy of sustainability education, its significant multidisciplinary focus, the critical connection it establishes between humans and their environment, and the wide variety of sustainability values that should be included in curricula regardless of the discipline being taught.

This Handbook provides a comprehensive introduction to the main concepts, learning approaches, values, and contextual influences in sustainability education. The authors presented in this Handbook have significant experience, and many are internationally renowned for their teaching and research in sustainability education. This Handbook provides a broad introduction to the critical role, value, and application of sustainability concepts in our modern lives. Taken together, the chapters in the Handbook will enable educators, academics, students, and policy makers to grasp the scale, complexity, and inherent responsibilities we have in educating and preparing for the challenges of the 21st-century sustainability transition.

The Handbook contains more than 60 chapters on sustainability education, developed from a wide array of disciplines, across several important curricula and pedagogical perspectives. The authors were chosen because of their leadership in the subject area and their expertise in sustainability education teaching and scholarship. This Handbook was specifically developed to provide readers with an interconnected and multidisciplinary introduction to sustainability education, one that brings together important sustainability contexts and concepts with a broad array of teaching pedagogies.

Currently there is no commonly agreed framework for the teaching of sustainability (Cebrián et al. 2020). What constitutes a sustainability education is largely still a work in progress in many education institutions across the world. Answering this very question is the raison d'être of this Handbook. It addresses this challenge through a focus on the following questions: What knowledge, thinking skills, and values do we need to foster in the sustainability transition? What focus and content should be included in sustainability education? And finally, what should educational institutions, and perhaps more broadly industry, do to lead, enable, and build sustainability education and encourage more sustainable development during this time?

In response, the Handbook's authors suggest that modern sustainability education and management should be founded on the principles of equity for future generations, systems thinking, eco-efficient production, resource recycling and recovery, eco-design, corporate social responsibility, community engagement, and environmental stewardship and impact assessment. Together they propose that modern sustainability education should reference these principles across the disciplines as part of engendering a comprehensive value system that supports and actions these principles.

Reference is made to various levels of sustainability education, including primary school and secondary school, but the book is largely focused on tertiary education, given the increasing importance of professional development education and university public good focused research and leadership in providing solutions for the sustainability transition.

The United Nations Millennium Development Goals (2015a) were a pivotal point for many educators in starting to recognize the need for an education focus on decoupling environmental and social impact from ongoing economic growth (United Nations, 2015a). The eight Millennium Development Goals were followed up in 2015 with the development of the 17 Sustainable Development Goals (SDGs), with a continued focus on third world poverty and education and an increased focus on major global environmental issues including global warming, marine pollution, and biodiversity loss (United Nations, 2015b).

These topics are fundamental to sustainable development but only provide part of the focus needed in sustainability education. Fundamentally, the SDGs are premised on a continuation of the traditional non-sustainable ways in which our modern economy, industry, and governance operate. There are also many additional imperatives that need to be considered that are not directly covered by the SDGs, including population growth and diminishing resource levels. This Handbook seeks to provide a more holistic conception of sustainable development in redressing the impacts of continued linear economic growth on our future.

We believe this Handbook will help modern educators appreciate the urgent need for transformative sustainability education development and encourage them to prioritise sustainability-focused content within their curricula. We also hope that this Handbook offers ideas and tools for how educators might go about the task of taking up the responsibility for sustainability education development and delivery.

Section 1 of this Handbook presents several topics that help frame the important role of sustainability education in the sustainability transition, including climate change education, ecological systems thinking perspectives, the importance of a sustainability mindset, and the honeybee as a metaphor for sustainability. In Section 2, we introduce the reader to important some of the fundamental concepts needed in sustainability education and the important language of sustainability, which is relevant to all disciplines.

In Section 3, we review the main sustainability challenges to be faced in the 21st century and frame the importance of these as prima facie features of sustainability management.

Section 4 discusses the 'key competencies' that should be included in sustainability education – the skills that all students should be familiar with to help frame and solve the 'wicked problems' we face in global sustainable development.

Section 5 reviews how to 'educate the educators' – the important task of giving our educators a sustainability education so that they can effectively teach sustainability. Given the scant regard that has been given to the training and development of teachers/educators/sustainability champions in sustainability education content and curricula development, this is an important contribution of the Handbook.

Section 6 provides a review of successful international strategies and teaching pedagogies in sustainability education across a wide variety of disciplines.

In Section 7 we give important recognition to both climate change and environmental education as fundamental components of sustainability education.

Section 8 examines the role of ethics, values, and governance in both framing sustainability education and in helping us to better understand our responsibilities in sustainable development.

In Section 9 we reflect on the critical role of university leadership in both sustainability education and sustainable development.

This Handbook calls for the urgent development of sustainability education as the world transitions to new reference points for good governance, environmental stewardship and public leadership, as we move toward a new regenerative sustainability paradigm, one that embraces increased responsibility and understanding of the 'common good' in community, global growth, and our natural environment.

Professor Michele John, Editor
December 2024

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SECTION 1

Global sustainability education and thinking for the 21st century

> *"The weight of our civilization has become so great, it now ranks as a global force and a significant wild card in the human future along with the Ice Ages and other vicissitudes of a volatile and changeable planetary system."*
>
> *(Dianne Dumanoski, 'Rethinking Environmentalism', 1998)*

There is an urgent need for sustainability-focused education and thinking, particularly given the significant array of global 'wicked problems' including climate change, sea level rise, biodiversity and habitat loss, resource depletion, and environmental degradation.

Since the beginning of the industrial age, we have unwittingly created these challenges in our quest for progress and development. Although the capitalist growth model has without doubt improved global health and lifestyles, it has come at a cost to world ecology and future generations. The management of this interface between the environment and our consumption and production is a major challenge in the 21st century's sustainability transition. Addressing these challenges poses many demands on sustainability education development.

Educational institutions have an increasingly important role in preparing our students as future leaders and global citizens, starting with an introduction to the interconnected economic, environmental, and social complexities of our modern world. As community leaders, educators have a responsibility to provide an education that prepares students and graduates for a world requiring increased resilience in management, anticipatory governance, recognition of the important value of First Nations wisdom and knowledge, and an overall understanding of the importance of the Earth's ecology in sustaining us.

Given the complex, multi- and transdisciplinary challenges of sustainability education development, several chapters are included in Section 1 to set the scene for the potential scope, definition, and challenges for sustainability education. First, an introduction to sustainability education is provided (see Chapter 1.1 in this volume). Second, given the importance of climate change as a global sustainability issue, two chapters on climate change – our historical climate change evolution (see Chapter 1.2 in this volume) and the importance of understanding global climate change pressures (see Chapter 1.3 in this volume) – are

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presented. Following this, four chapters are provided that use the metaphor of honeybees and pollinators as models of sustainable: living, thinking, management, and leadership.

These chapters help demonstrate the fundamental value and learnings we can take from our environment in the development of sustainability education and highlight the critical role of our global ecosystems in providing profound sustainability knowledge and thinking in the 21st century. Sustainability education needs to embrace several important environmental parameters, including the fact that we have only one Earth, and the need for all humans to play a critical role in maintaining and protecting Earth ecosystems, now and into the future.

These chapters also introduce several concepts and principles derived from the life of the honeybee, which help us to understand the critical value of nature and our ecosystems in providing the fundamental environmental education foundations of sustainability education. The bee and the hive metaphor also help frame the role and value of 'personal responsibility' in sustainability education.

The care and maintenance of our Earth ecosystems is an important tenet of this Handbook and is demonstrated well by the humble honeybees, with their commitment to their individual responsibilities in supporting both the hive and the next generation of honeybees. Bees are renowned for being hard-working, resilient and robust creatures, attuned to and protective of their environment. They symbiotically provide pollination services to their ecosystem, which in return provides pollen and nectar for the nourishment of the hive. They are an integral part of their ecosystem.

The same cannot easily be said of humans and the roles we play in our own ecosystems. Bees work together for the good of the hive. Each has a role to play as a worker bee gathering pollen, a drone taking care of the bee nursery, or the egglaying queen bee. Each must measure its productivity relative to the pollen and water available and various ecosystem threats and challenges, including seasonal variations. The management of the 'common good' is the hive's focus. What is good for one is good for all. As Roman Emperor Marcus Aurelius profoundly noted – "That which is not good for the beehive cannot be good for the bees."

Pavan Sukhdev, in the United Nations report, *The Economics of Ecosystems and Biodiversity* (2009) reflected on the services provided by bees and noted: "Not a single bee has ever sent you an invoice. And that is part of the problem; because most of what comes to us from nature is free, because it is not invoiced, because it is not priced, because it is not traded in markets, we tend to ignore it."

Campbell and Dixon (see Chapter 1.4 in this volume) explore the important role of the bee and bee pollination in our modern lives and our indirect impacts on bees and their pollination services, which play a vital role in our food production systems. They suggest that bees as pollinators are a key sustainability indicator of the health and productivity of our ecosystems, including in agricultural landscapes, noting that honeybees are one of tens of thousands of species of pollinators globally, each supporting a particular ecosystem niche. Campbell and Dixon however note that as pollinator populations have been in decline for several decades, the restoration and conservation of ecosystems in general, and for pollinators in particular, is becoming very important to their, and our human, long-term well-being and survival.

Next, the journal article by Patel et al. (*Ambio*, 50, 2021) (reproduced with permission in (reproduced with permission in Chapter 1.5 in this volume) highlights the crucial role that bee pollination plays in sustainable development through food security and biodiversity enhancement. They argue that bees contribute toward 15 of the 17 Sustainable Development Goals (SDGs) and at least 30 SDG targets and suggest that an improved understanding of bee contributions to sustainable development is crucial for ensuring viable bee systems and the attendant food security and biodiversity benefits. They advocate for appropriate natural resource management approaches as vital in allowing the continued success of bees in their natural role. Finally, they argue that we must reverse bee decline trajectories if we are going to rely on bees in future sustainable development efforts.

Cowie and Mildenhall (see Chapter 1.6 in this volume) discuss the strategic role of teachers as 'pollinators' of sustainability education and the critical role they play in fertilising the minds of our current generation with a sustainability ethic. They also note the important role of understanding and engaging with nature to help foster a sense of connection and interdependence, together with a recognition of responsibility for nature protection and conservation. They suggest that education, like that involving curricular exploration of the functioning of the beehive, can help provide foundational learning that highlights the inextricable link between human health and productivity and the health of our ecosystems.

In reviewing the broader context of sustainability management, Bergsteiner and Avery (see Chapter 1.7 in this volume) compare the leadership styles of honeybees and locust. They contrast 'honeybee' leadership and its focus on 'all in it together' with the self-focused 'locust' leadership. They suggest that business-as-usual 'locust' leadership emphasises the interests of single groups of stakeholders, such as owners and investors, seeking to maximise returns for those groups in the short term, often at the expense of other stakeholders. By contrast, sustainable 'honeybee' leadership focuses on long-term benefits to multiple stakeholders. These include individuals, groups, organisations, nations, human society, the natural environment, and future generations. They note that 'honeybee' educators should promote the kinds of decisions, actions, behaviours, and systems that deliver sustainable outcomes and reinforce sustainability thinking.

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1.1 A NOBLE EDUCATION

Sustainability education in the 21st century

Michele John

Introduction

"The aim of education is the knowledge, not of facts, but of values."

(William S. Burroughs)

Key concepts for sustainability education

- A noble education establishes the primacy of sustainability education and the critical connection it establishes between humans and their environment and includes a wide variety of sustainability responsibilities, ideals, and values within a multidisciplinary focus.
- The purpose of a noble education is to help teachers, educators, students, industry professionals, and policy makers gain a better understanding of important sustainability knowledge and thinking and our shared responsibilities in sustainable development, across all curricula.
- A noble education changes the dominant anthropocentric paradigm to one that views humankind as partners in an ecological system; accepts that all life forms are important and connected, and that this interdependence requires healthy ecosystems, values diversity, and social justice; and understands they are all valuable in achieving sustainability.
- Many of the challenges that the world faces, including climate change, economic growth versus planetary resource levels, increasing pressures on land use change, ongoing biodiversity loss, and ongoing changes in the way we assess our productivity and progress in the 21st century, need to be included in sustainability educational curricula.
- Educational institutions need to implement the necessary policies, practices, pedagogy, infrastructure, and accountability frameworks, to guide and measure their progress in sustainability education development.

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- Sustainability education should develop future-focused and environmentally conscious citizens with the resilience and foresight necessary to manage our world more sustainably than previous generations. This indeed would be a noble education.

A noble education: sustainability education in the 21st century

A 'noble education' in the 21st century should communicate the new paradigms of sustainability thinking, aid in the development of critical thinking skills to support collaborative sustainability decision making, encourage the development of personal sustainability commitment and leadership, provide an understanding of the values that support wellbeing for all ecosystems on earth, encourage the use of newly developing sustainability principles and values, and impassion the ideal of each individual having responsibility for being the sustainability change we need to see happen.

In helping to provide solutions for these new paradigms, increased focus on First Nations culture and perspectives, regenerative sustainable development values, and enhanced transdisciplinary collaboration will become more important in sustainability transition management (see Chapters 5.6, 6.5, and 7.6 in this volume).

With over 60 chapters, this Handbook helps to frame a wide discourse of important responsibilities, ideals, and values that are essential within a noble education. This Handbook aspires to help teachers, educators, students, industry, and policy makers gain a better understanding of current sustainability knowledge and thinking and our shared responsibilities in sustainable development.

We contend that a noble education should develop future-focused citizens with the resilience and foresight necessary to manage our world more sustainably than previous generations. Many of the chapters in this Handbook call for an increased focus on sustainability leadership, training, and governance by industry and government. From a sustainability education leadership perspective, we discuss university best practice in sustainability leadership and how to prepare educators to deliver effective sustainability education.

The connection between our environment and sustainability education

The metaphor of the honeybee and the beehive has been used in Section 1 in this Handbook to introduce sustainability thinking and highlight the connection between nature and productivity, on the one hand, and nature as a deftly self-organised ecosystem, on the other. Anthropocene thinking could learn from honeybees given their interdependency, self-sufficiency, and innate regard and respect for the ecosystems they inhabit. The hive and its bees are wonderful examples of sustainability – the hive works for the greater good, and all in the hive play an important role in its daily life and its future (see Chapters 1.4, 1.5, 1.6, and 1.7 in this volume). Honeybees innately understand the critical connection between their environment and their survival.

Research has demonstrated that connectedness to nature encourages sustainable behaviours and improves wellbeing in both adults and children. Our sense of understanding and value for nature and our connection with nature are clearly important features in our ability to value and protect the environment that sustains us (see Chapter 1.6 in this volume).

Consistent with this, UNESCO's 2021 report, 'Reimagining our futures together: A new social contract for education', asserted that:

> Curricula must enable re-learning how we are interconnected with a living, damaged planet.
>
> *(https://oidel.wordpress.com/2021/12/15/unescos-report-reimagining-our-future-together-a-new-social-contract-for-education/)*

Many of the anthropogenic challenges that the world faces, including climate change, continued demand for economic growth, increasing pressures on land use change, and biodiversity loss, will require fundamental changes in our educational curricula and the way we assess our productivity and progress in the 21st century. Section 1 in this volume examines many of these themes.

Climate change impacts will also demand increased global resilience in the 21st century. The most recent Intergovernmental Panel on Climate Change (IPCC) climate report, published in March 2023, warns that:

> There is a more than 50% chance that global temperature rise will reach or surpass 1.5 degrees C (2.7 degrees F) between 2021 and 2040 across studied scenarios, and under a high-emissions pathway, specifically, the world may hit this threshold even sooner – between 2018 and 2037. Global temperature rise in such a carbon-intensive scenario could also increase to 3.3 degrees C to 5.7 degrees C (5.9 degrees F to 10.3 degrees F) by 2100. To put this projected amount of warming into perspective, the last time global temperatures exceeded 2.5 degrees C (4.5 degrees F) above pre-industrial levels was more than 3 million years ago.
>
> *(IPCC 2023)*

Climate change is expected to create a myriad of problems across the world over the next 30–50 years, including increased flooding, fires, droughts, and heatwaves, in addition to its impact on public health. Furthermore, the question of the impact of climate change on our mental health and wellbeing could well put the challenges of the global COVID pandemic of the early 2020s metaphorically in the shade (see Chapters 1.2, 1.3, and 2.1 in this volume).

Resource depletion and sustainable resource management are also important sustainability topics to ensure that our resources are not depleted to the point that they will negatively impact current generations or limit future generations in their ability to meet their own growth needs (see Chapters 2.3, 2.7, and 2.8 in this volume).

Increasing 21st-century demand for agriculture and food production, industrial production, and renewable energy infrastructure will also place significant pressures on global resource management and environmental impact (see Chapters 2.5, 2.7, and 2.8 in this volume).

The 'Industrial Revolution 4.0' will see increasing automation and dematerialisation of industry and manufacturing, improving sustainability performance and increasing the focus on circular economy thinking. The futuristic 'Industrial Revolution 5.0' will put more emphasis on sustainability stewardship and circular economy resource efficiency and will incorporate more responsibility for sustainability performance. (see Chapters 2.4, 3.7, 4.5, 6.7, 7.7, and 8.4 in this volume).

The scale of environmental impacts that are associated with our increasing production and consumption decisions in the 21st century will also need to consider new paradigms in our economic business models, governance frameworks, and sustainability transition thinking (see Chapters 3.1, 7.3, 8.1, and 8.2 in this volume).

In helping to provide solutions for these new paradigms, increased focus on First Nations culture and perspectives, regenerative sustainable development values, and enhanced transdisciplinary collaboration will become more important in sustainability transition thinking and management (see Chapters 5.6, 6.5, and 7.6 in this volume).

A noble education will require educators to focus on transformative learning that highlights the life cycle impacts of our production and consumption activities on the environment, together with the development of curricula that can support the formation of a sustainability mindset that empowers students into sustainability action (see Chapters 3.4, 4.2, 4.3, 4.6, 5.3, 5.5, 6.2, 9.2, and 9.7 in this volume).

What capabilities should a noble education in sustainability develop?

> "Only when the last tree is cut down, the last fish eaten, and the last stream poisoned, you will realise that you cannot eat money."
>
> *(Cree Indian Proverb)*

A noble education should help develop resilience, wisdom, agility, and anticipatory precaution in students of the 21st-century sustainability transition. It should also include taking our global education pillars beyond fundamental literacy and numeracy into a domain that the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the United Nations Development Goals see as critical, where our students become global citizens, who work for the common good in order to foster the long-term welfare and wellbeing of current and future generations (see Chapter 7.2 and Section 9 in this volume).

Laufenberg-Beermann et al. (2019) suggest that education is now needed that helps to develop a 'sustainable mindset', where students can importantly demonstrate a range of characteristics that are not discipline specific and provide for a holistic consideration of the impacts associated with our production and consumption decisions and help develop the agency required to develop their own solutions.

Rimonaczy (2020) presents educators with '12 Principles for a Sustainability Mindset' including: 1) state-of-the-planet eco-literacy, 2) identifying ways in which we contribute to sustainability problems, 3) long-term thinking, 4) creative solutions that involve all stakeholders, 5) accepting that the laws of nature flow through cycles, 6) diversity and interconnectedness, 7) creative innovation and experimentation, 8) reflective practices, 9) self-awareness, 10) oneness with nature, 11) mindfulness, and 12) purpose to shape a better world. These principles are evident throughout this Handbook.

Kuzich (see Chapter 9.2 in this volume) notes that sustainability education needs to move from "peripheral, fragmented representation in the curriculum, where it may be considered just another 'important' topic, into becoming a more strategic, integrated, and holistic theme across all disciplines and which is valued in all curricula" (see Chapters 9.2 and 9.4 in this volume).

Sustainability education needs to change the dominant anthropocentric paradigm to one that views humankind as partners in an ecological system. It needs to present the many challenges and trade-offs inherent in the interdependence of social, economic, and ecological systems and provide an understanding that all life forms are important and connected, and that this interdependence requires healthy ecosystems, values diversity, and social justice, where they are all considered valuable in achieving sustainability.

To effectively teach these interdependencies, a number of threshold concepts could be presented that help to illustrate the critical link between human consumption and its environmental and social impacts (see Chapter 3.2 in this volume). How do we incorporate a critical systems thinking approach in the presentation of our sustainability challenges that helps us to understand the effects of our planning, design, and technology development on sustainable development (see Chapters 3.1, 3.3, 3.6, 4.1, and 4.2 in this volume) and that enables a transition away from an anthropocentric view of the world to an eco-centric vision of interdependency (see Chapters 7.1, 7.2, and 7.7 in this volume)?

Solid foundations in sustainability education need to shift our thinking and teaching away from a utilitarian framing of human existence to one in which the world is viewed through a socio-ecological lens where the human/nature relationship is framed in terms of environmental stewardship and responsibility (see Chapters 2.2 6.2, 7.1, 7.4, 7.7, 8.4, and 9.2 in this volume).

An educational system that includes complexity and systems thinking and provides students with an opportunity to deal with real-life sustainability-related problem solving is also critical (see Chapters 4.1, 6.3, and 6.4, in this volume).

In developing solid sustainability-focused curricula, competencies must be developed that enable students to critically understand prevailing values, policies, and practices, whilst empowering them to make decisions to act for change and transformative impact (Dlouhá et al. 2019) (also see Section 4 in this volume).

Pedagogical development that addresses cognitive, social, and affective dimensions of learning are also essential in sustainability education in the development of transformative thinking and behaviour (Sterling 2003; Kuzich 2019) (see Section 6 in this volume).

Sustainability values and principles

> "For many of us, water simply flows from a faucet, and we think little about it beyond this point of contact. We have lost a sense of respect for the wild river, for the complex workings of a wetland, for the intricate web of life that water supports".
>
> *(Sandra Postel, 'Last Oasis- Facing Water Scarcity', 2003)*

Given our current era of fast moving technology development, improvements in public health, global travel, large-scale resource mining, infrastructure development, and the exponential growth of conspicuous middle-class consumption, what values and sense of responsibility should we develop to help ensure the next generation enjoys the same opportunities? How do we ensure that the 'developing world' (i.e., Brazil, Russia, India, China, and Africa) are afforded the same opportunities for improvements in standards of living without inducing the same environmental and social costs that 20th-century economic growth presented in the 'developed world'? How can we prevent the same negative legacies from the 20th century from affecting the lives of our great grandchildren in the 22nd century? Intergenerational equity is a very important motive for action in sustainability education.

The determination of our primary sustainability values is a challenge for any educator and requires a comprehensive understanding of sustainability context, community values, and prevailing norms (see Chapters 2.4, 3.5, 4.5, and 9.5 in this volume).

This Handbook suggests that sustainability values should include the broad goals of the 17 Sustainable Development Goals (SDGs) and incorporate increased focus on climate change management, biodiversity protection and conservation, the replacement of fossil fuels with renewable energy options, and responsible production and consumption and circular economy thinking.

Additionally this Handbook has further highlighted the important role of the following principles, ideals, and future-focused expectations for the sustainability transition: life cycle and circular economy thinking (particularly around waste management); regenerative production systems; recognition of First Nations cultures and traditions; broader acceptance of community engagement and empowerment in modern governance systems; increased levels of corporate stewardship and corporate social responsibility; increasing expectations from sustainability leadership; the committed use of eco-design principles in our production and consumption activities; the need for increased sustainability assessment and sustainability performance measurement and governance; the urgent need to collaborate on a variety of local/national and international sustainability issues; the use of precautionary principles in production and development planning; and the paramount role of sustainability management and education in both developing and enabling the sustainability transition.

What do universities need to do to help lead in the sustainability transition?

> "But man is a part of nature, and his war against nature is inevitably a war against himself."
>
> *(Rachel Carson (1907–1964),* Silent Spring, *1962)*

At a university level, what is required is a reorientation or recontextualisation of our education curricula with an urgent sustainability focus and the need to support this with the implementation of necessary policies, practices, pedagogy, and infrastructure, together with the development of an accountability framework to measure the achievement (see Chapters 9.1, 9.2, 9.3, and 9.4 in this volume).

An additional missing link in the development of sustainability education is perhaps the need for sustainability education accreditation systems that could assist with the establishment and dissemination of sustainability courses to ensure a foundation for globally and nationally recognised sustainability education curricula. This could be provided at an industry level, a state level, or a national level and could be a valuable driver of sustainability education implementation and development.

Sustainability education will also need to provide important opportunities for negotiation skills and empathy development, which underpin ongoing sustainability dialogues and collaboration at local, regional, and international governance and policy levels (see Chapters 4.6, 5.4, 6.5, 6.6, 6.7, and 8.5 in this volume).

Furthermore, sustainability education needs to focus on the development of critical thinking, problem solving, and the mediation skills necessary to solve complex global sustainability issues (see Chapters 4.4 and 9.4 in this volume).

Sustainability education is therefore not only a process of learning new ways but is also a pivotal process in reconsidering, unlearning, and replacing dominant ways of seeing and acting in the world that have contributed to unsustainable practices (UNESCO 2021).

The UNESCO (2021) report ‘Reimagining our futures together. A new social contract for education’ highlights the importance of universities in developing the affective components of student understanding to help transform the learning experience in sustainability and developing the agency and emotional cognition needed for significant behaviour change towards sustainability outcomes.

Barrineau et al. (2021) discuss the scope of the sustainability education challenge for universities and asked: How can universities and university leadership help prepare students and society to deal with “unpredictable and incalculable futures” (Barrineau et al. 2021) (see also Chapters 9.1 and 9.2 in this volume).

Are our teachers and educators prepared for the sustainability transition?

> “The highest education is that which does not merely give us information but makes our life in harmony with all existence.”
>
> *(Rabindranath Tagore, 1861–1941)*

Teachers are critical sustainability education agents of change and can provide foundational learning that links human health and productivity and the health of our ecosystems (see Chapter 1.6 in this volume).

However, does the teaching profession have the knowledge and skills necessary to develop and teach a sustainability education program (see Chapters 5.1, 5.3, 5.4, and 5.5 in this volume)? Do they have adequate sustainability knowledge themselves to be able to discern the core sustainability principles for their discipline and teach them effectively? If academics have not received formal training in sustainability education content, curricula, and supporting pedagogies, how are they to effectively teach sustainability education?

In addition, sustainability education must provide supporting ethics and values that help to demonstrate the behaviour change and sustainability actions that will be needed for the sustainability transition (see Chapters 8.1 and 8.2 in this volume).

Teachers also need to be provided with the professional development necessary to design curricula and pedagogy for teaching sustainability and, importantly, must also be given the time and resources to develop the required courses (see Chapters 5.1, 5.3, 5.4, and 5.5 in this volume).

Schools and universities need to help encourage focus on sustainability education development and to develop internal organisational mechanisms that help guide and support the curricula being developed, help embed sustainability education in the institutional curricula culture, and encourage a transdisciplinary approach to education for sustainability (EfS) development and delivery (see Chapters 9.1, 9.2, and 9.3 in this volume).

The planning of this curricula development is also very important so that there is no fragmentation of sustainability subject content and a holistic and systems-based model of sustainability education is provided (see Chapter 9.2 in this volume).

Many universities are using the 17 UN SDGs (United Nations 2015) as a starting point in the framing and development of sustainability education. However, many academics regard the SDGs as a flawed framework (Steele and Rickards 2021 and see Chapter 9.2 in this volume) that does not effectively address many power imbalances and global structural inequalities. In addition, many would see the SDGs as reinforcing the linear economic growth model of development that has caused many of the sustainability issues that the SDGs are trying to address (McLoskey 2021).

Increased focus on sustainability governance

Sustainability governance responsibilities should also be included in sustainability curricula content (see Chapters 7.4, 7.5, 8.3, and 8.5 in this volume). Educational institution management, including sustainability metrics, sustainability education development, and sustainability leadership, are also important governance challenges to address (see Chapter 9.1 in this volume). Kuzich (see Chapter 9.2 of this volume) notes that "universities are in a unique position to influence thinking, given their remit for research, innovation and the creation of new knowledge, which has the potential to disrupt orthodoxies and the status quo; the kind of thinking that has brought us to the current crisis".

Sustainability governance and policy are natural extensions of the ethics and values required in sustainability education. In our increasingly complex world, the requirements for international treaties and governance are moving from the domain of enhanced trade and economic growth to encompass the all-important need for transnational decision making and environmental governance (see Chapters 7.5, and 8.5 in this volume). International governance organisations like the IPCC (IPCC 2022) have consistently highlighted the importance of the need for increasing understanding and management of our shared global inheritance.

Educational leadership in the sustainability transition

> "Sustainability education has come of age – precisely when our troubled age makes sustainability education imperative. The urgency of our times requires agency – to ensure decisively that globally and locally we make and take a pathway of safety and wellbeing, rather than descend into the chaotic scenario that is currently in prospect.
>
> The difference between these futures pivots on deep and widespread individual and societal learning. This is where higher education must now aspire to a higher purpose, something this timely and comprehensive Handbook calls 'noble education'.
>
> Over the past few decades, environmental and sustainability education has been developing, debated, and practised worldwide and now offers a rich, robust, hopeful and holistic vision for re-thinking and renewing educational paradigm, purpose, policy and practice as a whole.
>
> We have no time to lose. This Routledge Handbook of Global Sustainability Education and Thinking in the 21st Century is here to make a difference: to challenge, inspire and motivate the flourishing of education for the regenerative transformation that expert opinion underscores – and that the public senses is necessary to build a positive future."
>
> ***Stephen Sterling,*** *Emeritus Professor of Sustainability Education, University of Plymouth, Author:* Learning and Sustainability in Dangerous Times. *Agenda Publishing (2024)*

Sustainability education needs to play a significant role in establishing the 'true north' of sustainability management in our modern times. Given the reluctance shown by many nations in committing to serious climate change management though the IPCC Conference of the Parties (COP) meetings, a much broader avenue must be sought to enact the sustainability change we desperately need.

Furthermore, sustainable ('honeybee') education leadership will need to focus on long-term benefits to multiple stakeholders – individuals, groups, organisations, nations, human society, the natural environment, and future generations, with ('honeybee') educators seeking to promote the kinds of decisions, actions, behaviours, and systems that deliver sustainable outcomes (see Chapter 1.6 and 1.7 in this volume).

The roles of central governments, industrial companies and organisations, educational institutions, policy makers, and educators are also critical in the sustainability transition. Many developing countries like India, Indonesia, and China have already made notable progress in sustainability education by virtue of their central governments taking a leadership role in the development of national sustainability education curriculum (see Chapters 9.5, 9.6, and 9.8 in this volume). In addition, a number of international universities have made significant progress in sustainability education curricula and pedagogy development, many learnings of which have been presented in this Handbook (see Section 6 and 7 in this volume).

Developing sustainability education accreditation systems is another area of critical need, and such systems could play an important role in the promotion and development of sustainability education globally (see Chapters 3.2, 4.5, and 9.5 in this volume).

A noble education, covering a broad array of sustainability education content and sustainability values, is an essential catalyst and leverage point in the sustainability transition. Sustainability education will need to provide the knowledge and thinking skills necessary to elevate our community's understanding of the global challenges we face and the noble efforts that will need to be made to ensure a sustainable future.

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1.2
THE CO-EVOLUTION OF CLIMATE AND LIFE ON EARTH
A sustainability contest between survival, succession and extinction

Paul F. Greenwood and Kliti Grice

Key concepts for sustainability education

- Life on Earth started more than 4 billion years ago and has since evolved with increasing diversity and sophistication, with many resilient organisms able to survive periods of catastrophic environmental disturbances (e.g., mass extinction events).
- A baseline knowledge of environmental and biological processes and dynamics on Earth is required to appreciate present-day trajectories of concern – including those attributable to human activity – and to accurately assess their ecological threat.
- Better environmental literacy requires the incorporation of greater earth science content in scientific curricula, countering a tendency for it to be hidden within traditional science, technology, engineering and mathematics (STEM) subjects and narrow student perception of earth and environmental science subjects.
- Present-day climate change is real and at least partially attributable to the industrial activity of humans, with temperature and CO_2 rises over the last 200 years at close to historical highs. A reckoning of the potential ecological consequences of this climate crisis has led to intensified change action by developed societies, with harmful practices being phased out and mitigation strategies developed.
- Effective, wide communication of environmentally sustainable practices and technologies (including climate change mitigation) is needed, so that contemporary know-how is shared with and adopted by a large world community.

The evolution of life

The origins of life and evolution of mankind remain two of humanity's most profound and contentious issues. Scientists believe life on Earth commenced around 4 billion years ago, and its subsequent evolution has been closely linked with the planet's climate and biosphere trajectories. Given the sharp climate change of recent times and concerning predictions of alarming environmental headwinds, the future sustainability and viability of life on Earth, particularly human occupancy, are also now pressing issues.

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The first living organisms on our planet were likely created through the opportunistic interaction of simple organic compounds (e.g., CH_4, CHN), which may have been tectonically vented from the Earth's mantle or produced by reaction of CO_2 with other inorganic gases (e.g., H_2, N_2). With formulative development, the variety and complexity of early life slowly increased and ultimately acquired the ability to functionally reproduce, representing a key inflection point for a previously abiotic planet.

Single-celled prokaryotic microbes (i.e., bacteria) able to gain their energy from trace levels of methane were some of the earliest organisms on Earth and remained the dominant inhabitants for the billion odd years of the Archean period through which high levels of CO_2 persisted in the atmosphere (est. 6–70%, Lehmer et al. (2020); cf. today's atmospheric CO_2 level <0.5%). Greater biological sophistication and diversification subsequently evolved with major climatic factors, especially the rise in oxygen levels, which provided a metabolic benefit to advanced, multicellular organisms. The first significant increase in atmospheric O_2 can be attributed to stromatolites, which comprise layered structures (e.g., columns, mats) of cyanobacterial communities able to autotrophically convert CO_2 into O_2 via sunlight-induced photosynthesis. The fossil remains of stromatolites have been dated back to 3.5 billion years ago, and these microbial systems have proved exceptionally resilient, with viable communities persisting in modern niche environments like the hypersaline estuaries of Shark Bay (Western Australia). Atmospheric O_2 levels have increased sporadically from the trace Archean levels to ~21% today. Two celebrated periods of large O_2 bursts were the Great Oxidation Event (GOE) of the early Proterozoic (2.4–2.0 billion years ago) and the Neoproterozoic Oxidation Event (NOE) of the late Proterozoic (0.75–0.65 billion years ago), which saw O_2 reach close to the present atmospheric level (PAL) – more temporary in the case of GOE; Liu et al. (2019) – stimulating pulses of rapid biological expansion.

Geological records of biological and environmental dynamics

The detailed examination of fossils and geological sediments via a range of earth science approaches has provided a wealth of data about paleoenvironmental records and the history of life on Earth. For example, in our field of organic geochemistry, the organic matter in sedimentary rocks is commonly analysed for evidence of molecular biomarkers, which are organic compounds retaining a structural (or stable isotopic) link to their source organism. Biomarkers have proved a valuable complement to macro fossils (e.g., animal skeleton) explored by palaeontologists and on which much of the evolutionary framework for life on our planet has been traditionally based. Many cross disciplinary studies have contributed to a well-defined understanding of the biological trajectory on Earth, from simple microbial beginnings to today's wonderworld of amazingly diverse creatures. This advancement has certainly not been smoothly linear, but rather one of many fits and starts and even several near-complete busts. For instance, huge bursts in animal evolution and biodiversity (He et al., 2019) were stimulated by the multiple oxygen surges and efficient ocean ventilation through the Cambrian explosion (0.54–0.53 billion years ago). Many major animal phyla emerged through this time, though not yet our human ancestors who first appeared just 5 or so million years ago. Conversely, the ongoing viability of many organisms has been terminated or seriously threatened by periodical intervals of severe biotic stress. The most traumatic of these events are known as mass extinctions (MEs) where more than 70% of existing life was extinguished.

There have so far been five MEs, at approximately 443, 375–360, 252, 201 and 66 million years ago, with each linked to sharp climate and environmental gradients – reflecting a direct physicochemical control not dissimilar to periods of evolutionary ascension. Apart from the most recent end-Cretaceous (66 million years ago) ME, which was uniquely triggered by the collision of a giant meteor with Earth off the northern Mexican coastline, the preceding four MEs were all associated with large-scale volcanism leading to high atmospheric CO_2 emissions and temperature deviations lasting thousands to millions of years. Glacial ice melts at the end-Ordovician (443 million years ago) ME cooled the atmosphere, whereas the next three MEs coincided with notable increases in atmospheric temperature – and of a similar magnitude to the recent 8°C rise in atmospheric temperature measured over just the last 200 years (Glikson, 2018). Other consequences of the temperature rise connected to these MEs included higher continental wildfire intensity and high nutrient-induced eutrophic or acidic ocean waters, mirrored also by the recent increase of these climate-related catastrophes.

The durability of life on Earth

Science-based (and other) philosophical views about the long-term sustainability of life on Earth vary widely, from dire predictions of ultimate extinction to more optimistic faith in the biospheric resilience of our planet and its elasticity to cope with and regulate widely fluctuating climate conditions. The breadth of views is reflected by the contrasting Medean and Gaia concepts. The pessimistic Medean theory (Ward, 2009), named after the mythical Medea, a scorned wife who kills her children, considers the development of advanced organisms to inadvertently include a self-destructive element. Harm may arise, for example, from an unfavourable environmental or ecological consequence of their emergence, with such tendencies ironically believed to intensify with organismic sophistication and aptitude – a rather sobering thought for us humans, the current leaders in the evolutionary intelligence stakes. Indeed, human endeavour has led to the industrially induced Anthropocene era implicated in the concerning atmospheric CO_2 and temperature rises being witnessed today.

Contrary to the glum Medean viewpoint, the Gaia principle (Lovelock, 1972; Wallace and Norton, 1992), named after Gaia – the personified goddess of Earth, positively advocates the nurturing attributes of mother Earth. This maternal virtue may help extant life develop the adaptive intelligence and opportunism to successfully cope with evolving habitats. The natural survival and propagation instincts of many advanced organisms includes a sensitive radar to serious threats and a creative ability to implement appropriate adaptive responses. Certainly, the devastation of all previous MEs was followed by sustained periods of recovery in which the surviving life eventually found a way to flourish and diversify (Whiteside and Grice, 2016). Much can be learned from these previously successful adaptions to evolutionary turmoil, but full exploitation of this historical advantage requires the relevant learnings and knowledge to be communicated widely to communities across the world through targeted information-sharing mechanisms (i.e., critical sustainability education).

Whilst the ultimate fate for life on Earth attracts wide debate, there is increasing consensus that the sharp changes in climate through the modern Anthropocene period represents one of the most serious ecological challenges for several millennia. Some scientists worry the large rises in temperature (8°C) and CO_2 (1.5× to above 400 ppm) over the last 200 years are reminiscent of the early trajectories of past MEs (e.g., Barnosky et al., 2011; Ceballos and Ehrlich, 2002). The urgency to respond to this climate crisis is now being appreciated by a growing proportion of our community and, belatedly, some national governments.

Tangible transformative action will require wide cooperation and sharing of all relevant information and adoption of best practice technologies. An effective sustainability education programme will be crucial to these goals. As is well captured through the many important articles in this Handbook, sustainability education will be most successfully achieved by holistically addressing the many connected parts of this subject, which includes a consistent pedagogical framework for education providers; identification and communication of research priorities; policy guidance for governments on successful climate mitigation and remediation strategies, including the transition away from unsustainable technologies (e.g., decarbonisation); and a mindfulness of socioeconomic situations to assist societies from all nations to meet the transformative costs of adopting new sustainable practices. These features would form, as this chapter's title suggests – a noble education.

Conclusions

Over a 4-billion-year history, life on Earth has proven to be opportunistic, progressive, resilient and adaptive. It has survived several major traumas and maintained long-term trends of increased diversification and sophistication. But eternal life is by no means guaranteed. The Goldilocks biological niche of Earth could be compromised by further anthropogenic harm or some other impending catastrophe. Present-day climate change and its likely harmful ecological consequences is now accepted by all but an ignorant few. As climate change activism reaches a crescendo, mitigation and remediation technologies are being scaled up and new government policies sought to help transition away from environmentally damaging industrial and lifestyle practices. Indulgence in our superior (perhaps even super) intelligence encourages optimism that we can meet the current climate change challenge and continue to engineer favourable (Gaian-like) responses to new ecological threats as they emerge. Of course, the extent of any necessary repair can be mitigated by limiting the damage inflicted in the first place. There needs to be a concerted effort to minimise the ecological impact of the human footprint on Earth. A widely adopted and successful sustainability education campaign will be crucial to driving the transformative actions necessary to counter self-imposed and external threats to our life as we know it here on Earth. This Handbook is an excellent step in this direction, compiling advice from well-qualified experts on many key aspects relating to the teaching and practice of sustainability education. All peoples of the world need to be educated and unified in the commitment to protect our shared planet for future generations and to avoid the unpalatable alternative of our own extinction.

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1.3
CLIMATE CHANGE UNDERSTANDING AS A BASIS FOR SUSTAINABILITY EDUCATION

Wim Thiery

Key concepts for sustainability education

- There is overwhelming scientific evidence that humans are responsible for global warming through the emission of greenhouse gases.
- Human activity–induced increases in CO_2 levels come from two main sources: the combustion of greenhouse gases and land-use changes (mainly deforestation).
- Measurements in Hawaii (Mauna Loa Observatory) show that the annual average concentration of CO_2 in the atmosphere has increased from 316 parts per million (ppm) in 1959 to 416 ppm in 2021 (NOAA, 2022).
- In the worst-case scenario we will experience a warming of around 4°C by the end of the 21st century compared to the current climate, or around 5°C higher when compared to the preindustrial era.
- With a warming of 2°C or more, we may experience several metres of sea level rise over long time scales due to the crossing of tipping points in the climate system, particularly in Greenland and West Antarctica (IPCC, 2018).
- Limiting ultimate global warming to 1.5°C relative to the preindustrial era will require immediate, far-reaching, and sustained emissions reductions, with the transition to net zero emissions globally achieved by about 2050 and net negative emissions thereafter (IPCC, 2018).
- To mitigate advancing climate change, policy makers, organisations, individuals, and local communities will need to work together to implement policies in line with this scientific evidence.
- Climate change knowledge and understanding should be considered a fundamental basis for sustainability education given the reaching future impacts and the extensive need for personal and organisational behaviour change to help mitigate our carbon footprint.

Introduction

Today, we have overwhelming scientific evidence that humans are responsible for global warming through the emission of greenhouse gases. Over the past decades, observed warming

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on all continents and in the oceans has led to changes in ecosystems and societies, revealing their vulnerability. Limiting ultimate global warming to 1.5°C relative to the preindustrial era will require immediate, far-reaching, and sustained emissions reductions, with the transition to net zero emissions globally achieved by about 2050 and net negative emissions thereafter (IPCC, 2018). Therefore, to mitigate advancing climate change, policy makers, organisations, individuals, and local communities will need to work together to implement policies in line with this scientific evidence.

Climate science

Climate is the statistic of weather. Weather includes the state of the atmosphere at a given time and place (e.g., temperature, precipitation, clouds, air pressure, wind speed, humidity), while climate includes the average state of the atmosphere, oceans, sea ice, and more over a longer period (e.g., 30 years). The scientific study of the climate system – climate science – involves understanding the interactions between the different components of the climate system: the atmosphere, the oceans, the land, and the ice sheets. These interactions are enormously complex but at the same time obey fundamental physical laws, such as the conservation of mass and the conservation of energy.

An important aspect of the functioning of the climate system is the greenhouse effect: solar radiation reaches the Earth's surface in the form of visible light and ultraviolet (UV) radiation. The Earth absorbs this energy and emits it back into space in the form of infrared radiation. Greenhouse gases in the atmosphere (mainly H_2O, CO_2, CH_4, and N_2O) absorb part of that infrared radiation and send it back to the Earth, making it warmer on Earth than it would be without these greenhouse gases. This effect is also present without human interference: without greenhouse gases, the average temperature on Earth would be about –18°C instead of about +15°C. In this context, we speak of the natural greenhouse effect. However, the emission of greenhouse gases by humans increases this effect, in which case we speak of the human (or increased) greenhouse effect.

Observed changes

Measurements in Hawaii (Mauna Loa Observatory) show that the annual average concentration of CO_2 in the atmosphere has increased from 316 parts per million (ppm) in 1959 to 416 ppm in 2021 (NOAA, 2022). In doing so, we are currently reaching concentrations that have probably not occurred in the last 3 million years, and certainly not since the emergence of humanity (*Homo sapiens*) some 350,000 years ago (Meinshausen et al., 2017). Thanks to scientific research, we know that the increase in CO_2 comes from human activity, and in particular from two main sources: the combustion of greenhouse gases and land-use changes (mainly deforestation). For the period 2007–2016, 88% of total CO_2 emissions came from fossil fuel combustion (34.3 $GtCO_2$/yr), while 12% (4.9 $GtCO_2$/yr) came from land-use change (Le Quéré et al., 2017). Of the total emissions, only 47% are currently released permanently into the atmosphere (17.3 $GtCO_2$/yr), while 30% are absorbed by the land (11.2 $GtCO_2$/yr) and 23% by the oceans (8.7 $GtCO_2$/yr; Le Quéré et al., 2017).

Human emissions of greenhouse gases lead to global warming. Since the beginning of the industrial period, the Earth's average surface temperature has increased by about 0.99°C (2001–2020 compared to 1850–1900; IPCC, 2021). At the time of writing, the last eight years (2014–2021) are also the five warmest since regular temperature measurements began in the mid-19th century (UK Metoffice, 2022). The temperature increases more strongly over land than over the oceans and is also stronger towards the poles (polar amplification; IPCC, 2021). Thanks to scientific research with climate models, we know that the observed warming can only be explained if human activity is explicitly considered in the computer simulations (IPCC, 2013, 2021).

The observed warming leads to numerous changes in the Earth system. For example, there is an increase in the number of heat waves and in some areas an increase in the intensity of droughts and forest fires (IPCC, 2013; Jolly et al., 2015). Globally, glaciers are melting, sea levels are rising, and, in the Arctic, there is a decrease in the area of sea ice (IPCC, 2013). Extreme rainfall is generally increasing (Fischer and Knutti, 2015), and hurricanes are becoming more powerful (Webster et al., 2005).

Projections for the future

Looking into the future, there are several scenarios in which the climate may evolve. If we continue to behave along a worst-case scenario, as we have been doing in recent decades, we will experience a warming of around 4 degrees by the end of the 21st century compared to the current climate (2.6°C–4.8°C for 2081–2100 compared to 1986–2005; IPCC, 2013), or around 5°C compared to the preindustrial era. Once again, the Arctic will warm faster than the global average and land temperatures will rise more than ocean temperatures. However, alternative future scenarios are equally possible, in which temperatures are limited to 1.5°C compared to the beginning of the industrial era (IPCC, 2018, 2021). Thus, 1.5°C–5°C is the warming we can expect by the end of this century, depending on the choices we as humanity make in the coming decades. Doing nothing is also a choice.

Risks

Scientific research with computer models shows the need to limit future warming as much as possible (Thiery et al., 2021). After all, the effects of climate change increase disproportionately as the average temperature on Earth rises. A warming of 2°C compared to the preindustrial period will lead to an increased risk of extreme weather events, further sea level rise, and ocean acidification. This will most likely mean the end of our corals and the viability of several island states (IPCC, 2018). It may also endanger several ecosystems and societies, especially small islands, river deltas, and low-lying coastal areas. With a warming of 2°C or more, we may experience several metres of sea level rise over long time scales due to the crossing of tipping points in the climate system, particularly in Greenland and West Antarctica (IPCC, 2018). A warming of 4°C or more could lead to the extinction of a large number of animal species, global and regional food scarcity, and fundamental consequences for human activities that we take for granted today.

Action

Protecting our future generations therefore requires action in line with the scientific evidence. Political leaders from more than 190 countries therefore adopted an agreement in 2015 to mitigate climate change and related impacts. In the Paris Agreement, countries set themselves the goal of limiting the rise in the Earth's average temperature to well below 2°C compared to preindustrial levels and to make efforts to limit the temperature increase to 1.5°C compared to preindustrial levels, acknowledging that this substantially reduces the risks and consequences of climate change (COP21, 2015).

Scientists have since calculated the total amount of greenhouse gases humanity can still emit in order to stay below a predetermined warming level with a given probability (the carbon budget). The results show that limiting warming to 2°C compared with the preindustrial era will require a sharp and permanent reduction in greenhouse gas emissions. This includes an inevitable transition to a zero-emissions world by the second half of this century (IPCC, 2013, 2021). Limiting eventual global warming to 1.5°C will require immediate, far-reaching, and sustained emissions reductions, with (i) global CO_2 emissions roughly halved from current levels by 2030, (ii) the transition to net-zero CO_2 emissions globally achieved by about 2050, and (iii) net-negative CO_2 emissions achieved in the following decades (IPCC, 2018).

Looking at the reality, however, it must be noted that extrapolating the current 2030 targets of individual countries would add up to a warming of 2.4°C (+1.9°C–3.0°C) by 2100 relative to the preindustrial era; if we consider actual policies, this could even reach 2.7°C (+2.0°C to +3.6°C; CAN, 2022). At present, therefore, countries' policies and pledges are not in line with the Paris Agreement commitments. Governments, businesses, nonprofit organisations, scientists, and citizens must therefore work together to raise their levels of ambition if we are to have any chance of staying within the limits of the Paris Agreement. While individuals can consciously change their own lives, the key to achieving the goals of the Paris Agreement lies in cross-sectoral, consistent, and ambitious policies.

Opportunities

Today, however, we still have the opportunity to limit global warming and its negative consequences. For example, low-carbon technologies already offer enormous potential for innovation today. Acting now will also reduce the enormous costs that would otherwise be required to adapt our societies to the adverse, and potentially catastrophic, effects of climate change. Finally, societies can also enjoy the many other benefits of limiting global warming, such as securing our food, energy, and water supplies; improving air quality and public health; ameliorating the liveability of cities; and preserving existing ecosystem services.

Conclusion

Sustainability education benefits society best when it is rooted in state-of-the-art scientific knowledge on climate change. This chapter elaborated briefly on the key concepts and recent findings from climate science that should be included in sustainability education.

Research shows how observed atmospheric greenhouse gas concentrations have been rising in recent decades mainly due to fossil fuel burning, thereby reinforcing the greenhouse effect and increasing atmospheric temperatures.

Future greenhouse gas emissions will lead to further warming in the next decades, thereby exacerbating risks for natural and human systems.

Actions are required to limit global warming to the limits set within the Paris Agreement and showcase how climate action may bring important co-benefits regarding human health, cities' liveability, water, and food security, among many others.

Sustainability education needs to provide a fundamental understanding of climate change impacts and should across all disciplines include opportunity for developing personal and industry/business-based climate change mitigation strategies and outcomes. The responsibility for managing and mitigating climate change is everyone's . . . not just those reporting the climate science research.

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1.4

ARE BEES AND POLLINATORS OUR MOST IMPORTANT SUSTAINABILITY INDICATOR?

Tristan Campbell and Kingsley W. Dixon

Key concepts for sustainability education

- Sustainability, human health, biodiversity and pollinators are all intrinsically linked.
- Pollinators are key indicators of ecosystem health and productivity, including agriculture.
- Pollinators have been in decline for decades, which is strongly linked to global decline of ecosystems.
- Conservation and restoration of ecosystems are both fundamental to reverse this trend.
- Engaging in simple nature-based projects improves sustainability education outcomes.

Why are pollinators important?

With over 85% of flowering plants requiring animal pollination (Ollerton et al., 2011), the importance of pollinators in natural systems cannot be overstated. Over a third of human food varieties rely upon pollination by insects, particularly bees (Westerkamp & Gottsberger, 2000), equating to an annual global economic value of up to $US577 billion (Potts et al., 2016). Should pollinators disappear, production of these foods that are crucial for micronutrients, vitamins and minerals in healthy diets (Coghlan & Bhagwat, 2022) would reduce by up to 85% (see Figure 1.4.1), with a significant global impact on human health. In some areas, pollinators have declined to the point that pollination is done by hand, even on large commercial crops, or farming practices are being forced to change to crops that are less reliant on pollinators (Partap & Ya, 2012). Therefore, putting environmental considerations aside, pollinators are vital to us purely in terms of enlightened self-interest.

Taking a broader view of the relationship between the environment and human health, the role of pollinators in nonagricultural systems is still critical to human health. With human-driven ecosystem degradation linked to increases in pathogens such as severe acute respiratory syndrome (SARS), avian and porcine flu and COVID-19 (Schmeller et al., 2020), preservation of biodiversity and restoration of degraded systems are again vital to humans from purely a self-interest perspective. There is also a growing body of work demonstrating the positive links between human physical and mental health and biodiversity (Marselle et al., 2021).

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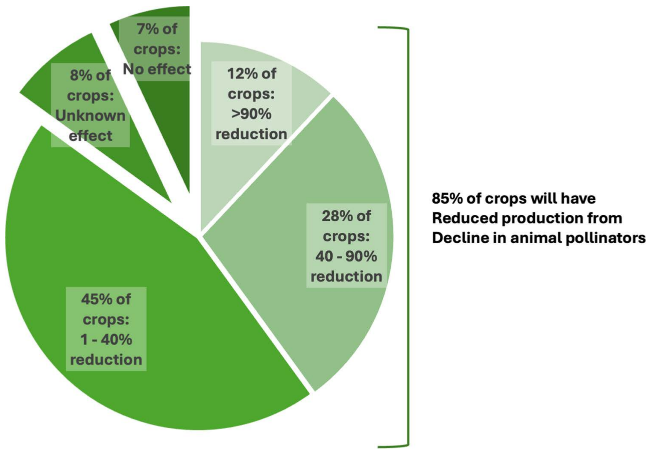

Figure 1.4.1 Dependence on animal-pollinated crops used directly for human consumption (i.e. fruits or seeds). Even one poor season can have significant long-term impacts due to disruption of the reproductive cycle. Adapted from Potts et al. (2016).

With the two-way link between biodiverse terrestrial ecosystems and pollinators, pollinators make ideal indicators for sustainability. This is been documented by the extent that pollinators can contribute to achieving the majority of the UN's Sustainable Development Goals (SDGs) (Patel et al., 2020) and can be used as the key metric for global monitoring of progress towards sustainability (Balvanera et al., 2022).

Honeybees: not the bee-all and end-all

Herein lies the complexity of the issue: not all pollinators are created equal. The co-evolution of flowering plants and pollinators has been documented since Darwin (1859), including the highly specific interactions between flora and fauna that in some cases result in a plant relying entirely on a single species of animal for pollination. This led to one of Darwin's more infamous quotes: 'Good heavens, what insect could suck it!' in reference to his observations of the comet orchid with its long nectary spur (Arditti et al., 2012). Multiple studies have shown global decreases in pollinator populations and diversity over recent decades (Zattara & Aizen, 2021), leading to a breakdown of these crucial interactions.

While much has been made of the decline in pollinators, many of the pollinator policy and conservation initiatives across several continents have focused on the western honeybee (*Apis mellifera*) (Colla & MacIvor, 2017), even where the western honeybee is not a native species (Smith & Saunders, 2016). The western honeybee is only one of over 20,000 species of insects that contribute to pollination (Lieutier et al., 2017). Even when considering commercial crop pollination, a diversity of pollinators beyond honeybees can be significantly more efficient and cost effective, e.g. Westerkamp & Gottsberger (2000), dos Santos et al. (2009).

The impact of honeybees on native pollinator networks is complex (Iwasaki & Hogendoorn, 2021) and can be negative (Garibaldi et al., 2021), neutral (Roubik & Wolda, 2001) or positive (Rodríguez et al., 2021). Even within an ecosystem, the impact of honeybees can vary between specific native pollinator species and seasonal variations in pollen and nectar availability (Semida & Elbanna, 2006), and there is often a significant lack of empirical evidence to sufficiently quantify the impacts of honeybees in time and space (Prendergast et al., 2022).

Noninsect pollinators are less numerous in terms of the number of species; however, in some regions they perform a significant proportion of pollination services, e.g. Stewart & Dudash (2017), Ford et al. (1979), with plants developing specific evolutionary traits for certain classes of insect versus noninsect pollinators, e.g. Shrestha et al. (2013). Noninsect pollinators are represented by a range of animals including birds (Stiles, 1978), bats (Fleming et al., 2009), nonflying mammals (Goldingay et al., 2016) and even reptiles (Cozien et al., 2019). Like insect pollinators, these noninsect pollinators are in global decline (Regan et al., 2015).

Why is ecosystem restoration important?

Effective ecosystem restoration is integral to the concept of sustainability and has the potential to reverse some of the declines in pollinators mentioned earlier. When implemented effectively, ecosystem restoration delivers significant ancillary benefits, particularly when native and biodiverse restoration is undertaken. The process of restoring ecosystems improves human health and wellbeing; increases food and water security; delivers goods, services, and economic prosperity; and supports climate change mitigation, resilience and adaptation (Gann et al., 2019). Ecosystem restoration delivers these flow-on benefits to the degree that the United Nations (UN) declared the decade of 2021 to 2030 the 'Decade of Restoration', with a goal of restoring 350 million hectares of degraded ecosystems as a key strategy to achieve over half of the UN's SDGs. Targeted restoration of degraded land has the potential to avoid 60% of expected extinctions and sequester 30% of the total increase in atmospheric CO_2 since the Industrial Revolution (Strassburg et al., 2020).

The leading professional body for ecosystem restoration, the Society for Ecological Restoration (SER, www.ser.org), defines ecosystem restoration as 'the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed' (Society for Ecological Restoration International Science & Policy Working Group, 2004). The cornerstone of this definition is the term 'ecosystem'; this goes beyond planting trees or even a polyculture of species (such as carbon-based plantings or reforestation where low species diversity is often the norm) that result in a facsimile of an ecosystem but is not natural or capable of supporting the broader suite of native organisms and ecosystem functions.

The restoration revolution that is sweeping the planet is necessary and essential for redressing human impact upon the climate and biodiversity. To ensure effective restoration occurs, principles and standards have been developed that provide the framework for designing, implementing and assessing restoration programs (Gann et al., 2019). A key principle in the standards is the use of native reference ecosystems or an equivalent to guide what to restore. Such a principle provides the best approach for ensuring nature and natural ecosystems continue to thrive and support the many ecosystem services, such as pollinator services, that are essential to human wellbeing.

How do we plan restoration for pollinators?

Successful ecosystem restoration can demonstrate a succession of increasing ecosystem functions as the ecosystem becomes more diverse and complex (Devoto et al., 2012), with associated increases in ecosystem resilience and production (Kaiser-Bunbury et al., 2017). However, to achieve this outcome, restoration needs to focus on the ability of landscapes to host pollinators through suitable resources such as floral resources, nesting sites and water, to name a few, rather than introducing the pollinators themselves (Christmann, 2019).

As it sounds, this is by no means a straightforward process. Pollination networks are often compartmentalised rather than being uniform across landscapes (Corbet, 2000), meaning that the landscape as a system must be restored, not a single vegetation complex over the restoration area. The networks are also often strongly asymmetrical, with certain plants having an outsized impact on other species (Pocock et al., 2012). The pollinator network diagram in Figure 1.4.2 is a simplified example from the United Kingdom of some of this complexity, with bumblebees pollinating seven plant species versus the pyralid moths pollinating two. The sphingid moths pollinate three plant species but are the only moth that pollinates the fragrant orchid.

By focusing the early stages of restoration projects on establishing flora that can operate as a framework for the pollinator network, bridging and magnet species for pollinators can use this asymmetry to facilitate earlier reintroduction of species and improve the early growth of ecosystem function (Dixon, 2009). However, the value of these high-benefit species also needs to be weighed against their ability to be reintroduced, as keystone species can have significant environmental and physical constraints to being successfully introduced early in the restoration process (Menz et al., 2011).

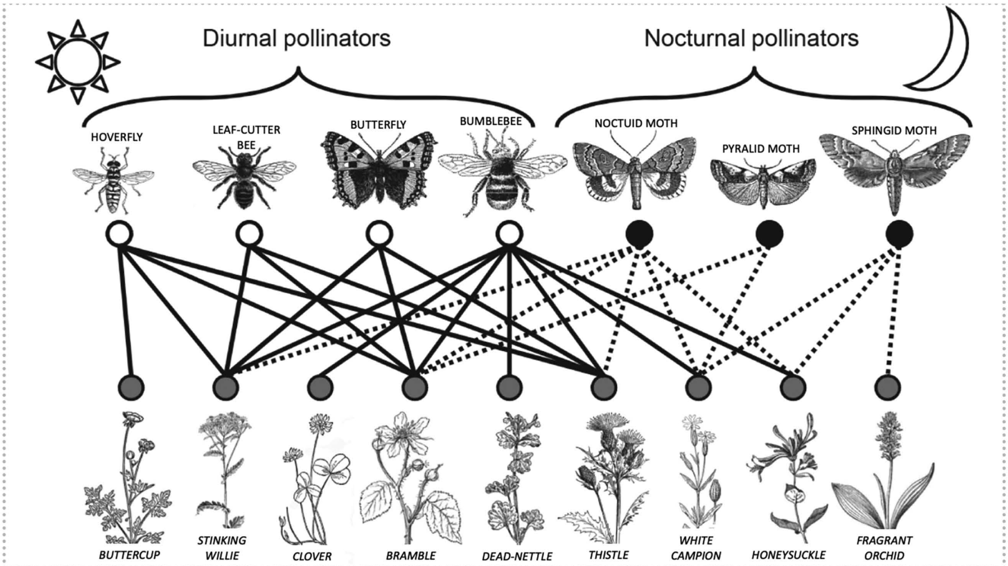

Figure 1.4.2 Simplified pollinator network diagram from United Kingdom, adapted from Macgregor et al. (2015). Complete network diagrams for ecosystems can consist of up to several hundred pollinators and plants.

The asymmetry in the pollination networks can also be highly skewed towards particular pollinator types or species that are 'generalist' foragers (Fleming & Muchhala, 2008). Restoration of plant species that attract these generalist pollinators can result in faster growth in ecosystem function than focusing on the more specialised pollination relationships in the early stages of restoration. It should be noted that with increasing natural biodiversity there is generally a commensurate increase in pollination specialisation (Vamosi et al., 2006).

It is at this point where the importance of international restoration standards, developed by the Society for Ecological Restoration (Gann et al., 2019), becomes clear by giving a robust yet locally adaptable framework to plan, execute and monitor restoration projects. Ecosystem restoration projects utilizing these standards are underpinned by eight principles that are globally relevant but also designed to be applied on a local scale. As discussed earlier, key in this process is the use of a reference ecosystem which allows a detailed understanding of the ecosystem functions to be developed. If there are sufficient habitat links between the reference and restored ecosystems, the reference ecosystems can potentially allow migration of pollinators across to the restored area as the restoration progresses (Christmann, 2019).

But, again, the situation may not be that straightforward. The effects of climate change or long-altered ecologies may mean that restoration of a previous ecosystem may not be possible and a climate-adapted version of the reference ecosystem may need to be developed (Harris et al., 2006). Or the ecosystem may have degraded to beyond what is deemed to be an 'irreversible' threshold, where it may be not possible, practical or economical to restore the ecosystem to its previous condition. Crossing the threshold may be due to a variety of factors such as loss of soil productivity, structure and geochemistry (Gao et al., 2011); significant structural changes in vegetation structure due to prolonged alterations in fire regimes (Bielski et al., 2021); or pollution and changes in water quality (Mao & Richards, 2012). Due to these considerations, the reference ecosystem should be selected based on the flowchart in Figure 1.4.3 to select the most appropriate reference system for the program constraints, noting that SER's standards incorporate socio-economic and cultural factors to assist with community and stakeholder engagement for such decisions.

Pollinators, restoration and sustainability education

So how do pollinators and ecosystem restoration relate to sustainability education? Bees and other pollinators have long been a part of the human experience, with representations of bees in cave art up to 8,000 years old (Prendergast et al., 2021). In recent times, bees have garnered a wealth of support and have been used in various ways to promote concepts of sustainability. This includes built environment design (Graham, 2009), sustainable leadership styles (Avery & Bergsteiner, 2012) and the whole of community approach to sustainability (Marshman, 2019).

In a practical setting, it has been well established that connectedness to nature is related to sustainable behaviours, and happiness, in both adults and children (Barrera-Hernández et al., 2020). In addition, connectedness and the resulting sustainable behaviours are also linked to better health in individuals, while 'traditional' environmental education does not tend to result in these outcomes (Barragan-Jason et al., 2021).

Preservation and restoration of pollinators and pollinator networks, even in urban environments, present many low-cost, readily achievable ways to encourage people to increase their connectedness to nature (Knapp et al., 2021), potentially in their own backyard. From

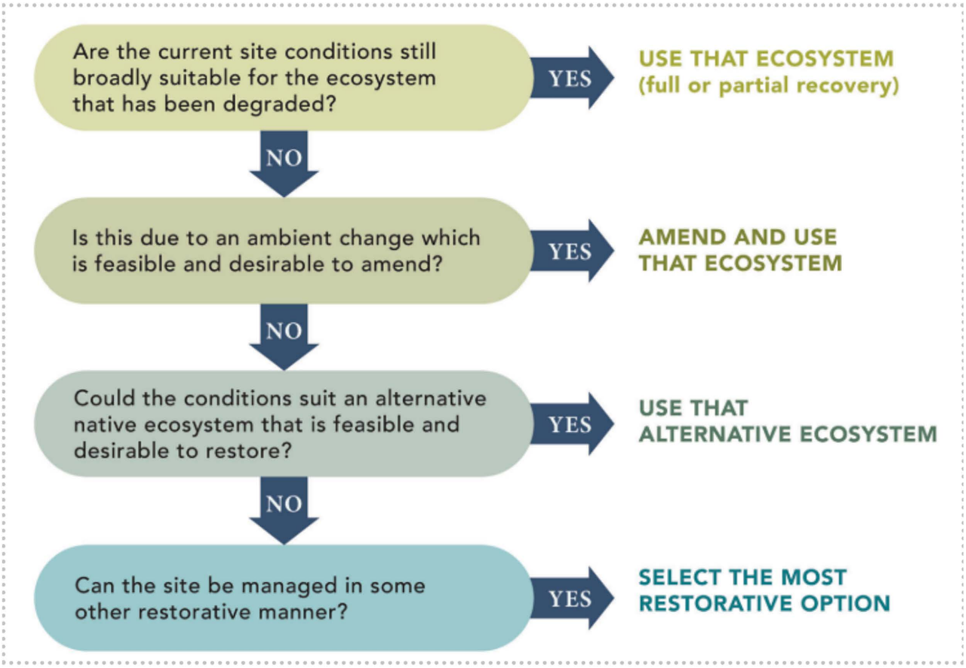

Figure 1.4.3 Decision tree for selection of reference ecosystem for restoration (from Gann et al., 2019).

this foundation, further connectedness can be grown and the resulting improvements in sustainable behaviours and health used to further enhance sustainability educational outcomes. At a more advanced level, there are many parallels between the eight principles of ecosystem restoration and sustainability, as summarised in Table 1.4.1, allowing educators to demonstrate the links between pollinators, restoration and sustainability in both the practical and theoretical space.

Therefore, engaging people in the practice of restoration to support pollinators provides educators with a combined practical and theoretical framework while also supporting improved wellbeing and healthier communities with more sustainable behaviours. These communities are also better equipped to advance and scale up sustainability from their solid grounding in the key aspects of sustainability through the practical metaphor of ecological restoration.

Conclusions

Humans form part of the Earth's biosphere, no matter how much we may think we are independent of this, and sustainability education must consider this fundamental principle. The often intricate relationships between plants and pollinators underpins the complex web of ecosystem functions required to sustain the biosphere, which we rely on for the food we eat, the water we drink and even the air we breathe.

Globally, pollinator populations and diversity have been in decline for several decades, to the degree that in some regions agricultural crops are pollinated by hand or are replaced

Table 1.4.1 The eight principles of ecosystem restoration and how they relate to sustainability

Ecosystem Restoration Principle	*Relevance to Sustainability*
Engages stakeholders	Stakeholder engagement and empowerment improve sustainability program outcomes (Fraser et al., 2006)
Draws on many types of knowledge	Achieving the UN SDGs requires cooperation across many knowledge bases (Polónia, 2021)
Is informed by native reference ecosystems, while considering environmental change	Political, economic and other aspects need to be considered to effectively achieve sustainability goals (Bandali et al., 2021)
Supports ecosystem recovery processes	In a societal context, empowerment accelerates the rate of sustainability transition ('recovery') (Kivimaa et al., 2020)
Is assessed against clear goals and objectives using measurable indicators	Measurable metrics are key for achieving the UN SDGs (Diaz-Sarachaga et al., 2018)
Seeks the highest level of recovery possible	The UN SDGs are 'aspirational goals', designed to motivate member states to achieve the highest possible results (Finnemore & Jurkovich, 2020)
Gains cumulative value when applied at large scales	Individual and community impacts scale up to large impacts on a regional or global scale (Vita et al., 2019)
Is part of a continuum of restoration activities	Sustainability activities recognised as part of a scale are more resilient and effective (Goworek et al., 2018)

with wind- or self-pollinated crops. Global-scale restoration of ecosystems is crucial to halt and reverse this trend and offers close parallels to broader sustainability challenges in that although the principles of restoration are consistent, the local requirements and implementation strategy can vary immensely. Strong stakeholder engagement is needed for the success of both restoration and sustainability programs.

The intrinsic links between pollinators, restoration and sustainability give educators both practical and theoretical frameworks for improved learning outcomes, which may have greater impact and encourage more sustainable behaviours when the curriculum includes an increased physical connection to nature. Even the inclusion of simple projects to benefit local pollinators in programs can give students an intrinsically improved understanding of sustainability in a practical sense, better embed the educational outcomes from the sustainability program and result in longer-lasting sustainability behaviours.

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1.5
WHY BEES ARE CRITICAL FOR ACHIEVING SUSTAINABLE DEVELOPMENT[1]

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Introduction

The United Nations 17 Sustainable Development Goals (SDGs) are designed to achieve synergy between human well-being and the maintenance of environmental resources by 2030, through the pursuit of 169 targets and more than 200 indicators (UN 2015). The biosphere is the foundation for all SDGs (Folke et al. 2016; Rockstrom and Sukhdev 2016; Leal Filho et al. 2018), and yet biodiversity conservation remains a persistent global challenge (Tittensor et al. 2014). An examination of how a particular suite of organisms within the global wealth of biodiversity can contribute to the attainment of the SDGs holds the potential to link sustainable development policy with conservation through the design of integrated solutions. We explore the interconnections between bees – a critical group of insects with diverse economic, social, cultural and ecological values – and people in the context of the SDGs.

Bees, people and the planet

Bees comprise ~20 000 described species across seven recognised families (Ascher and Pickering 2014), with many more species yet to be described (Figure 1.5.1). The evolutionary radiation of bees coincided with the evolutionary radiation of flowering plants (Cappellari et al. 2013), and bees occupy an important ecological role as pollinators of a range of flowering plant species. Although bees are not the most diverse group of pollinators (butterflies and moths comprise over 140,000 species), they are the most dominant taxonomic group amongst pollinators; only in the Arctic regions is another group (flies) more dominant (Ollerton et al. 2011). The ability of bees to transport large numbers of pollen grains on their hairy bodies, reliance on floral resources and the semi-social or eu-social nature of some species are amongst the characteristics that make bees important and effective pollinators (Ollerton et al. 2011; Klein et al. 2018). Fifty bee species are managed by people, of which around 12 are managed for crop pollination (Potts et al. 2016a).

The potential importance of bees for crop pollination has been highlighted as a particular reason to conserve wild bees and their habitat (Klein et al. 2007; Gill et al. 2016; Potts

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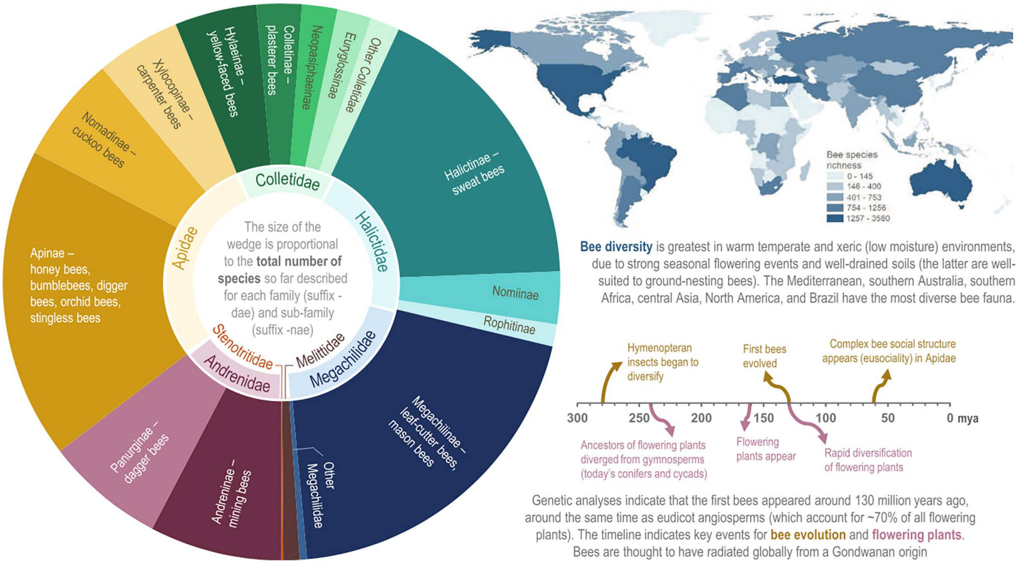

Figure 1.5.1 A snapshot of the diversity of bees. Bees are taxonomically classified under the insect order Hymenoptera, along with ants, wasps and sawflies, and are part of the superfamily Apoidea and clade Anthophila, with seven recognised families. Although only 50 of the ~ 20,000 described bee species are actively managed by people, the entire clade is important for ecosystem functioning and human well-being. Bees and flowering plants have co-evolved, making bees effective pollinators of a large proportion of flowering plant species. There are perhaps a further ~5,000 bee species that are yet to be described.

Data source: Ascher and Pickering (2014). Information for this figure was sourced from Michener 1979, 2000; Michez and Patiny 2007; Litman et al. 2011; Cappellari et al. 2013; Peters et al. 2017; Meiners et al. 2019

et al. 2016a; Klein et al. 2018). More than 90% of the world's top 107 crops are visited by bees; however, wind- and self-pollinated grasses account for around 60% of global food production and do not require animal pollination (Klein et al. 2007). Wild bees contribute an average of USD$3,251 ha^{-1} to the production of insect-pollinated crops, similar to that provided by managed honeybees (Kleijn et al. 2015). A very small number of mostly common wild bee species provide the majority of bee-related crop pollination services (Kleijn et al. 2015), and other insects such as flies, wasps, beetles and butterflies have an important, underemphasised role in crop pollination (Rader et al. 2016). Such research has highlighted the danger of exclusively highlighting the importance of bees for crop pollination, to the potential detriment of conserving diversity across the landscape (Kleijn et al. 2015; Senapathi et al. 2015). In our assessment of bees and the SDGs, we highlight that the diversity of wild and managed bees has crucial ecological, economic and social importance including and beyond crop pollination.

Long-standing associations exist across multiple bee species and human societies. Documented ancient bee–people interactions include honey hunting dating back to the Stone Age for the honeybee *Apis mellifera* in Europe (Roffet-Salque et al. 2015), more than 2,000 years of keeping the honeybee *Apis cerana* in Asia (Crane 1995) and beekeeping reaching back to at least pre-Columbian times for stingless bees (*Melipona beechii*) in Mayan Mexico (Quezada-Euán 2018). Bees also appear in many religious scriptures and are found within mythology, cosmology and iconography (Fijn 2014; Roffet-Salque et al. 2015; Potts et al. 2016a; Quezada-Euán 2018). Beeswax from culturally significant sugarbag bees (*Tetragonula* spp.) has been used in the production of rock art by Aboriginal peoples in northern Australia for at least 4,000 years (Watchman and Jones 2002). In Greek society, bees are closely linked with the cycle of birth and death and considered an emblem of immortality (Cook 2013). "Telling the bees" was a popular tradition in 19th-century New England; it was customary for keepers to inform their bees of any major event such as a birth, death, marriage or long journey (Hagge 1957). These reciprocal bee–human relationships have historic legacy and are highly important for informing current practices around bee management.

Today, the long-standing mutualistic relationship between bees and people is jeopardised by recent reported declines in bee populations (Potts et al. 2016b). The loss of managed honeybee colonies (e.g. Potts et al. 2010) and declines in wild bee pollinators (e.g. Biesmeijer et al. 2006; Koh et al. 2016) have been observed, particularly in Europe and North America. However, much remains undocumented about the conservation status of most bee species (Goulson et al. 2015; Jamieson et al. 2019). The global conservation status of just 483 bee species has been assessed by the IUCN, most of which were 'data deficient' (IUCN 2019). The European Red List assessment of 1,965 species of European bees found that 9.2% were threatened, whilst insufficient data were available to assess the conservation status of nearly 57% of European species; many of these may also be threatened (Nieto et al. 2014). Goulson et al. (2015) reason that declines in wild bees definitively noted for Europe and North America are likely to have occurred elsewhere.

With a decline in bee populations, there has been a surge of research focusing on the drivers of bee decline and the impacts on provisioning ecosystem services (Goulson et al. 2015; Decourtye et al. 2019). Drivers such as habitat loss, pesticide use, the proliferation of parasites, availability and diversity of forage, change in land use and climate and species competition have all contributed to the reduction in bee populations (Goulson et al. 2015; Sánchez-Bayo and Wyckhuys 2019; Wagner 2020). These drivers interact in complex ways; for example, market-driven agricultural intensification has limited bees' access to forage resources and at the same time potentially increased bees' exposure to harmful agrichemicals (Durant 2019; Sánchez-Bayo and Goka 2014). People can act as a positive influence for ecosystem function through designing bee-friendly policies and contributing to bee conservation approaches (Potts et al. 2016a; Matias et al. 2017; Hill et al. 2019). Acknowledging the plethora of literature addressing the decline in bee populations and the consequences for agriculture, we contend that the ubiquitous importance of bees in connecting the planet and people remains relatively less explored, particularly with regard to broader goals in sustainable development.

Framing the broader importance of bees to sustainable development

Bees provide a range of ecosystem services that contribute to the wellbeing of people whilst maintaining the planet's life support systems (Gill et al. 2016; Matias et al. 2017). Ecosystem services inherently contribute to achieving global sustainable development (Wood et al. 2018). Yet the extent to which bees contribute towards the achievement of the full suite of the SDGs has not been explored in detail. Existing research has highlighted the importance of insects in achieving multiple SDGs through the regulation of natural cycles, biological pest control, pollination, seed dispersal and even as bio-inspiration (Gill et al. 2016;

Sánchez-Bayo and Wyckhuys 2019; Dangles and Casas 2019). Bee pollination has been identified as directly contributing to food security (SDG2) and biodiversity (SDG15) (Dangles and Casas 2019). However, bees could also contribute to a broader range of SDGs.

We explicitly identify the realised and potential contributions of bees towards achieving the SDGs, presenting evidence to highlight the interconnectedness between bees, people and the planet from an integrated system perspective (Stafford-Smith et al. 2017). We review the SDGs alongside the potential contributions of bees in achieving individual SDG targets. As the SDGs explicitly build on the foundation of the biosphere (Folke et al. 2016; Leal Filho et al. 2018), the perspective presented here may help in designing implementation pathways to achieve SDG targets. We identify 30 targets to which bees may contribute (Table 1.5.1) through a range of direct and indirect connections between bees, people and the planet.

We incorporate contributions from all bee species, including wild and managed populations. The European honeybee (*A. mellifera*) and buff-tailed bumblebee (*Bombus terrestris*) could be considered as "massively introduced species" having greatly expanded their geographic range through human management and escape (Geslin et al. 2017). We note the extensive and evolving literature on the interactions between native wild bees, introduced domesticated bees and feral bees, noting evidence of competition for forage and nesting resources, disruption of native plant–pollinator networks and potential for viral disease transmission between species (e.g. Geslin et al. 2017; Mallinger et al. 2017; Wojcik et al. 2018; Alger et al. 2019; Murray et al. 2019; Valido et al. 2019). We pursue a holistic perspective that encompasses native wild and managed introduced bees, following Kleijn et al.'s (2015, 2018) calls for an inclusive approach that safeguards all pollinators.

The identified critical role of bees in sustainable development

The importance of bee pollination for food crops has been widely acknowledged, with growing concern of a global crisis as demand for pollination services continues to outstrip supply, with an associated increase in less diverse, pollinator-dependant agriculture systems (Aizen and Harder 2009; Aizen et al. 2019). In addition to improving the yield of some crops (target 2.3) (Klein et al. 2007, 2018; Stein et al. 2017), bee pollination contributes to enhanced nutritional value (target 2.2) and improved quality and longer shelf life of many fruits and vegetables (Klatt et al. 2014), which could potentially help in reducing food waste (target 12.3) resulting from aesthetic imperfections (Gunders and Bloom 2017).

Less explored aspects of bee pollination include the contribution to biofuels (SDG7). Despite being self-pollinated, oil seed crops show increased yield when pollinated by bees (target 7.2) (Halinski et al. 2018; Perrot et al. 2018). Research in Mexico on the performance of bees on *Jatropha curcas* found significant improvement in the seed set when the self-pollinated varieties were supported with bee pollination (Romero and Quezada-Euán 2013). Canola, another self-pollinating oilseed crop, also shows a positive association between higher yields and bee diversity (Halinski et al. 2018).

Beyond agricultural landscapes, research in urban bee ecology aids understanding of bee dynamics in our cities and informs urban bee conservation initiatives (Hernandez et al. 2009; Stange et al. 2017). Urban beekeeping strengthens residents' connection to nature (Stange et al. 2018). Planting aesthetically pleasing, bee-attractive flowering species in landscape planning can provide forage for bees, and close proximity to such plantings may result in pollination rewards for trees and other species in public green spaces (target 11.7) (Lowenstein et al. 2015; Hausmann et al. 2016). European honeybees can be used as an

Table 1.5.1 The contributions of bees towards relevant SDG targets

Sustainable development goal (SDG)[a]	*Contributions From bees to SDG targets*	*Examples of supporting literature*[b]	*Details on the contributions that bees may provide towards achieving the SDG targets*
1. No Poverty	1.1 1.4 1.5	Bradbear, 2009; Amulen et al. 2019; Pocol and McDonough 2015	Keeping bees offers economic diversity as an income source (1.1) helping build resilient livelihoods for poor and vulnerable peoples (1.5), whilst potentially providing equal access to economic and natural resources for both men and women (1.4)
2. Zero hunger	2.2 2.3	Klein et al. 2007; Kleijn et al. 2015; Potts et al. 2016a; Stein et al. 2017; Klein et al. 2018	Bee pollination increases crop yield (2.3) and enhances the nutritional value of fruits, vegetables, and seeds (2.2)
3. Good health and well-being	3.4 3.8 3.9	Bradbear, 2009; Brockerhoff et al. 2017; Pasupuleti et al. 2017; Sforcin et al.2017; Kocot et al. 2018; Easton-Calabria et al. 2019	Bee Products provide safe and affordable medicinal sources (3.8) used in traditional and modern medicine to treat non-communicable diseases such as cancer through strong bioactive compounds (3.4). Bee pollination potentially contributes to the growth and diversity of plants that are important for improved air quality (3.9)
4. Quality education	4.3 4.4 4.5	Pocol and McDonough 2015; Mburu et al. 2017; Ekele et al. 2019	Vocational training for keeping bees can enhance equal opportunities for employment, training and entrepreneurship amongst men, women and indigenous people (with traditional knowledge) (4.3, 4.4 and 4.5).
5. Gender equality	5.5 5.a	Pocol and McDonough 2015; Mburu et al. 2017	Keeping bees as a hobby or being involved in beekeeping can enhance opportunities for women's involvement in economic, social and political decision-making processes even in communities that deprive women of property rights (5.5, 5.a
6. Clean water and sanitation	6.6	Brockerhoff et al. 2017; Creed and van Noorwijk 2018	Bee pollination may contribute to growth and diversity in water-related ecosystems, such as mountains and forest. Appropriate afforestation efforts may provide new resources for commercial bee operations whilst potentially contributing to regional water supply (6.6)
7. Affordable and clean energy	7.2	Romero and Quezada-Eua´n 2013; Halinski et al. 2018; Perrot et al. 2018	Bee pollination improves production for oilseed crops used as biofuel such as sunflower, canola and rapeseed (7.2)

(*Continued*)

Table 1.5.1 (Continued)

Sustainable development goal (SDG)[a]	*Contributions From bees to SDG targets*	*Examples of supporting literature*[b]	*Details on the contributions that bees may provide towards achieving the SDG targets*
8. Decent work and economic growth	8.1 8.6 8.9	Arih and Korošec 2015; Mazorodze 2015; Pocol and McDonough 2015; Stein et al. 2017; Quezada-Euán 2018; Vinci et al. 2018	Improved agricultural production from bee pollination may contribute to the gross domestic product (GDP) of nations (8.1). Beekeeping can diversify livelihood opportunities for men and women in rural areas (8.6) and support nature-based tourism initiatives (8.9).
9. Industry innovation and infrastructure	9.b	Xing and Gao 2014; Zhang et al. 2015; Sahlabadi and Hutapea 2018	Bees are an element of nature that inspires human innovations (e.g., airplane design and computer algorithm development) and new honey-related products (9.b)
10. Reduced inequality	10.1 10.2	Carroll and Kinsella 2013; Tomaselli et al. 2014; Mburu et al. 2017	Improved livelihoods from beekeeping and the contribution of bee pollination towards GDP can support sustainable income growth for lower income groups (10.1) which can potentially contribute to promoting inclusive social, economic and institutional development (10.2)
11. Sustainable cities and communities	11.6 11.7	Lowenstein et al. 2015; Van der Steen et al. 2015; Hausmann et al. 2016; Stange et al. 2018; Zhou et al. 2018	Bees can be useful in monitoring air quality in urban areas, as pollination of urban flora can support improved local air quality (11.6). Bees can enhance pollination and self-sustainability of urban gardens and public open spaces (11.7)
12. Responsible Consumption and production	12.3 12.b	Klatt et al. 2014; Lemelin 2019	Bee pollination can contribute to reducing food waste by improving visual aesthetics of food (shape, size and colour) and increase shelf life (12.3). Beekeeping can be marketed as sustainable tourism for regional development (12.b)
13. Climate action ns	13.3	Van der Steen et al. 2015; Smith et al. 2019	Use of bees and bee products for environmental monitoring can improve understanding of climate impacts on the environment (13.3)

(*Continued*)

Table 1.5.1 (Continued)

Sustainable development goal (SDG)[a]	*Contributions From bees to SDG targets*	*Examples of supporting literature*[b]	*Details on the contributions that bees may provide towards achieving the SDG targets*
14. Life below water	14.4	Amjad Khan et al. 2017	Bees can potentially contribute to improved production of plant-based sources of compounds commonly found in fish. Overharvesting of fish can be managed by promoting production and consumption of alternative plant-based nutrient sources (14.4)
15. Life on land	15.1 15.5 15.9	Senapathi et al. 2015; Minja and Nkumilwa 2016 Chanthayod et al. 2017; Klein et al. 2018; Mudzengi et al. 2019	Bees contribute to biodiversity by pollinating flowering trees and plants (15.5) and beekeeping can contribute to forest conservation (15.1). Incorporating beekeeping in local planning processes may support reforestation activities which can result in poverty reduction and sustainable regional development (15.9).

[a] SDG16 (peace, justice and strong institutions) and SDG17 (partnership for the goals) were cluded from this analysis given their focus on governance and policy

[b] Supporting literature includes a mix of direct and indirect evidence. The details on bees' potential contribution to SDGs have been provided using the language used in SDG targets, which may differ from the language used in the supporting literature

indicator species for tracking contaminants and monitoring environmental health (target 13.3) in urban areas (Zhou et al. 2018). In addition, understanding bee forage preference, suitability of habitat and mobility between different habitat types is critical for designing sustainable urban (target 11.7) and rural landscapes (target 15.9) to optimize pollination benefits as well as support bee health (Stange et al. 2017; Langellotto et al. 2018). For example, the United Kingdom's Protection of Pollinators Bill was proposed to develop a national network of wildflower corridors called B-lines to support bee populations and other pollinators (UK Parliament, House of Commons 2017).

The contribution of wild and managed bees in pollinating wild plants in natural ecosystems and managed forests (target 15.1) is well-acknowledged (Senapathi et al. 2015; Klein et al. 2018). The biodiversity found within forests provides a critical range of ecosystem services including water cycle regulation (target 6.6) and carbon sequestration (Brockerhoff et al. 2017; Creed and van Noordwijk 2018). Bee-pollinated plants provide a source of food for wildlife and non-timber forest products for people (Bradbear 2009; Senapathi et al. 2015). For example, Brazil nut trees (*Bertholletia excelsa*) require bee pollination to set their high-value fruit, with much greater productivity in the wild, likely due to low numbers of native bees in plantations (Cavalcante et al. 2012). Beekeeping within forest boundaries can support forest conservation (target 15.1) alongside rural livelihoods (Sande et al. 2009; Chanthayod et al. 2017; Mudzengi et al. 2019).

Keeping bees provides opportunities for income diversity (target 1.1) with low start-up costs through diverse products and services including honey, pollen, beeswax, propolis, royal jelly and pollination services (Bradbear 2009). Initiatives to promote beekeeping and pollination services in Kenya have resulted in livelihood improvements for smallholder farmers through increased farm productivity and an additional income stream (target 1.5) (Carroll and Kinsella 2013). However, in other regions of Africa, constraints to improve livelihoods through bee-related activities have been attributed to a lack of knowledge concerning bee husbandry processes, access to equipment and training (Minja and Nkumilwa 2016). Vocational education in beekeeping (target 4.3) could promote economic opportunities for employment and entrepreneurial enterprise (targets 8.6 and 4.4) and diversification for Indigenous groups (targets 1.4 and 4.5), as well as help empower women (target 5.5) including those within traditionally patriarchal societies to promote gender equality (target 5.a) (Pocol and McDonough 2015; Mburu et al. 2017).

Beekeeping can be an important strategy for livelihood diversification (Bradbear 2009), which can directly contribute to an increase in per capita and household income (target 8.1) (Mazorodze 2015; Chanthayod et al. 2017) and also allow for enhanced fiscal opportunities (e.g. tourism) and sustained income growth for people in rural areas, irrespective of social and economic status (targets 10.1 and 10.2) (Pocol and McDonough 2015; Vinci et al. 2018). An initiative for sustainable tourism in Slovenia packages bee-related education and healing experiences with bee products, together with opportunities to create and purchase original crafts using bee products (Arih and Korošec 2015). In Fiji, the Earth Care Agency is working to promote organic honey production on remote islands to provide economic alternatives for indigenous Fijians (Matava Fiji Untouched 2019). These initiatives contribute to local economies and, in the case of Slovenia (Arih and Korošec 2015), help in marketing the country's natural attractions whilst providing additional livelihood opportunities through increased tourism activities (target 8.9).

In relation to health, honey, bee pollen, propolis, royal jelly, beeswax and bee venom have all been used in traditional and modern medicine (target 3.8) (Kocot et al. 2018;

Easton-Calabria et al. 2019). Researchers have identified bioactive properties of honey, propolis and royal jelly which suggest the presence of compounds with antimicrobial, anti-inflammatory, antioxidant, antitumor and anticancer activities (Pasupuleti et al. 2017; Kocot et al. 2018; Easton-Calabria et al. 2019). Honey is used in wound and ulcer care, to enhance oral health, fight gastric disorders and liver and pancreatic diseases, as well as to promote cardiovascular health (Pasupuleti et al. 2017; Easton-Calabria et al. 2019). Propolis is used in gynaecological care, oral health, dermatology care and oncology treatments, whilst royal jelly is used in reproductive care, neurodegenerative and aging diseases and wound healing (target 3.4) (Pasupuleti et al. 2017).

Bees have contributed to industry, innovation and infrastructure by inspiring the design and development of a range of structures, devices and algorithms that can benefit sustainable development (target 9b). The honeycomb structure of beehives is often a mainstay in structural engineering (Zhang et al. 2015). Drawing inspiration from bee anatomy, the medical industry has benefited from innovations such as surgical needles adopted from the design of bee stingers (Sahlabadi and Hutapea 2018). Bee behaviour has inspired complex computer-based search and optimisation processes informing a new wave of genetic algorithms (Xing and Gao 2014).

Towards sustainable bee systems

The decline in global insect populations has attracted the attention of the scientific community, general public and policymakers (Potts et al. 2016a), with heightened public awareness of the importance of bees for pollination. Our research has highlighted the contribution bees can provide towards achieving a diverse range of SDG targets in addition to their crucial role in pollination. The increasingly positive attitude of the public towards bees, and insect pollinators more broadly, provides opportunities for efforts to conserve bee habitat and support pro-pollinator initiatives in land management, agricultural diversification and urban greening (Senapathi et al. 2015; Schönfelder and Bogner 2017).

A holistic view of ecosystems including wild and managed bees and humans is necessary to address sustainability challenges (Kleijn et al. 2018; Saunders et al. 2018). By employing a system approach, we can better understand the interconnections between elements within coupled human–environment systems. We strongly advocate the need for appropriate natural resource management approaches for maintaining sustainable systems as vital for allowing the continued success of bees in their natural role. We summarise our findings by suggesting eight key thematic priority areas whereby bees can play a crucial role in meeting the SDGs (Figure 1.5.2).

These themes provide a foundation for an emerging, yet urgently needed research agenda to explore the complex relationship between bees, people and the planet. A range of important questions should guide this research agenda including: (i) What social and ecological entities contribute to a bee–human system, what feedback and trade-offs exist amongst these entities and how can understanding structural interconnectivities within this bee–human system contribute to sustainable decision making at various spatial scales? (ii) Are there critical thresholds of bee species diversity and/or bee population abundance beyond which there are significant impacts to meeting certain SDG targets, and do these thresholds vary by geographic regions? (iii) What ecosystem services can be optimized with existing bee diversity in a region, to what extent can they contribute to achieving SDG targets and does the introduction of managed species enhance or suppress existing ecosystem services?

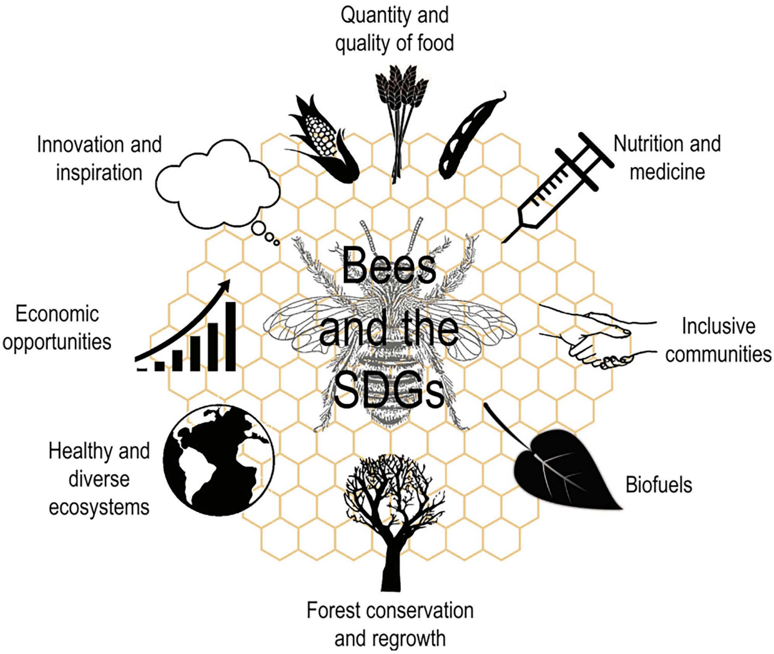

Figure 1.5.2 Bees and the SDGs. Overarching themes whereby bees contribute to sustainable development targets.

In addition, the distinct roles of wild and managed bees provide a further research lens for identifying the critical role that bees can provide in achieving the SDGs. We must strive to restore balance and reverse bee decline trajectories if we are to encounter a future in which bees continue to contribute to the sustainable development of society.

Note

1 This article is reprinted under the commons licence and with the permission of the editors of *Ambio*. Patel, V., Pauli, N., Biggs, E. et al. Why bees are critical for achieving sustainable development. *Ambio* 50, 49–59 (2021). https://doi.org/10.1007/s13280-020-01333-9.

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1.6

THE IMPORTANT ROLE OF POLLINATORS IN SUSTAINABILITY EDUCATION

Bronwen Cowie and Paula Mildenhall

Key concepts for sustainability education

- Sustainability education aims to develop knowledge and awareness and to foster a sense of connection and interdependence with nature, along with understanding and recognition of responsibility for actions that could protect and conserve our ecosystem.
- Sustainability education emphasises empowerment that includes the capacity to take action in partnership with others.
- Teachers are critical agents of change as pollinators of sustainability education who can provide foundational learning in nature-based education that highlights the inextricable link between human wellbeing and productivity and the health of our ecosystems.
- Sustainability education can usefully engage students/learners, teachers and school communities in networks of mutual and reciprocal influence and action to support biodiversity and sustainability.
- Pollinators, with bees as an example, are a productive context for learning about and taking action in support of biodiversity/sustainability. They are a wonderful, ubiquitous and often unseen example of the multiple interdependencies between humans and the natural world.

Introduction

"The bee is more honored than other animals, not because she labors, but because she labors for others."

–St. John Chrysostom

In this chapter we illustrate some of the ways the education sector can play a key role not just in educating and activating students as advocates for and agents of sustainability but also in motivating and mobilising communities towards a sustainability agenda. Current interest in learning across time and spaces has led to the realisation that education can usefully be conceptualised as a learning ecosystem of "critical interdependencies

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across contexts" (Barron 2006, 195). This realisation has led us to understand that learning happens, and can be fostered, within and across formal, semi-formal and informal spaces; organisations; and activities that can be material/physical and or virtual (Falk et al. 2015; Hecht and Crowley 2020; Mueller and Toutain 2015). Working within this view we conceptualise early learning centres, schools and universities as learning ecosystems that are nested within a wider learning ecosystem, which in turn is nested within larger societal, national and global ecosystems. Seen this way, these learning environments are understood as sites where flows of ideas and resources along with opportunities for learning intersect, interact and emerge: the social geography of learning and participation in matters to do with sustainability is viewed as encompassing students/learners, teachers and school communities in networks of mutual and reciprocal influence and action (Uzzell 1999). In this chapter we explore the potential of education, when viewed through this lens, to contribute to understanding of and action on the challenges faced by pollinators.

Despite the dramatic declines in their numbers and species, the challenges faced by pollinators, along with their centrality to our lives, is often under-acknowledged (Bélanger and Pilling 2019; Hallmann et al. 2017; Powney et al. 2019; Potts et al. 2016). Pollinator diversity decline is important because it threatens ecosystem function and human and animal food security. More specifically, around 75% of the plants cultivated for human consumption benefit from insect pollination. In the chapter we focus on bees, honeybees in particular. Bees have been called a "canary in a coalmine" representative of the decline faced by pollinators (Geldmann and González-Varo 2018) and a "flagship species" for the conservation of pollinator species (Penn et al. 2019; Schönfelder and Bogner 2017). There is clear evidence of a concerning reduction in global bee populations. While the role of bee pollination in sustainable development goals through food security and biodiversity is generally recognised, bees also contribute to other sustainable development goals such as keeping waterways clean through support for plant growth and diversity and supporting the creation of medicines (Bengtsson et al. 2018; Patel et al. 2021; next chapter) making their plight worthy of focused attention.

There is a long history to the interaction between humans and bees, with societies around the world valuing the honey and beeswax they produce long before we came to appreciate their crucial role in pollination. Honeybees are now at the forefront of concerns about the decline in pollinators, with the global monitoring of numbers just one example of the level of concern in relation to their plight. Honeybees are accessible as a focus for learning from the early years through schooling and on into tertiary education and community life. They offer a focus where adults and children can come together to develop and share knowledge and expertise and take local action that has a potential for powerful impact. Ironically, the prominence accorded to the plight of honeybees has masked the impact of their dominance over native bees and the role of other pollinators. While honeybees are currently the poster species for pollinators and for bees in general, concerns are emerging that the role of and issues faced by wild and native bees are being marginalised by widespread ignorance about the actual diversity of bees (Hall and Martins 2020; Matias et al. 2017). In addition to their contribution to pollination, native bees play an important role as a buffer to honeybee decline because diseases such as colony collapse disorder do not affect native bees because they tend to be solitary (Winfree et al. 2007).

In this contribution we scope the plight of bees as important pollinators, then use ideas from this analysis to suggest how bees might serve as a foundation for sustainability education in line with recommendations by the United Nations Educational, Scientific and Cultural Organization UNESCO 2021 (see Gough, Chapters 5.1, 7.2 and 9.3 in this volume). We outline some of the ways teachers and students within early childhood centres, schools and tertiary settings can raise awareness of the significance of pollinator conservation both locally and more widely through outreach activities that involve mutual and reciprocal engagement; learning; and action with parents, school communities, businesses and other organisations. Education and outreach have a crucial role to play because, despite the increase in awareness of and actions to support pollinators, there is still a wide mismatch between evidence of impacts and conservation efforts.

For the good of the hive

The oldest known evidence of bees is a 100-million-year-old specimen that was found in tree sap and is thought to be at least 35–45 million years older than any other known bee fossil (http://news.bbc.co.uk/2/hi/science/nature/6084974.stm). The discovery of this fossil coincided with the publication of the genetic blueprint of the honeybee, which reveals surprising links with mammals, including humans. There is evidence humans identified early on that bees could enhance their lives, most obviously through the collection of honey (Carlson 2015; Wilson-Rich et al. 2018). However worldwide, the portrayal of the links between humans and bees often has a religious and spiritual dimension (Prendergast et al. 2021). For example, the ancient Egyptians are thought to have practiced bee keeping, with honey used in many aspects of their lives from religious rituals to bartering systems. Bees feature in India's oldest sacred book, the Rig-Veda, which was probably compiled between 2000 and 3000 BCE. It was written in Sanskrit – the Sanskrit word for honey is madhu, which is etymologically identical to the Greek methu and the Anglo-Saxon medu, or mead. There is less mention of bees in early texts and artefacts from China. Early associations were often negative, although Guo Pu (276–324 CE), a Chinese historian, conceived of bees as a well-ordered imperial court ruled by a bee-king (Pattinson 2018). The connection of Australia's indigenous aboriginal people with bees can be traced to around 65,000 years ago with bee products used as medicine and as food and bees featuring as part of creation stories and represented in rock art (Perichon et al. 2021).

The over 20,000 bee species we know of today range in size, shape and preferred habitat. Only a fraction of these produce honey and have the social organisation we associate with bees, or in reality, we associate with the European honeybee. At this time sustainability concerns about the decline of pollinators tend to be anchored around a concern with honeybee decline because of the key role honeybees play in agricultural management and productivity. However, scientists are increasingly cautioning against a focus on one species. They argue we need to consider the situations faced by other pollinators (wild and native bee species, flies, wasps, butterflies and moths) that depend on the preservation of more diverse habitats than those of managed honeybees (Geldmann and González-Varo 2018; Saunders et al. 2018a). Honeybees compete with other pollinators for floral resources, which can put them at risk. This poses a biodiversity sustainability challenge to these pollinators and to the plants that are adapted to them as pollinators. In what follows we offer examples of how education and education outreach can enhance knowledge and understanding of bees and the roles they play; provoke shifts in affective responses towards bees, including intentions to act to protect them; and offer avenues for engagement and action by students, community members and organisations.

Teachers as pollinators of sustainability education

Conservation and sustainability studies in educational settings (early childhood centres, schools and tertiary institutions) often focus on large exotic (and iconic) vertebrate species – birds, tigers, elephants – rather than invertebrates. However, bees – their life cycle, social organisation, diversity and contributions – offer a rich site for inquiry and action. While mention of bees often brings forth fears about being stung, there is evidence students, like the general population, have limited knowledge of bees and the contributions they make as pollinators to biodiversity, ecosystem function and our food supply (Penn et al. 2019; Wilson et al. 2017). Even more importantly, they may not appreciate how our actions including the use of pesticides, monoculture and the reduction of habitat are contributing to pollinator and bee decline. Taken together this means education not only needs to develop knowledge and awareness, it also needs to address affective perceptions of danger and to foster a sense of connection and interdependence coupled with a recognition of responsibility for action (Chawla 2020; Ruck and Mannion 2021; Schönfelder and Bogner 2018). Knowledge, while sufficient, is not enough. Each of these aspects requires attention when the goal is for students, now and into the future (Gough, See Chapter 7.2 in this volume; UNESCO 2020), to be willing and able to take informed action to protect bees (Cho and Lee 2018; Knapp et al. 2021). Fortunately, education about and with bees has been shown to decrease the fear of bees (Cho and Lee 2018), to lead more positive attitudes (Silva and Minor 2017) and to provoke intentions to protect bees (Schönfelder and Bogner 2018). Teaching and learning that includes opportunities to develop knowledge and appreciation, to problem solve and to take individual and/or collective action have been found to empower students and learners of all ages through the realisation that they can intervene and act as agents for change (Chawla, 2020; von Braun 2017; Walker, 2017). Ideally, education offers these experiences to learners from a young age so that they are well prepared to be citizens as leaders who act in support of sustainability and conservation.

Weldemariam (2020), in his study in a Swedish preschool with children aged 4–6 years old, provides evidence of the value of early intervention. He describes the impact of a theatrical performance where the children were encouraged to “become-like a bee” (396) and participate with two actors in dancing, pollinating, fighting back people who spray pesticide on flowers and other activities typical of a beehive. With active teacher support, the children pursued an interest in bees over time, planting flowers, composing songs, spontaneously acknowledging “bees give us apples” (399) and caring for a sick bee. These activities transformed the learning experience from an alarming and pessimistic view to one that mobilised children’s affective engagement and led children to empathise with bees in a positive and proactive way.

As stated in the examples earlier, bees can offer a rich context for learning for all ages. In the study by Baptista et al. (2018), the teacher worked with a class of 26 children aged 8 and 9 years. The school was in a rural setting in inland Portugal where agriculture was the main source of subsistence. The children engaged in collective action related to: “What is happening to bees?” The teacher began by asking the children to discuss what they knew and to bring to class stories related to the importance of bees in their lives and those of their families. Children then engaged with a scenario where two friends called a relative to ask him to prepare their favourite honey and honey cookies for when they visited him. The relative replied he could not because bees were dying and no honey was being produced. The children explored this problem then participated in a role-play where different groups took on different roles such as pesticide industry representative, scientist, beekeeper and farmer. To reach out to the local community, the children crafted a manifesto and asked community members to subscribe to it. They also created slogans to draw attention to the problem and wrote a letter to the Ministry of Environment outlining their concerns. This study highlights how it is possible to educate children in ways that empower them to become active members of society who work towards a fairer world (Gough 2024; UNESCO 2021). This coupled with an ability to know when and how to take action is essential if a democratic society is to function sustainably.

In yet another example, children aged 9 and 10 in Western Australia learned about the plight of bees (Mildenhall et al. 2021). The Honey Bees module began with a local apiarist visiting the class of 9- and 10-year-olds and explaining how she cared for her bees and hives and the honey extraction process. The children researched what foods relied on pollination and what were some of the causes of declining honeybee numbers. The teacher then negotiated with the class that they would design a board game based on the roles bees play and how to ameliorate the challenges bees face to share what they had learned. The children invited their families, other teachers and the wider community (including the apiarist and other beekeepers) to the school to play their games. They received positive feedback from attendees on their enthusiasm and what the attendees had learned. When interviewed at a later date, attendees reported they had planted more flowering plants and were allowing vegetable plants to flower – two everyday and achievable actions that are advocated as supporting pollinators. The children decided they wanted to encourage bees and insects around their school and, with parent support, created bee-insect "hotels" which they hung in trees around the school grounds. School and university grounds and urban public spaces such as parks, while often overlooked, are readily accessible sites for biodiversity action, ones that have the advantage that students and the public can observe and track the impact of their actions (Harvey et al. 2020; Ruck and Mannion 2021). Pollinator gardens can be planted in ways that offer floral resources for managed, wild and native pollinators. Through the strategic inclusion of native plants, they can support flora biodiversity whilst providing children and adults with compelling aesthetic and sensory experiences of nature.

Observation of a beehive, both real and virtual, can provide rich opportunities for learning for students as adolescents. Working with students aged 13 and 14 years, Schönfelder and Bogner (2018) found that when these students observed a beehive and were able to comprehend it as a complex system of interdependencies between bees, the hive and local floral resources, their interest in and their awareness of the need to conserve bees as pollinators increased. This was the case for students' actual and virtual interaction with a hive and bees. Schönfelder and Bogner argue that student interactions with living animals in educational settings is essential, especially when students' affective orientations are a consideration. Having students care for an actual hive comes with the advantage that they have opportunities to gain and share their expertise and passion with their families and with community members – beekeepers (hobby and professional), people from garden shops and clubs and horticultural societies who have knowledge of flowers and business people who can advise on marketing and selling honey and beeswax.

Riley and Noble (2021) identified a similar impact on New Zealand students aged 10–12 years old when they were charged with caring for an observational beehive or apiscope located in their classroom. These authors highlighted the value of students interacting with a living system, with student learning spanning a number of curriculum areas including science and sustainability (bee life cycles and threats), mathematics (honeycomb construction and navigation) and dance (how bees communicate). The outreach activities that were part of the project involved students in authoring and publishing books for young readers, composing and performing songs, choreographing dances and producing music videos about bees. Each of these activities required students, in groups, to form relationships with community members – scientists, bee keepers, illustrators, musicians, video makers and so on. Through these activities students came to appreciate that while individuals may have different roles, each is essential and the school became "a cell better connected to the world around it" (Amery 2021, 249).

Looking more broadly, students and the public are increasingly being invited to engage in citizen science projects where they engage to various extents in the collection, collation, sharing and analysis of data locally, regionally, nationally and globally. Community members, both adults and children, as citizen science volunteers have conducted counts and helped gather the data needed to understand wild and native bee populations in urban areas (e.g., Mason and Arathi 2019) and factors mediating pollinator population decline (e.g., Le Féon et al. 2016; Pocock et al. 2018). Notably, in 2017 the United Nations designated 20 May as World Bee Day to raise awareness of the importance of pollinators; Anton Janša (1734–1773), who pioneered modern beekeeping techniques in Slovenia, was born on this day. In 2020 people from 65 countries uploaded over 20,000 photographs of bees to the Bee Day app. More locally, students, through their involvement in citizen science projects, are able to work with scientists and contribute to "real" science (Steinke et al. 2017). Citizen science projects, when managed well, have been found to foster long-term scientist-school partnerships which generate data and insights about bees that are of interest to the scientific community and to the public (Brewer 2002; Serret et al. 2019; Sharma et al. 2019). In one example of this potential, five schools in New South Wales, Australia, monitored insect prevalence and type in different urban habitats (Saunders et al. 2018b). Involvement in the project developed students' science and data literacy skills and supported research in the area despite challenges around managing the quality of data and differences in interests. In an example with older students, an undergraduate ecology class at the University of Georgia collected and analysed data on pollinators in yards, gardens, schools and parks. The undergraduate class produced a film that promoted participation in the project, and they created a garden that included bee-pollinated flowers. This process enhanced the local community and increased the undergraduates' own science inquiry skills (Oberhauser and LeBuhn 2012).

To highlight just how successful citizen science can be, it is useful to consider the novel study conducted by children in England. The 25 children, who were 8–10 years old, conducted an experiment to find out if bees could learn to solve puzzles. They published their peer-reviewed findings that bees have the capacity to learn and memorise a pattern in the journal *Biology Letters* (Blackawton et al. 2011). The research study found that bees can use shape to make decisions about which flowers to visit, an ability that is important for the sustainability of the species if and when they face a decline in some types of flowers. Overall, the study produced valuable data that contributed to our understanding of bees which is, of course, essential if we are to halt their demise.

Sustainability education: a hive of activity

While knowledge and concern about the global decline in pollinator/bee numbers are now widespread in the scientific community, public knowledge tends to be limited, in part because invertebrate conservation has received limited attention. When people know more about pollinators and bees, their contributions to our lives and the impact of our actions in their decline, there is evidence that people are motivated to take action, although, for a number of reasons, they may not always do so. In this contribution we have provided some examples of how educational settings have an important role in developing knowledge and motivating and empowering learners of all ages to take action for sustainability (Goug 2024; UNESCO 2021), in this instance, for bees as keystone pollinators. Teachers can provide students in early years to tertiary settings with opportunities to experience how their individual and collective actions can make a difference. They can support students to appreciate the local implications of global issues and also that their actions can make a difference beyond the local. Both of these aspects are important if students are to avoid being overwhelmed by a sense of powerlessness and hopelessness (Chawla 2020). Looking towards a future when today's young people are influential decision-makers, it is beneficial that these learning experiences are available from the early years (Davis 2014; Istead and Shapiro 2014; Lindemann-Matthies et al. 2021). Then, hopefully, children's propensity to act will continue into adulthood. Also relevant, children can be important pollinators (catalysts) of, and participants in, learning and action that engage family and community members (Ballantyne et al. 1998; Mannion 2016; Uzzell 1994, 1999). Teachers can encourage and support children to share what they learn at home with family members and the wider community; children can influence and educate their parents and other adults by communicating their learning and through their commitment to live in a more sustainable manner. At the same time, students can benefit from experts and community members sharing their knowledge, expertise and passions: these processes of cross pollination come with mutual benefit, with the added benefit that they illustrate the role of interdependence that is so critical to understand in relation to sustainability. Experience of these processes is an important contribution education can make, given that contemporary concerns about sustainability mean it is essential that all members of society recognise the interdependence of the human and more-than-human and material world (Gough 2024). Similarly, it is important that everyone is knowledgeable about what might constitute productive action. As society commits to a sustainable future, pedagogical approaches such as those outlined previously are examples of how we might move the sustainability agenda forward.

Looking back over time, there is evidence that many cultures have recognised and valued the contributions bees make to our lives and have sought to manage them in some way. Currently, scientists are moving to recognise and engage with indigenous knowledge in order to better understand how to support biodiversity and sustainability (e.g., Athayde et al. 2016; Perichon et al. 2021). Indigenous and local community values and knowledge, albeit diverse, often offer an alternative understanding of the relationship between people and nature, one that blurs the distinction and emphasises the need to sustain respectful and reciprocal relationships (Brondízio et al. 2021). Formal curricula worldwide are moving to acknowledge and include the diverse knowledges and practices of indigenous and local communities. This aspect is ripe for further development, especially in relation to native species which can be abundant in urban parks, home gardens, wild spaces and the countryside, making them a rich resource for learning and site for action.

Concluding comments

Overall, we propose that education, formal and semi-formal and across and amongst people of all ages, is key for the pollination of the desire to and knowledge of how to live sustainably. Sustainability education in each of these contexts can actively engage students/learners, teachers and school communities in networks of mutual and reciprocal influence and action to support biodiversity and sustainability. Bees as pollinators can provide a productive context for learning about and taking action in support of biodiversity and sustainability. Bees are a diverse and fascinating species that is indispensable to many aspects of the world we live in, but they are often overlooked as an example of the many interdependencies between humans and the natural world. However, when sustainability education aims to develop knowledge and awareness, to foster a sense of connection with nature and to promote recognition of responsibility to protect and conserve our ecosystem, the study of bees can be a rich context for awareness and action. Honeybees in particular are an engaging and accessible context for learning about sustainability and taking action that is both local and global. In this contribution we have argued and illustrated that teachers are critical agents of change as pollinators of sustainability education. Teachers are ideally positioned to provide foundational learning in nature-based sustainable education that highlights the inextricable link between human wellbeing and productivity and the health of our ecosystems.

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1.7
HONEYBEE LEADERSHIP
Many winners and no losers

Harald Bergsteiner and Gayle C Avery

Key concepts for sustainability education

- Sustainable leadership is about how our decisions and actions impact all living things as well as the broader environment. Educators play a major role in this process.
- Leaders and leadership should be distinguished: leaders are persons occupying a particular role, whereas leadership is systemic – it emerges when leaders and followers interact in a particular context.
- We use insect metaphors to describe two diametrically opposed leadership systems offering vastly different outcomes: honeybee and locust.
- Business-as-usual "locust" leadership emphasises the interests of single groups of stakeholders such as employers and investors, seeking to maximise returns for those groups in the short term, often at the expense of other stakeholders.
- Sustainable "honeybee" leadership focuses on long-term benefits to multiple stakeholders – individuals, groups, organisations, nations, human society, the natural environment and future generations.
- Sustainable leadership is not a zero-sum game and strives for positive outcomes for multiple stakeholders.
- Leadership outcomes should be broadened beyond traditional financial metrics to encompass a wide range of benefits including – at the broadest level – promoting wellbeing, self-reliance, resilience and "immunity".
- Research and practice provide comprehensive guidelines for delivering sustainable "honeybee" outcomes, including for educators.
- "Honeybee" educators seek to promote the kinds of decisions, actions, behaviours and systems that deliver sustainable outcomes.

Introduction

It's clear that the sustainability of our way of life and the very existence of the planet on which we live are under serious threat. The Intergovernmental Panel on Climate Change

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(IPCC 2023) details the consequences of not addressing climate change in its many scientific reports. We know the facts, we need urgent action.

Educators play an important role in promoting sustainable practices given the failure of many governments and businesses to adopt meaningful solutions to sustainability challenges, despite potential benefits to their nations, organisations and stakeholders. A cross-disciplinary literature review (Feeney et al. 2023) pinpointed learning as an essential process for encouraging sustainable action. This requires broadening the thinking of key actors, such as politicians and business leaders, beyond national and organisational boundaries and for them to engage more with their constituents and stakeholders. Findings from the review highlight the "different ways that power relations influence learning and decision-making processes, and how entrenched traditional value structures and 'reflexive complicity' limit practitioners and researchers alike in finding meaningful sustainability solutions" (Feeney et al. 2023, p. 217). One behavioural pattern in particular that needs educators' attention is the "reflexive complicity" expressed by many key actors. Reflexive complicity occurs when someone who knows about social or environmental inequities can observe them and even claims to want to change things but does nothing to advance that change.

Many of us look to governments to deal with the consequences of poverty, war, climate change and the accompanying loss of biodiversity – problems that are of such magnitude it puts them beyond the capability of any group or individual to solve. The United Nations (UN) Agenda 2030 has moved away from a sole focus on government action to calling for the private sector to also step up. The good news is that many corporations are responding by addressing some or all of the UN's Sustainable Development Goals by redefining the purpose of the organisation with a view to enriching the world and itself socially, environmentally *and* economically. Doing good to do well.

Many governments have disappointed by ignoring the science and prioritising economics over people and nature. Similarly, business schools have generally let us down with their focus on teaching students about making money for investors at all costs. Attempts to change this mentality at one leading Australian business school shortly after the turn of the millennium were disrupted by administrators who did not understand the value of establishing an integrated research and teaching program focused on sustainability in the broadest sense. Kramar (2013) reports on the challenges in making fundamental changes to a leading MBA curriculum, despite wide-ranging stakeholder involvement, action research and even government support for this initiative. Another Australian business school went to market with a new product whose slogan was: "Me First", implying a self-focused curriculum.

The good news is that in the last 5 to 10 years much has changed outside universities and government. Business practice is changing from a shareholder to a stakeholder focus; CEOs are increasingly pursuing sustainable practices, and the corporate sector is often ahead of governments and even universities; employees, consumers and shareholders are demanding change; and some legislators are putting the onus on directors to act more responsibly.

Research shows that doing so is good for business and has beneficial national implications (Bergsteiner & Avery 2019). Not all organisations adopt a responsible approach, which we term *sustainable leadership,* but major business firms that have thrived on it for decades or even generations are found in most countries and sectors. Examples include diverse corporations like Cascade Engineering and WL Gore & Associates (USA), BMW and Munich Reinsurance (Germany) and B. Grimm and Siam Cement Group (Thailand) as well as many small- and medium-sized companies. Sustainable leadership is particularly likely where the founders or the founding family are still involved in the business, as they are at Dell Technologies and Nordstrom.

Sustainable leadership

The theory and practice of sustainable leadership (Avery & Bergsteiner 2011) is based on the premise that what counts in the final analysis is whether leadership and the actions of leaders, followers and other stakeholders produce sustainable social, environmental, economic and cultural outcomes at the level of individuals, groups, organisations and societies. In other words, we view leadership very much as *the input* that more than any other facilitates or impedes achieving a range of *sustainable outcomes*. In this sense, leadership is systemic, created through the actions of leaders and followers within a particular context.

Taking a systemic view rather than a person-centric view of leadership requires us to distinguish between the concepts of leader and leadership. Most people, including educators, think of individual leaders when discussing leadership. However, leaders are persons in a particular role within a group or organisation. Leadership emerges when those leaders interact with others in the system ("followers") and is shaped by contextual factors such as national and organisational cultures, policies, procedures, strategy and available resources.

The concept of sustainable leadership is a radical departure from conceptions of leadership that somewhat problematically define leaders by reference to various specific *leader traits* (e.g. authentic), which can never cover the full gamut of desirable leader traits because a leader should also be compassionate, trustworthy and so on. To complicate things further, some leader *traits* can apply to both desirable and dysfunctional *leader behaviours* (e.g. while Vladimir Putin can be described as authentic, confident and decisive, few people would ascribe positive traits such as compassionate, considerate, fair, generous, honest, humble, moral, thoughtful, transparent or truthful to him). Under a best-case scenario, leadership is systemic, in which case we talk about a *leadership culture* that guides people about what needs to be done, when and how, rather than about a specific kind of leader. The leadership culture may well outlast an individual leader.

Whereas the adjectives applied earlier can be ambiguous, narrow, confusing and even misleading, the notions of economic, social, environmental and cultural *sustainability* can be expressed in unequivocal terms that are measurable and verifiable. For example, an international commitment is emerging that the world needs to reach net-zero emissions by 2050. Similarly, we can set, implement, measure and adjust organisational goals that align with regional, national and global targets. In each case, the objective is sustainability through sustainable leadership. To make this somewhat abstract concept more accessible, we apply the honeybee metaphor to leadership practices in organisations of all types and sizes that strive to achieve high business performance while caring for the planet and its inhabitants. We contrast *honeybee leadership* with *locust leadership*.

Honeybee and locust metaphors in sustainability

A honeybee metaphor, while not perfect, is useful because it shows us that bee communities can achieve sustainable outcomes even though – as far as we are aware – they do not make conscious decisions about how they do things. And yet, despite their small brains, every member of their highly efficient community "knows" what their purpose, roles and tasks are, no-one gives orders (i.e. there is no formal leader!) and the role of the queen is to guarantee the survival of the community by laying eggs, which are then tended and defended by specialist bees. But it gets better: the bee communities are so good at what they do that they have become the world's most prolific pollinators and producers of honey, which coincidentally also benefits us. It is what we would call a virtuous loop that benefits them, us and the environment. Honeybee leadership promotes a comparable virtuous loop.

Now, we are not being anthropomorphic here. Bees do not do their stuff out of the goodness of their hearts and brains; it is simply how they have evolved to their and our benefit. That being the case, one might have expected that we, with our large and powerful brains, would protect and nurture bees to the greatest extent possible. Instead, large bee populations across the world are being wiped out through the pesticides we spray in order to control or eradicate unwanted pests. The bees are "merely" collateral damage in the profit-making process.

This is where locusts come in – of the insect and human variety. During droughts, when fodder is scarce, locusts are basically solitary creatures, but when droughts are followed by heavy rains and vegetation blooms, locust populations can explode to plague proportions to the point where available fodder rapidly becomes scarce and the population collapses. Again, this is not some sort of strategy that locusts follow, but simply *their* evolutionary path. Locusts don't build communities, but survive in boom and bust cycles. Unlike bees, locusts have very few friends, even though they have been eaten by humans throughout history and are considered a delicacy in some countries. However, because of the huge damage they cause in countries such as in Africa, insecticides have been extensively used to control or eradicate them, killing entire bee populations in the process, which creates sustainability issues for the plants and the people that depend on them.

Both bees and locusts have been around for a long time, and so on that basis can be regarded as sustainable species, each in its own way. We humans can choose our evolutionary path: do we want to behave more like bees or like locusts? It is essentially a moral choice we can and should make. If our morals, ethics and even laws tell us that it is unacceptable for large numbers of people, animals and plants to die when this is clearly avoidable, then we need to design and implement appropriate mental and physical systems that ensure that this occurs. Education is one vital part of this process. Sadly, there are many individuals, organisations and countries that eschew morals and adopt the locust approach to leadership, feeding their greed for money, stature and power. The most obvious example that comes to mind is Vladimir Putin, but there are many others at the top of government and business.

Locust leadership in action

Launched in 1995, Amazon has grown into one of the largest technology corporations in the world using a locust *corporate strategy* of exploiting its workforce to the maximum legal extent. It does this by keeping wages and conditions to the bare legal minimum; micro-managing what each employee does, when and how; avoiding costs that do not directly contribute to the bottom line; strictly applying punitive policies; firing employees who do not comply with the company's rigorous demands; and preventing unionisation (Head 2014). As this example shows, corporate strategy is about how an organisation's system is structured and how its resources (capital, infrastructure, equipment and human) are used – or in Amazon's case, abused.

A Google search of Amazon's (2019, 2020) annual reports produced no hits for "stakeholder" or "social responsibility"; nor did the terms donation, altruism, philanthropy or endowment appear. However, the company does issue a separate sustainability report in which its social responsibility activities are described, particularly its environmental measures. Somewhat belatedly, in 2020 Jeff Bezos established the philanthropic Bezos Earth Fund with a $10 billion grant commitment to fight climate change and protect nature to be disbursed by 2030. Given the other business practices at Amazon, one could ask whether this is greenwashing or just a catch-up.

When Amazon's "sustainability" is examined in terms of how much it has contributed to the wellbeing of stakeholders of the business, including its employees, local communities and society at large, a rather dismal picture emerges. Employee hourly salary was a meagre $15 in 2018, whereas the estimated hourly income of the company's primary shareholder was approaching $10 million. Notably, employees on $15 per hour have to pay tax on their income, whereas Amazon's US federal income tax in 2018 was $0.0 (Drucker Institute 2019). So basically, this is a matter of the winner – in this case the shareholders – taking all the tax breaks favouring large corporations. It is unlikely that the abused and vulnerable employees that Head (2014) describes would see themselves as committed followers of the company or its then CEO.

Introducing sustainable honeybee leadership

Educators can play an important role in introducing their students to an evidence-based alternative to the widely taught locust approach to leadership, namely honeybee leadership. Honeybee leadership puts long-term individual, organisational and community resilience; longevity; and high-performance front and centre and still generates profits. Honeybee leadership describes a system that generates a cohesive and humane culture. This perspective is important at a time when media and others are preoccupied with egocentric leaders while ignoring the important role of committed and engaged followers and the effects of the broader context on leadership and sustainability management.

We define sustainable honeybee leadership as:

> Sustainable leadership occurs when an individual, an influential group or an organisational culture energises, enables and guides people to pursue a collective purpose and vision that produce outcomes that enrich and strengthen the wellbeing, self-reliance, resilience and immunity of organisations, stakeholders and their communities.

The honeybee leadership philosophy centres around 23 evidence-based leadership practices that are diametrically opposed to the locust business-as-usual practices with their only focus on creating short-term financial returns to investors and shareholders. Honeybee leadership takes a long-term view and embraces the interests of a wide range of stakeholders in making decisions, including the environment, society and future generations.

Honeybee-led firms care for and develop their people, try to protect the planet, care for the local communities in which they operate, consider the needs of a wide range of involved or affected parties and protect their image and brand through ethical behaviour. Just as social ties hold the bees in a hive together, so collaboration and a shared vision and purpose are vital for honeybee-led organisations. While these enterprises and their stakeholders continue to prosper, by contrast, locust leadership creates poverty, insecurity and misery for many.

Honeybee leadership is highly strategic, steeped in science and sophisticated, creating resilience and wealth for the many rather than the few. With its long-term focus and holistic approach, honeybee leadership delivers better outcomes more responsibly for more stakeholders.

Research shows that honeybee leadership enhances five important performance outcomes: brand and reputation, customer satisfaction, financial performance, shareholder value and long-term stakeholder value. This broadens the concept of performance way beyond the traditional financial outcomes that many businesses narrowly report on.

The sustainable leadership pyramid

The 23 honeybee practices are organised into a pyramid (see Figure 1.7.1). The practices themselves are arranged in three groups that help clarify the vertical and horizontal web of relationships and the mutually supportive practices. These and the outcomes are:

1. The foundation practices. These practices relate to management. Managers can embark upon these at any time. For example, management can introduce and share an organisational vision or purpose at any time, introduce systems for promoting ethical behaviour or establish continuous training and development programs for all employees.
2. Higher-level practices are those that one wants employees to master and are difficult for management to impose. For example, intrinsic motivation, knowledge sharing and self-management involve employees. Although foundation practices set the stage for the higher-level practices, the latter are not directly under the control of management.
3. Key performance drivers are practices that customers value, namely staff engagement, and the quality and innovativeness of services and products.

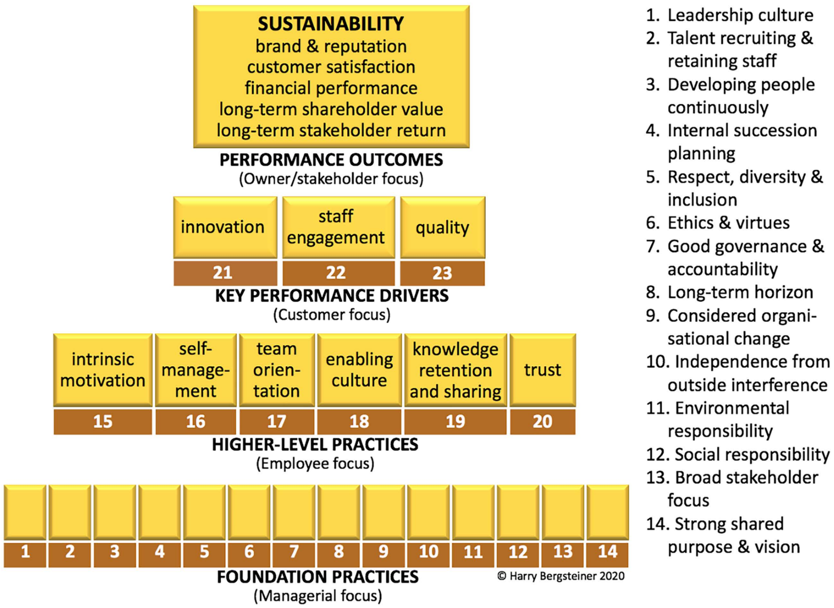

Figure 1.7.1 Sustainable leadership pyramid.

4. Performance outcomes form the apex of the pyramid, which impact diverse stakeholders as well as the organisation itself. When decisions enhance the wellbeing of all stakeholders (including the planet and its inhabitants), the decision maximises its sustainability potential.

Research shows that each individual practice adds value to an organisation, much of it being measurable (Avery & Bergsteiner 2011). Increasing ethical behaviour, for example, enhances outcomes at the national, corporate and individual levels (Ethics Centre & Deloitte Access Economics 2020). Being perceived as more ethical could raise Australians' average income by $1,800 a year and lift the nation's gross domestic product (GDP) by $45 billion. At the company level, being seen as more ethical can increase return on assets by about 7%. For individual citizens, benefits encompass better wages, trust and mental health. Other individual practices add different kinds of value to an organisation including talent attraction and retention and improved innovation potential, which also benefit the bottom line.

However, since leadership practices form a system, all these practices and outcomes also interact with each other to contribute to the overall sustainability of a group or enterprise. One practice can affect other practices, positively or negatively. For example, in a negative organisational culture such as at Amazon distribution centres where trust is low, motivation suffers, self-management is not allowed, team orientation is undermined, the culture is disabling and so-called "gatekeepers" hoard knowledge instead of sharing it.

In the positive honeybee culture found at automaker BMW, the practices augment each other. For example, extensive training and development that encompass everyone (the budget for this is about the size of a medium-sized university's budget) interacts with high levels of employee retention. Keeping employees also requires a visible career path with succession planning for each person, as well as ongoing skill development. As part of respecting employees, BMW offers about 100 work flexibility programs to foster work-life balance, and the company rewards innovative suggestions financially. These policies are based on a long-term time horizon and a broad shared vision and purpose. Highly skilled and engaged workers who share the vision and purpose collaborate in self-managing teams to generate high levels of innovation and quality for the organisation's products and services. Thus, under honeybee leadership, the practices augment and support one another.

Leadership culture

The first and most critical practice on Figure 1.7.1 is *leadership culture*, which generally takes one of four basic forms – classical, transactional, visionary and organic – depending on the nature, structure and strategy of the business (Avery 2004; Avery & Bergsteiner 2011). Classical leadership arises when a powerful individual or group directs others what to do, as at Amazon. This is sometimes known as command-and-control leadership. While labour is remunerated under all paradigms, the focus under transactional leadership is very much on the money side. Transactional leadership, as its name suggests, is based on a deal between employees and employers – workers provide their labour in return for a certain salary and conditions. The centrality of money changes under visionary leadership, where the employees are motivated by a common vision and purpose, making them willing to collaborate to achieve those outcomes. A shared vision and values are key to successful visionary leadership, as is teamwork.

The first three leadership cultures reflect different ways in which leaders relate to their employees, but in an organic leadership culture there may be no formal leaders. Persons occupying leader roles may change as circumstances require different skills or experience. Like visionary leadership, an organic leadership culture is built around shared vision, purpose and values, as well as high levels of collaboration. However, while organic leadership cultures are distinguished by not necessarily having permanently appointed leaders, the decision-making power passes to the team members – empowering the people.

It is very important that an organisation adapts its leadership culture to suit the parties concerned: the leaders, followers and the context in which they are operating. Public service organisations – even universities – often display a transactional leadership culture, whereas at BMW, a visionary leadership culture operates across this large global organisation. Highly skilled employees are also expected to bring business "nous" and be engaged in developing the organisation, which is team based at all levels. WL Gore and Associates (makers of Gore-Tex) is legendary for its egalitarian organic leadership culture that enables high levels of innovation. New recruits are inducted into the prevailing leadership culture.

Education changes mindsets

Sustainability-minded educators function in a world dominated by big business where locust thinking is still widespread. An inspiring example of how an entire nationwide school system was changed towards sustainable thinking comes from Thailand, where about 23,000 of the country's almost 40,000 schools became "sufficiency schools" under a major initiative.

The sufficiency-based school movement embedded sustainability principles in the curriculum in age-appropriate ways, as well as encouraged school principals to change how their administrations worked to further role-model the behaviours (Dharmapiya & Saratun 2016). Beginning in about 2008, nearly half (46%) of Thai primary and secondary schools had been certified as "sufficiency-based", with sustainability principles integrated directly into relevant lessons or indirectly as decision-making principles. By change management standards, this dramatic transformation within only eight years happened very quickly, particularly given all the stakeholders involved in education – including parents, students, teachers, principals, counsellors, the local community and suppliers and government authorities.

The sufficiency approach refers to a national sustainable development philosophy promoted by the late King Bhumibol Adulyadej of Thailand, called the Sufficiency Economy Philosophy (SEP). The SEP is highly relevant to honeybee leadership because the 23 honeybee practices are embedded in the SEP process developed for teaching and research (Bergsteiner & Dharmapiya 2016). The SEP was introduced across all sectors of Thai society, from business to healthcare, agriculture to environmental management and community development (Avery & Bergsteiner 2016).

The first step was to educate principals and teachers to understand sufficiency thinking so that they could teach their students about it. The curriculum was designed to develop students in using the SEP in decision making, to be virtuous (moral, ethical with desirable values, disciplined and practising spirituality) and to embrace and apply sufficiency thinking in their daily lives. This was done partly through a QPAR process: teachers ask Questions, students develop Plans, learning is through Action and application and all Reflect afterwards on the learnings.

The results of this rapidly adopted initiative in creating sufficiency-based schools were impressive: academic results improved, including on national tests; more students were accepted into university; enrolments increased as parents scrambled to send their children to these schools; community involvement rose; and even student manners and self-confidence benefitted. A further problem in Thailand was that teachers and locals had struggled with financial management and many had accrued considerable debt, so the program also helped by providing financial literacy for students, teachers and the community.

In this example, a powerful and much-loved leader, the late Thai king, led the way for the change with his SEP approach to lifting the development of his nation. Government authorities and local communities recognised the need for change and that changing mindsets towards greater sustainability begins with educating the next generation. Considerable support was provided to the teachers and school administration, who were also motivated by recognition and celebration of their achievements and evidence of success.

Implications for educators

Given the strength of locust thinking and inaction on sustainability permeating our business world, media and even universities, what can educators do to promote a more sustainable world using honeybee leadership? The 23 honeybee leadership practices are individually, as well as in bundles, part of a system supported by research, management theorists and the demonstrable longevity and performance outcomes of many well-known organisations around the world. What can we learn about how educators in all disciplines can make a significant shift in the mindsets of the next generation?

Firstly, it is useful to note that honeybee organisations place a huge emphasis on education through multiple channels – for all members of the organisation, not just for the top talent or high potential employees. Everyone is continually being trained and developed using a wide variety of techniques from conventional classroom learning to mentoring, on-the-job training and apprenticeship programs. Courses cover not just technical skills and knowledge but are also about processes such as leading teams, managing meetings, resolving conflicts and other essential interpersonal skills. BMW can be regarded as a role model for learning organisations given its investment at all levels in education. For example, BMW managers spend two to three days a year on the factory floor to learn about production issues; whole teams engage in three-day residential workshops not only to learn about new vehicles but also to share the purpose and values of the organisation. BMW is also a recognised leader in sustainability, having issued its first sustainability report in 1989, and continues to operate with sustainability at the core of its business strategy. Educators come from many sources – universities, private trainers, the teams and special training areas. An extensive focus on upskilling the workforce is typical of honeybee organisations and is maintained even in economic downturns.

Secondly, descriptions of honeybee leadership in businesses and other organisations might sound remote for those of us working in universities and other educational settings. However, we are all part of leadership systems that pass the values of the organisation on to others – the university, department or research groups we belong to all reflect leadership systems. Which values prevail in your leadership systems: short-term locust thinking with a focus on finance to please the university or department head or a long-term honeybee perspective that is mindful of a wide range of stakeholders affected by decisions? It's important to remember that every additional honeybee practice has the potential to enhance outcomes for an organisation, so could your own teams, departments, schools, faculties or other academic groupings improve by adopting more honeybee practices and moving away from a locust culture?

Thirdly, many educators are teachers formally employed in schools and universities. These professionals can use honeybee leadership principles to shape the views and values of their students. For a start, in business schools corporate leaders should be taught that they do not have to sacrifice firm performance in shifting towards sustainable leadership because honeybee practices typically enhance business outcomes. It may not be possible to change mindsets on the scale we saw in Thailand, but class by class, this can happen once the teachers have adjusted their own mindsets towards creating a more sustainable future using systemic honeybee leadership practices.

Fourthly, some people may be sceptical that honeybee leadership applies to educational institutions, but in executive education programs and on our sustainable leadership study tours, school principals have immediately related to the 23 practices and seen how they can improve their own school leadership. Knowing that honeybee leadership produces better outcomes for organisations of all kinds should prompt you to examine the practices that you find in your educational organisation.

Fifth, examine the leadership culture in your own university, department, or team. What sort of leadership culture prevails, and is it appropriate for the high-knowledge workers likely to be found and produced there? Universities sound well suited for organic leadership cultures – everyone is supposed to be equal and following the same vision and values, wanting to be included in decision making. But often classical or transactional leadership cultures dominate.

Sixth, educators themselves are leaders when teaching others. Which leadership culture do you create in your classroom? What about in other groups you run? What organisational or leadership cultural systems are dominant in your sustainability teaching – and is this really the best system of leadership?

Seventh, the five performance outcomes developed for a business context need to be modified slightly to suit most educational institutions, but all still apply. Maintaining and enhancing the institution's brand and reputation are vital for research and teaching rankings and attracting the best talent; customer (= student) satisfaction is clearly important, as is managing within set budgets. While government institutions do not have investors, they are accountable for achieving goals and targets, including financial ones, and should be providing long-term value for taxpayers or other funders.

Eighth, what is the purpose of the institution an educator belongs to? Without doubt, universities and schools are supposed to generate benefits for all stakeholders – wellbeing, self-reliance, resilience and immunity to setbacks for individuals and their communities. On top of this, universities should have a broad social purpose such as that espoused by Leuphana University (2022) in Germany (see Chapter 9.7 – Weiss, Mula, Zimmermann and Diethart in this volume):

> Leuphana contributes to the sustainable development of society through education and research. It contributes to the promotion of skills in dealing with complexity, interdisciplinary problem solving, independent and self-directed learning, the willingness and ability to assume social responsibility, in short: the ability to shape society.

Ninth, what is the purpose of education? Is it not incumbent upon educators to ensure that students are sensitive to their social, environmental and cultural obligations, no matter which field they graduate in? Therefore, the next generation should be taught to take account of the needs of society and the ecosystem in which they will work and how to contribute positively to it, as happened in Thai schools. We live and operate in a global and an ecological system – surely our leadership style should reflect and respect these inherent systems.

Conclusion

Returning to the honeybee and locust metaphors, as in nature, research and practice show that the honeybee approach is demonstrably better for the enterprise itself and its own sustainability, as well as for the welfare of nature and society. Sustainability educators can provide the honeybee approach as an alternative and show how the self-centred locust culture contains the seeds of its own destruction, as some corporations have discovered, including Walmart, the largest Fortune 500 company. Accused of exploiting its people, local communities and the environment and plagued by employee class actions and disgruntled stakeholders more than 15 years ago, Walmart began to morph from a locust towards embracing more of a honeybee business management model. It has been a long transition requiring widespread education of all leaders and employees from then to today. Walmart (2024) describes its aim as:

> We aim to build a better world – helping people live better and renew the planet while building thriving, resilient communities.

Walmart employees did not escape the 2023 layoffs, but when honeybee employers have to lay off staff, they try to do so in a humane, employee-centred way. During the 2008–2009 global financial crisis, BMW did deals with the unions and government to ensure that it retained its employees through a four-day working week.

For both Walmart and BMW, following honeybee leadership practices means bringing prosperity to the enterprise, environment and society, just as the living honeybees ensure prosperity for the planet and its inhabitants. This is surely a critical message for sustainability educators to send.

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SECTION 2

Modern sustainability challenges

"Saving our planet, lifting people out of poverty, advancing economic growth . . . these are one and the same fight. We must connect the dots between climate change, water scarcity, energy shortages, global health, food security and women's empowerment. Solutions to one problem must be solutions for all."

(Ban Ki-moon, Address to the 66th General Assembly: "We the Peoples" 2011) https://www.un.org/sg/en/content/sg/speeches/2011-09-21/address-66th-general-assembly-we-peoples

Section 2 presents fundamental concepts needed in sustainability education and the important language of sustainability that is relevant to all disciplines. We review the main sustainability challenges of the 21st century and frame them as critical content in sustainability education.

Some of the challenges faced in the development of sustainability education include the scope and breadth of topics that are crucial to the contextual understanding of sustainability issues, tipping points, and potential solutions.

This section also investigates several important and interconnected issues that are among the biggest sustainability challenges the world faces. These include climate change mitigation and adaptation, population growth pressures, increasing deforestation, air pollution and air quality issues, biodiversity loss, waste management, sustainable agriculture and food production, the increasing need for community engagement, and renewable energy development.

Brown et al. (see Chapter 2.1 in this volume) note that climate change is one of the most important human-created challenges faced by the world. The recent focus on limiting greenhouse gas (GHG) emissions to reduce climate pressures to between 1.5 and 2 degrees Celsius has been the focus of many discussions and negotiations since the Kyoto Protocol meeting in 1997 set the scene for urgent global carbon management. The complexity of our GHG management is made more complicated with global feedback mechanisms. Climate modelling is helping to focus our attention on the need for largescale and rapid transformations in decarbonising our industrial production and the critical need for renewable energy.

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The World Wildlife Fund's (WWF's) *Living Planet Report 2022* noted an average decline of 69% in species populations across the world since 1970. Biodiversity loss due to environmental impact from agricultural production, pollution, deforestation, and land degradation could lead to a breakdown in the ecosystems that currently support life on Earth.

> "The evidence is unequivocal – we are living through the dual crises of biodiversity loss and climate change driven by the unsustainable use of our planet's resources. Scientists are clear: unless we stop treating these emergencies as two separate issues neither problem will be addressed effectively."
>
> *(WWF, Living Planet Report 2022)*

Environmental pollution, including air, soil, and water pollution, is the by-product of the past century of significant economic growth and development, but this prosperity has not been shared by our environment and its ecosystem health. According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services:

> "Currently, degradation of the Earth's land surface through human activities is negatively impacting the well-being of at least 3.2 billion people, pushing the planet towards a sixth mass species extinction, and costing more than 10 per cent of the annual global gross product in loss of biodiversity and ecosystem services."
>
> *(IPBES 2018)*
>
> https://www.ipbes.net/news/media-release-worsening-worldwide-land-degradation-now-%E2%80%98critical%E2%80%99-undermining-well-being-32

Air quality in major cities like Beijing and New Delhi is also in decline, with particulate matter at dangerous levels and plastic in our oceans and micro-plastics ingested by marine animals another significant challenge (see Chapter 2.2 in this volume).

Lianos (see Chapter 2.3 in this volume) contends that population growth is another important sustainability challenge that does not frequently get discussed in curricula. Whilst the developing world is considering the challenges associated with an aging population and negative population growth, developing countries like India and countries in Africa are experiencing exponential growth and face significant challenges in terms of resource sufficiency and human well-being into the future. The world's population reached 8 billion in 2022, with the UN predicting it will peak at 9.7 billion by 2050.

Rumsa et al. (see Chapter 2.4 in this volume) present waste management as an increasingly important area of public concern, as our fast-moving, consumer good – obsessed lifestyles generate waste levels that may exceed the Earth's ability to act as a sink for the waste we produce. From GHG emissions to plastic waste accumulation and limited suitable landfill disposal sites, the litany of environmental damage that is created by our consumption and production behaviours, both in terms of public health hazard and also increasingly in terms of the use of scarce resources, highlights the need for more focus on sustainability values leadership and important waste principles like resource recovery, waste recycling, and waste reuse.

Kingwell (see Chapter 2.5 in this volume) suggests that agricultural production and food security are fundamental sustainability challenges as we seek to strike a fine balance between sustainable agricultural production, land degradation, and food security, given the pressures of both population growth and climate change.

Say (see Chapter 2.5 in this volume) highlights the strategic role of renewable energy as a key component in sustainable energy discussions as the world looks for decarbonised energy production given increasing pressures from GHG emissions. Renewable energy also has the potential to provide job creation and new industry development that is more in line with modern sustainability expectations.

Tost (see Chapter 2.7 in this volume) notes the significant sustainability issues that will also be faced in our resource sectors as increasing demands on resources are also met with increasing pressures on supply. Loch and Adamson (see Chapter 2.8 in this volume) add to the sustainable resources challenge with their discussion on critical global water supply and water management issues, which may further be impacted by climate change.

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2.1
INTRODUCTORY UNIVERSITY CLIMATE CHANGE EDUCATION
An Australian review

Richard J. Brown, S.M. Ashrafur Rahman, Branka Miljevic, Charith Rathnayaka, Thuy Chu Van and Zoran Ristovski

Key concepts for sustainability education

- Sustainability education, including climate change education (CCE), is a rapidly developing field at the tertiary level globally, but until recently, it lagged behind primary and secondary education.
- CCE is an essential component of sustainability education.
- The approach to CCE varies significantly among universities, depending on their local and national context, but there is an interconnectedness among education, natural, societal and scientific concepts.
- Staff attitudes and student experiences and attitudes towards climate change affect the outcomes of CCE units, even if unsupported by scientific evidence.
- The curricula of CCE offerings vary significantly in content and emphasis, with textbooks covering a wide range of approaches from science, engineering, geography, economics and social science.
- There is a need for increased curriculum coordination and accreditation for CCE to address the significant variation in approaches to CCE implementation and its outcomes, especially with the increasing demand for graduates competent in climate science adaptation and mitigation.

Terminology

Several key educational terms do not have a universal definition, so we have adopted the following terminology:

Unit: component of study focused on a particular subject or topic, typically the equivalent of one quarter of a full-time student's load for one semester.
Course: the degree program in which a student is studying, comprising many units.

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Introduction and literature review

Peer-reviewed literature and books on climate change education (CCE) are dominated by attention to primary and secondary education sectors. In the database Scopus, the earliest such publication found with the specific search term "climate change education" was by Henderson and Holman (1993). There are no more publications until 2003. Material relevant to tertiary CCE is no more than 15% of the 506 publications found, and the first paper was only 12 years ago (Oruonye, 2011). Recent growth has been very rapid, with 60% of all papers having been published in the last four years. Several recent books have addressed CCE in general (Wilson and Stevenson (2015) and Walsh (2022)). Others have specifically included the role of universities in climate change awareness, justice and equity, though not necessarily their role in CCE of their own graduates (Reimers, 2021; Filho and Leal-Arcas, 2019; Kelly et al., 2022).

Across the globe, CCE is becoming an essential part of tertiary education. However, the approach taken by individual higher education institutions (HEIs) is highly variable and can even differ significantly within individual HEIs (Molthan-Hill et al., 2019). The independence of HEIs enables each one to develop the most appropriate CCE approach relevant to their very different countries and contexts. The role and responses of academic/teaching staff have been found to have a statistically significant variation based on the age of their institution and its region (Filho et al., 2021). These staff differences were primarily in awareness of climate-related initiatives, perception of the demand for experts and professionals in climate change, expectations on increases in climate change in the future and demand by students for training in climate change.

From this very brief literature summary, it appears, surprisingly, that HEIs have been slower than primary and secondary education providers to incorporate CCE for their own undergraduates. While good progress has certainly been made in some disciplines in some HEIs, their effectiveness has been mixed. For example, in the case of a series of studies of engineering students, misconceptions about and the desire to address climate change in their future careers of choice were not found to be appropriate for future professional engineers (Milovanovic et al., 2022; Shealy et al., 2021a, 2021b). Such findings have motivated influential voices within leading professional associations such as the American Society of Civil Engineers and the American Society for Engineering Education to strongly call for a significant increase in the amount and effectiveness of CCE for tertiary engineering students (Grubert, 2018; Editorial, 2022). In a very recent paper on CCE in China, undergraduate students of environmental science and applied psychology who completed a unit called "Climate Change" still had attitudes toward climate change that correlated to attitudes on entry, even if these were scientifically unsupported by evidence. To overcome these pedagogical challenges, better use of multimedia (relevant to Gen Z undergraduates), involvement in community projects and role plays are suggested (Tang, 2022).

Australian universities play a critical role in both research and education of future climate change leaders. Universities can provide students with the information and skills needed to address this complex challenge by including CCE into their curricula across all academic fields. Universities are crucial not just for educating students about the consequences of climate change but also for encouraging sustainability on campus and motivating students to become leaders in their fields. Universities play a critical role in generating a strong public mandate for change by offering the technology, information and skills required for Australia's transition to a more sustainable future. Universities must go beyond the conventional conceptions of being counsellors to the corporate sector or autonomous institutions to embrace the need for open communication and collaboration in the battle against climate change.

Much critical knowledge on climate change and its solutions has and is coming from universities, yet in relation to CCE, universities need reminding of their higher purpose: civic transformation and the public good. Such organisations direct their efforts to increasing human understanding and action on the most important issue to our planet – climate change. Failure to fully integrate CCE into the curriculum would weaken faith in universities, particularly among their major constituency – young people and diverse sections of society such as the business, community and public sectors (Gardner, 2019).

Universities do provide intellectual leadership in many fields, yet regarding climate change, other groups have a higher public profile, including students, corporations, non-profit organisations and most governments. The activities of universities are coming under scrutiny, considering their stance on climate change. In particular, there is increased focus on those companies with whom they invest, support and collaborate and whose future employees they educate. All stakeholders in the fossil fuel business, including banks, insurance brokers and researchers, are under pressure to abandon a system that rewards a small number while endangering the entire globe. Organisations like the International Universities Climate Alliance (IUCA, 2023), the Global Alliance of Universities on Climate (GAUC, 2023) and Australasian Campuses Towards Sustainability (ACTS, 2023) are encouraging reform in the university sector. These three significant university networks prepared an open letter that was signed by over 7,000 HEIs (O'Malley, 2019), which urged the academic sector to reduce emissions and engage in climate change research, teaching and outreach. Even more organisations have signed the Sustainable Development Goals (SDGs) Accord's declaration on climate emergency, which asks for action directly relevant to CCE (Race To Zero, 2019):

1. Increased funding for action-oriented climate change research and skill development.
2. A commitment to achieve carbon neutrality by 2030 or 2050, at the latest.
3. Improving environmental and sustainability teaching throughout curriculum, campus and community outreach activities.

There is also rising pressure on organisations associated with universities such as superannuation funds to sell down investments that endanger staff members' futures. Significant pressure has been applied by Australian academic and professional staff to UniSuper to take the initiative as a long-term investor to target companies taking a proactive approach towards reducing emissions, having a clear understanding of potential climate risks in their businesses and being transparent in their activities and actions related to addressing climate change (UniSuper, n.d.; Market Forces, 2023).

More consolidation of CCE is needed in the tertiary sector. While many tertiary students can now select climate change–related studies and electives, this is insufficient. Climate change should not be regarded as a separate issue, but rather as one that must be addressed across all disciplines. A recent study found a lack of interest in management research dealing with the consequences of climate change (Nyberg and Wright, 2022; Wohlgezogen et al., 2022). Undergraduate engineering students frequently feel that their work will have a positive impact on society and the environment. Seniors are more likely to choose careers that address environmental challenges, but students in general do not place enough emphasis on social disparities in their education (France et al., 2022). It is critical to acknowledge the extensive overlap between work that has instrumental usefulness for climate change action and work that highlights the inherent importance of human understanding to educate future generations. Australian universities can enable open-minded and open-ended study and conversation to meet the intellectual and social problems posed by climate change. Australian universities must not only provide knowledge but also take action to solve climate change. This entails reassessing institutions considering the modifications required to address the existing and future implications of climate change.

Universities can assist in creating the expertise and knowledge required for the global community to reduce emissions and deal with the effects of climate change. The National Skills Commission reported in 2021 that one out of every five professional occupations, including design, engineering, science and transportation, had a skilled labour shortage (Symons, 2022; National Skills Commission, 2020). This is a huge problem for companies with large emissions that want to attain net-zero targets rapidly, as well as for incorporating science and climate change data into their daily decision-making. Universities are well positioned to solve this problem, and more than half of all domestic students are currently enrolled in courses that address these essential gaps (Symons, 2022).

A recent study revealed that in developed countries, a person's level of education significantly affects their pro–climate change attitudes (Czarnek et al., 2021). Those with higher levels of education have been shown to be more cognisant of the presence of climate change and the knowledge that it is a result of human activity. Additionally, they tend to view it as a more severe problem and show stronger support for pertinent legislation. Particularly noticeable were these educational benefits in developing and underdeveloped nations. Right-wing ideologies were nevertheless shown to reduce the benefits of education in nations with high levels of development. The study also discovered that left-right identification had just a little moderating influence on belief in climate change, but the strongest interaction effects were identified in connection to support for climate change policies.

A study of Bangladesh final-year university student perceptions across a variety of academic disciplines investigated three perceived changes: in temperature, rainfall and causes of climate change. These three aspects were found to be variously correlated with gender, experience of extreme weather events in their home locality, the completion of a climate change–related unit and involvement in an environmental organisation (Haq and Ahmed, 2020). This is in contrast to the study discussed earlier in a developed country where level of education was more significant than personal experience (Czarnek et al., 2021). Students in Bangladesh experience climate change effects much more severely and personally than others in developed countries due to the level of infrastructure, and this is most likely to influence their views and attitudes.

Tertiary climate change education in Australia

We now focus on the Australian context by considering tertiary climate change at the individual unit and whole degree levels. Note that only bachelor's and master's degrees were included in the surveys. Terminology in Australia classifies these degrees as Australian Quality Framework (AQF) Levels 7, 8 and 9 (AQF, 2013).

Single-semester introductory climate change units

A survey of Australian introductory climate change units is summarised in Appendix 1. The appendix lists all such undergraduate units that could be found, based on a search of each university's website. Of the 40 Australian universities (excluding international universities), 34 were found to have a unit that had a primary focus of an introduction to climate change. Units that had a component of CCE but where it was not the main focus were not included. Such an example would be a unit on professional studies for engineering students, which includes climate change, along with many other issues relevant to practicing as an engineer. Most of the units in Appendix 1 have been introduced in the last four years.

Even though there are 34 universities offering units on climate change in Australia, the content and scope of the unit descriptions vary widely. The unit outlines and specified textbooks cover a wide range, including approaches from science, engineering, geography and economics with hardly any overlap of textbooks between units. In order to identify the broader spectrum of themes emerging through all these unit descriptions, a preliminary-level automated text-mining analysis was conducted using Leximancer, which is a computer-driven content analysis software (Leximancer, 2018). Such an analysis can be helpful to identify the main themes and concepts within this text-based qualitative dataset and how those concepts are related to each other through word frequency statistics and subsequent visualisations (i.e., concept maps) (Wilk et al., 2021). In this study, a combination of all the unit descriptions was used as the qualitative dataset, which was fed into Leximancer for analysis. The resulting concept map is shown in Figure 2.1.1. According to one perspective, it demonstrates how climate change/variability connects to educational (e.g.,

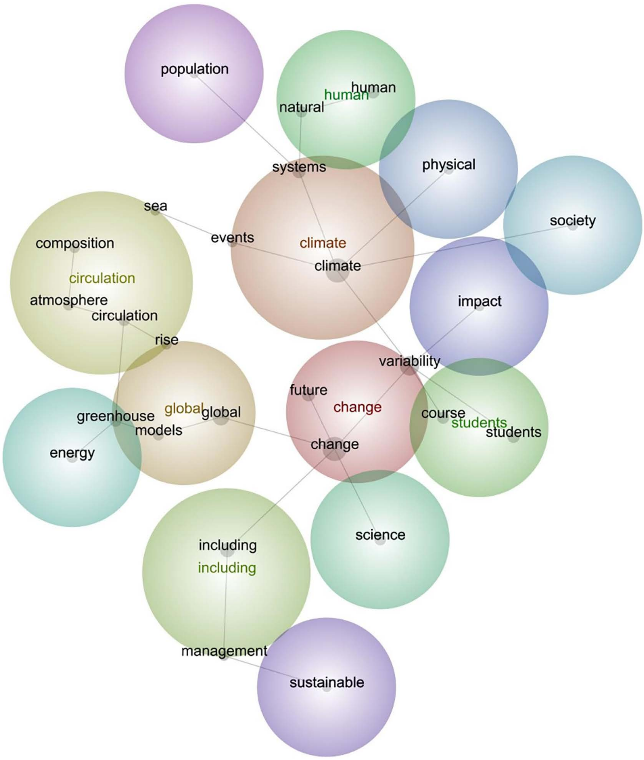

Figure 2.1.1 Concept map showing the emerging themes and their interconnectedness based on all the unit outlines for the considered introductory climate change education units.

students, courses) as well as natural (e.g., sea, atmosphere), societal (e.g., society, population) and scientific aspects (e.g., science, greenhouse, energy, models). In addition, it can be observed that the emerging themes resonate well with most of the key insights derived through the aforementioned literature review.

Undergraduate/postgraduate coursework climate change degrees

There has been recent growth in bachelor's degrees that have a significant component on climate change/climate science. Australian universities mainly offer these degrees from science faculties, as shown in Appendix 2. The appendix also shows corresponding master's degrees have a strong appeal to career professionals wishing to gain advanced knowledge and skills in this dynamic field, enabling them to be more competitive in the job market and to have the potential to access mid-career climate change opportunities. Due to the interdisciplinary nature of climate change, master's degrees often cover multiple disciplines, including science, engineering, policy, economics and social sciences. A number of the universities highlighted the networking opportunities of a master's degree program in climate change, which can give access to other professionals and experts in this field, including academic researchers, policy makers and practitioners. These networks can be valuable sources of information, support and opportunities for professional growth.

Climate change education case study: Queensland University of Technology

Formal CCE commenced with an introductory single-semester unit. A description of the content, curricula design, pedagogies and a framework for the critical elements that form an introduction to CCE will now be given, with a focus on the single-semester teaching unit.

The demand for greater depth and breadth of CCE motivated the recent development and introduction of a climate science minor in 2022 and corresponding major in 2023. A brief overview of the minor and major will then be given.

Single-semester unit on climate change

An introductory unit on climate was commenced by the Faculty of Science. PQB360 Introduction to Climate Change was first taught in 2004 to six physics students as a one-semester unit, seeking to understand the science and impacts of climate change, as well as some of the strategies needed to address it. In 2010, the unit was also made available to education students preparing to be science teachers, with 18 students in total. Later in 2012 the unit was made available to all 40,000 students in the university, and the student numbers grew to 26. PQB360 enrolments have progressively expanded, and in 2023 were 123. The unit has always been offered once per year. In 2018 the teaching team of the unit was expanded to include academics from both Science and Engineering Faculties.

The current unit outline as given on the QUT website is (for full content see Appendix 1, PQB360):

> This unit is designed to offer science, engineering and other students an opportunity to understand fundamentals of climate and climate change, together with sustainable development efforts related to clean energy technologies. It provides students with an overview of global climate and climate change drivers, meteorological parameters

and global air circulation, as well as an overview of technological pathways towards a low carbon society. Students will explore global energy balance and climate change through an investigation of (i) Energy-related environmental problems on local and global scale; (ii) Earth's climate, meteorology and transport of pollutants in the atmosphere; (iii) Working principles in selected conventional and alternative energy technologies to reduce energy-related environmental consequences.

Experience of the teaching team

We now review and summarise the experience of the teaching team (academics) and sessional staff (tutors and demonstrators) in PQB360 Climate Change over the last four years. It is hoped that this may assist and stimulate others in their own educational journey and provide opportunity for others to critique our approach to teaching this unit and support future development.

In a role of a unit coordinator, management of the sessional staff, training and finding the appropriate people play a crucial role in the success of the CCE unit, which requires science lecturers who have expertise in climate science and environmental science, engineering lecturers who have expertise in renewable energy and decarbonisation and social studies educators who can explore the cultural, economic and political dimensions of climate change. Each semester in this unit (PQB360), we include guest speakers such as industry specialists/consultants, climate activists and policymakers who can bring in outside expertise and community resources to supplement the curriculum, help to increase student engagement and connect climate change to real-world examples. We encouraged students' critical thinking by requesting them to explore the social, economic and political factors that influence climate change and to discuss ways that individuals (their own roles), communities and governments can take action to reduce greenhouse gas emissions, promote renewable energy and adapt to the impacts of climate change through their group presentations.

The formal lectures are supplemented by practical sessions, which have consisted of (i) computer laboratories for developing and running climate simulation models and (ii) aerosol instrumentation laboratories using resources available at the International Laboratory for Air Quality and Health (ILAQH) at Queensland University of Technology (QUT) to support the teaching for this unit. Students experience the operation and application of the aerosol instrumentation such as the condensation particle counter (CPC), electrostatic classifier (EC), neutralizer, scanning mobility particle sizer (SMPS) and DustTrak. Practicals consist of actual air pollution measurements, collection of data and carrying out data analysis. This requires our sessional staff (tutors and demonstrators) to be knowledgeable in the field of aerosol science. In preparing practicals for each semester, advantage is taken of current opportunities from research/consulting projects being conducted at the time. Opportunities at other HEIs will vary depending on their research focus and availability of equipment.

Drawing on the teaching experience of PQB360 over the last four years, we offer the following key points that others may be able to use in their teaching of climate change units or if they are starting to teach this unit for the first time:

- Start with the basics: before diving into the complexities of climate change, it's important to establish the basics. Begin by introducing the Intergovernmental Panel on Climate Change (IPCC) and its role, defining climate change and discussing its causes, effects and impacts on the environment and society.

- Use multimedia resources: incorporating videos, infographics and other multimedia resources can help engage students and make complex concepts easier to understand.
- Connect climate change to real-world examples: this includes extreme weather events, natural disasters or the impacts of climate change on communities and ecosystems.
- Encourage critical thinking: encourage students to think critically about climate change and its solutions. Encourage them to explore the social, economic and political factors that surround climate change and to consider their own role in mitigating its impacts.
- Focus on solutions: while it's important to acknowledge the severity of the problem, it's also important to focus on solutions. Discuss ways that individuals, communities and governments can take action to reduce greenhouse gas emissions, promote renewable energy and adapt to the impacts of climate change.
- Make it interdisciplinary: climate change is a complex and interdisciplinary issue that touches on many fields of study. Consider incorporating elements of science, social studies, economics and ethics into your teaching to provide a holistic understanding of the issue.
- Emphasise the urgency: climate change is a pressing global issue that demands urgent action. Encourage your students to take action in their own lives and to advocate for change in their communities and beyond.

In terms of student enquiries and administrative issues, we experienced a large number of student enquiries related to registration and scheduling, in particular, students requesting assistance with managing timetabling/scheduling conflicts, particularly with their group presentations. Unlike some other units, this unit is open to science and engineering students and students in other courses so their timetables are expected to differ significantly. Other inquiries included how this unit fits into their degree program and approvals required for its acceptance in their overall academic plan.

Curriculum design

The curriculum design for this unit aims to be comprehensive, engaging and critical, and the focus is scientific, which is supplemented by a background of the regulatory, political and social perspectives of climate change. Students develop the skills and knowledge needed to address the challenges of climate change and work towards a more sustainable future in their chosen careers.

Pedagogy

Pedagogies were selected to engage students and encourage them to think critically about the issues. These include using simulations and models of climate change on a global scale, interactive activities, industry/government guest lectures, case studies (on individual, national and global levels) and problem-based learning exercises, as well as some more traditional lectures, quizzes throughout the semester and an invigilated examination. Students were tasked with developing and presenting a climate change mitigation and adaptation plan for either a local community or country or at global level. These types of hands-on, experiential learning activities can help students better understand the complexities of climate change and develop the skills and knowledge needed to address it. Students are also encouraged to reflect on their own experience of extreme weather events or other climate change–related impacts and to evaluate these in light of the unit content.

Critical framework

An important point of reference for tertiary CCE is IPCC Reports (2023), as they represent our current state of knowledge on human-induced climate change. The IPCC assesses the current state of scientific understanding on aspects of contemporary climate change. Their assessments span the physical science of climate change, impacts on human and natural systems and options for adaptation and mitigation. Challenges in disseminating physical science in IPCC reports to undergraduate students include how to simplify complex climate science ideas without losing scientific accuracy and how to communicate recent scientific advances to recipients with a range of background knowledge. These challenges can be summarised as follows:

- Written for politicians, policymakers, experts and specialists.
- Information on a single topic can spread out throughout multiple reports.
- Global/regional focus can be hard for students accustomed to only local issues.
- Figures are not interactive.
- Some parts can become outdated quickly due to contemporary events.
- Use of jargon.

Finally, it is important to understand the critical elements that form the foundation of CCE. This includes an understanding of the scientific basis of climate change, as well as the social and political dimensions of the issue. It is essential to examine the ways in which climate change is impacting different communities, as well as the role that systemic issues such as globalisation and inequality play in exacerbating the impacts of climate change. A critical framework for CCE should also consider the potential solutions to the issue, including mitigation strategies, such as reducing greenhouse gas emissions, and adaptation strategies, such as building resilience to the impacts of climate change.

Major and minor in climate change/climate science

Climate science minor

In 2022, a climate science minor (equivalent to one full semester) was made available to all students at QUT in response to several drivers including national and international attention on CCE, the QUT Sustainability Strategy (2021) and employer and student demand.

Overview: Climate change is the foremost critical challenge to the sustainability and habitability of the Earth as we know it. There is rapidly growing demand for expertise in the science that governs climate and that informs models of climate change – across the private sector, within many Australian government organisations and within research institutions. This minor delivers a strong understanding of climate science and combines it with relevant knowledge about ocean-atmosphere interaction, insight into global change, sustainability and air quality and climate change mitigation measures. This combination is ideally suited to equip students with diverse backgrounds and primary interests to tackle the mounting challenges in areas such as sea level change mitigation, local climate adaptation, sustainable resource management and coastal ocean climate mitigation.

The minor is available to science, engineering and other students as a one-semester equivalent full-time study comprising four units:

PQB360 – Introduction to Climate Change (modified existing unit)
ERB202 – Marine and Atmospheric Systems (modified existing unit)
ERB211 – Global Change (new unit)
ERB311 – Dynamic Atmosphere (new unit)

Learning outcomes for the climate science minor:

1. Understand the significance, scale and impact of energy resources used globally, including fossil fuels, nuclear fuels and renewable energy resources.
2. Knowledge of the planetary feedbacks that have stabilised the Earth's climate for over 4 billion years and ensured that the planet has remained habitable.
3. Interpret and analyse the interactions between the atmosphere and ocean that drive weather and climate worldwide.
4. Understand the relationships between energy consumption, the resulting pollutants and their impact on health, climate, and the environment.
5. Understand the roles played by scientists and engineers in society and the short- and long-term social, environmental and climatic impacts of the decisions they make.

Climate science major

Plans are in progress at QUT to develop a climate science major starting in 2023 (equivalent of around three full semesters). The major consists of 11 units composed of 10 core units and 1 optional unit and has the same overview as the minor described earlier.

Within the QUT jargon, a major is a set of units within a course which together form a coherent body of knowledge and skills that provide the main focus of a course. A course may have two levels of study area: study area A and study area B. Study areas may have study area learning outcomes (SLOs) that align with, but are subordinate to, course learning outcomes. The SLOs for the climate science major are:

SLO1 Provide evidence of a depth of knowledge and understanding of the underlying principles and core concepts of climate science.
SLO2 Provide evidence of a systematic approach to problem solving using appropriate practical, research and technical methods.
SLO3 Provide evidence of collection, recording, analysis and interpretation of information through scientific argument, judgement and deduction.
SLO4 Provide evidence of the synthesis of knowledge within climate science and its sub-disciplines and across disciplines.
SLO5 Provide evidence of the use of appropriate styles to communicate scientific data, information and arguments to scientific peer groups and the broader community.
SLO6 Provide evidence of ethical behaviour and an understanding of the societal impacts of climate science and the application of technologies developed from earth science research.
SLO7 Provide evidence of independent activity and collaboration in multidisciplinary teams which may include members with cultural differences.

Overview and graduate profile

Climate change is the foremost critical challenge to the sustainability and habitability of the Earth as we know it. There is a rapidly growing demand for expertise in the science that governs the climate and that informs models of climate change – across the private sector, within many Australian government organisations and in research institutions. Both the climate change/climate science minors and majors deliver a strong understanding of climate science and combine it with relevant knowledge about ocean-atmosphere interaction, insight into global change, sustainability, air and water quality and climate change mitigation measures. This combination is ideally suited to equip students with diverse backgrounds and primary interests to tackle the mounting challenges in areas such as sea level change mitigation, local climate adaptation, sustainable resource management and coastal ocean climate mitigation.

Examples of jobs and science and engineering career pathways:

- Climate risk modelling/estimator for large insurance companies and investment banking
- Greenhouse gas (GHG) mapping and reporting officer
- Decarbonisation officer/consultant
- Climate change response planning in federal, state and local government agencies
- Air quality and weather observations and forecasting
- Climate change/sustainability policy and adaptation
- Carbon emissions advisory and auditing consultant
- Forecasting climate change impacts
- Secondary science teaching
- Science communication (corporate, tourism and government)
- Renewable energy engineer
- Sustainable building engineer
- Climate change adaptation engineer
- Research career, higher-degree research (HDR) student

The climate change–ready graduate (focus on science/engineering students)

Industries, government and the not-for-profit sector need climate change–ready graduates who have a deep understanding of the science, policy and societal dimensions of this issue, as well as the skills and experience needed to address it. This requires interdisciplinary and problem-solving approaches to education, as well as a commitment to practical and real-world experiences that prepare graduates for a rapidly changing and complex world.

From the authors' experience with students and their future employers for over a decade, we summarise the graduate skill requirements of industries, government and the not-for-profit sector as follows:

Industries

- Industries need graduates who have a deep understanding of the science and technology behind climate change, including energy efficiency, renewable energy and GHG reduction strategies.
- They also need graduates with skills in risk assessment, sustainable supply chain management and carbon footprint reduction to help them transition to a low-carbon economy.

- Graduates with experience in data analysis, modelling and decision making are also in high demand, as industries need to make informed decisions about their operations and investments in a changing climate.

Government

- Governments need graduates who understand the policy and regulatory frameworks associated with climate change, including carbon pricing, emissions reduction targets and international agreements.
- They need graduates with skills in communication, negotiation and stakeholder engagement, as well as the ability to implement programs and initiatives that address the impacts of climate change.
- Graduates with experience in urban planning and design, infrastructure development and community resilience are also in high demand as governments work to adapt to the impacts of climate change.

Not-for-profit sector

- The not-for-profit sector needs graduates who understand the social and environmental justice dimensions of climate change, including the disproportionate impacts on vulnerable communities and ecosystems.
- They need graduates with skills in advocacy, community engagement and coalition-building to drive change and mobilise resources towards a sustainable future.
- Graduates with experience in sustainable agriculture, conservation biology and ecosystem management are also in high demand as the not-for-profit sector works to protect and restore critical ecosystems in the face of climate change.

Conclusion

CCE at the tertiary level is an area of rapid development globally and, until recently, has lagged behind developments in primary and secondary education. Graduates competent in climate science change adaptation and mitigation are in great demand by industry, government and not-for-profit sectors. While knowledge and skill development are evident in graduates who have studied climate change, exit attitudes in a number of studies were found to still be variously dependent on personal experience of climate change, country of origin/university location and political or religious views.

Thirty-four out of forty domestic universities in Australia have at least a one-semester unit of study on climate change. The number of bachelor's and master's coursework degrees with a significant component on climate change/climate science are 11 and 10, respectively. While most units and degrees are taught within science and, to a lesser extent, engineering faculties, other offerings have influence from policy, economics and law educators. The curricula of these many offerings of CCE vary significantly in content and emphasis. For example, the specified textbooks cover a wide range including approaches from science, engineering, geography and economics, with hardly any overlap of textbooks between the units. At the same time, as observed through unit outlines and descriptions, there is an inherent interconnectedness through a range of education, natural, societal and scientific concepts.

Moreover, given the current global critical need for climate change policy development and mitigation measures, there is clearly an urgent need for increased curriculum coordination and accreditation for CCE across all disciplines, as global universities will play a critical role in educating future climate change leaders.

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APPENDIX 1: LISTING OF AUSTRALIAN INTRODUCTORY CLIMATE CHANGE UNITS

The QUT unit PQB360 is shown here. A full table showing an additional 33 units from other Australian universities can be downloaded from:

Brown, Richard J.; Rahman, S.M. Ashrafur; Miljevic, Branka; Rathnayaka, Charith; Van, Thuy Chu; Ristovski, Zoran; (2023): Appendices to 'Introductory University Climate Change Education: An Australian review'. Queensland University of Technology. (Dataset) https://doi.org/10.25912/RDF_1682661322999

Territory **State/**	*University Name*	*Course Code*	*Course Name*	*Faculty/ School*	*Course Convener*	*Year of degree*	*Compulsory or optional*	*Unit Content Summary*	*Textbooks*	#
	QUT	PQB360	Introduction to Climate Change		Richard Brown/ Zoran Ris-tovski	2023		• Intro to atmosphere: Origins and composition of the atmosphere, greenhouse gases, atmospheric pressure and the structure of the atmosphere; • Global energy balance and temperature: black body radiation, interaction with solar radiation and atmosphere, greenhouse effect, energy balance models – zero-dimensional model of Earth. • Meteorological elements: 1) Atmospheric moisture; Relative humidity; Super-saturated conditions in the atmosphere and cloud formation • Meteorological elements: 2) Atmospheric pressure and circulation; Simple general circulation model and global pressure belts. • Meteorological elements: 3) Weather phenomena: air masses and fronts; mid-latitude cyclones; tropical storms; ocean atmosphere interaction (El Nino/La Nina).	Aguado and Burt (2015) Delaney and Delaney (2018) Botkin, and Keller (2014)	18

(Continued)

(Continued)

Territory **State/**	*University Name*	*Course Code*	*Course Name*	*Faculty/ School*	*Course Convener*	*Year of degree*	*Compulsory or optional*	*Unit Content Summary*	*Textbooks*	*#*
								• Stability and sensitivity of climate system; Climate variability vs climate change (or natural vs. human causes of climate change), Global warming and climate change + aerosols. • Human effects on the atmosphere: air pollution; stratospheric ozone depletion; urban heat islands. • Aerosol physical and chemical properties + sources; transport. • GHG regulatory environment: Scope 1, 2 and 3 reporting. • Sustainable approaches to energy supply. • Climate change mitigation strategies • Building a low-carbon society 1): societal, political and individual dimensions • Building a low-carbon society 2). Case studies: global, national and individual		

APPENDIX 2: AUSTRALIAN BACHELOR'S AND MASTER'S COURSEWORK DEGREES WITH A SIGNIFICANT COMPONENT ON CLIMATE CHANGE/CLIMATE SCIENCE

(https://www.gooduniversitiesguide.com.au; https://www.courseseeker.edu.au)

Bachelor of Environmental Science (Climate Change)	Faculty of Science	University of Melbourne
Bachelor of Science (Climate and Weather Major)	Faculty of Science	University of Melbourne
Bachelor of Climate Science and Management	Faculty of Science	University of New South Wales
Bachelor of Science (Environmental Science and Management)	Faculty of Science	University of Sydney
Bachelor of Environmental Science (Climate Change)	Faculty of Science	Monash University
Bachelor of Science (Environmental Science)	Faculty of Science	University of Western Australia
Bachelor of Environmental Science	Faculty of Science	Australian National University
Bachelor of Environmental Management and Development	College of Arts and Social Sciences	Australian National University
Bachelor of Environmental Science	Faculty of Science Engineering and Technology	University of Tasmania
Bachelor of Environmental Science	Faculty of Science and Engineering	Macquarie University
Bachelor of Marine Biology and Climate Change	Faculty of Science	University of Technology, Sydney
Bachelor of Engineering (Honours) (Environmental and Climate Solutions)	Faculty of Sciences, Engineering and Technology	University of Adelaide
Bachelor of Climate Science and Adaptation	College of Engineering, Science and Environment	University of Newcastle

(*Continued*)

(Continued)

Master of Environment and Climate Emergency		Curtin University
Master of Climate Change	Faculty of Science	University of Melbourne
Master of Climate Science and Management	Faculty of Science	University of New South Wales
Master of Climate Change	Faculty of Science	University of Sydney
Master of Climate Science and Policy	Faculty of Science	Monash University
Master of Climate Change Science and Management	Faculty of Science	University of Western Australia
Master of Climate Change	Faculty of Science	Australian National University
Master of Climate Science	Faculty of Science Engineering and Technology	University of Tasmania
Master of Environmental Science and Management	Faculty of Science and Engineering	Macquarie University
Master of Climate Change Adaptation	Faculty of Science	Griffith University

2.2
SUSTAINABILITY WITHIN A GLOBAL ENVIRONMENTAL CHANGE CONTEXT

Simone L. Stevenson, Kyle Hilliam, Cal Faubel, Roberto Venegas and Eric A. Treml

Key concepts for sustainability education

- Human wellbeing and sustainable living require healthy, functioning ecosystems; intact biodiversity; and equitable social, cultural, and economic systems.
- Our choices and actions are making both gradual and sudden changes to ecosystems throughout the world.
- Human values, consumption, economies, science and technology and governance all influence these choices.
- Climate change, land and sea use, pollution, over-exploitation and invasive species are the key drivers of environmental change.
- These collective human activities are having significant and often irreversible damage to biodiversity and ecosystems throughout the world.
- Human actions that create changes like these usually benefit some people while disadvantaging others, creating strong inequalities.
- Understanding natural biodiversity, from genes to ecosystems, and the tight connection with human wellbeing is essential for effective sustainability education.
- We can secure a sustainable future, but it requires education and transformative change to institutions, communities and individual behaviours.

Introduction

The Earth provides people with essential resources to thrive, including food, materials, water and oxygen. These resources are commonly referred to as 'ecosystem services' because they are produced by nature, and they have a significant influence on human health and wellbeing. In this respect, maintaining healthy, functional processes within our natural ecosystems is essential for long-term sustainability and human survival. This broad-scale ecosystem integrity is also vital for creating and sustaining natural biodiversity – the diversity of all living organisms on Earth. Biodiversity means different things to different people and cultures, but is essential to the long-term provision and quality of ecosystem services (Hooper et al. 2005). The term biodiversity refers to the range of ecosystems, the number

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of species and the variability of genes within species (CBD 1992). This variety is so vast that existing knowledge only captures a small fraction of it. Currently, it is believed that there are around 8.7 million species alive (2.2 million in the oceans) but is estimated that more than 85% of these (many of which are invertebrates) have yet to be discovered and named (Mora et al. 2011). Biodiversity itself must be a key ingredient in any movement towards sustainability.

It is not only the presence of different species and habitats that produce essential ecosystem services but also the interactions between them (Hooper et al. 2005). Across all levels of biodiversity, from genes to ecosystems, it is the variation in environmental conditions (e.g., temperatures, elevation, depth), geologic history and context and even the influence of humans that shape the biological variety on Earth (Schluter and Pennell 2017). This ecological complexity and interconnectedness mean that altering one aspect of an ecosystem, for example, a species going extinct or a shift in temperature, can produce unexpected and profound flow-on effects (Chapin et al. 2000; Hooper et al. 2005). For example, the accidental and intentional introduction of organisms into new habitats (islands in particular) have contributed to many extinctions of local plants and animals, forever changing ecosystems and influencing local cultures (Tershy et al. 2015).

Descriptions of environmental change and conversations around sustainability commonly focus on the land – after all, this is where humans live, and it is what we know best. However, the land and ocean are inherently linked by ecological, climate and coastal processes, and human actions are having a strong influence across both domains. The ocean, taking up more than 70% of the planet, is a home and food source for fish, mammals, plants, birds, reptiles, viruses, bacteria, algae, plankton and other marine organisms. The marine environment plays a very significant role in Earth's atmospheric and geochemical functioning, as well as the provision of social, economic and cultural benefits to people. Due to the inordinate influence of the marine environment on biodiversity, ecosystem services and human wellbeing and prosperity, this chapter uses the oceans as a natural focus in highlighting how human activity is affecting the global environment and sustainability approaches.

Unfortunately, the combination of increasing human populations and our associated consumption of materials and use of ecosystem services is fast outstripping the capacity of the planet to provide them (Steffen et al. 2015). A recent estimate suggests we are using the planet 1.75 times faster than it can regenerate (York University, Ecological Footprint Initiative, and Global Footprint Network 2022). Humans not only use biodiversity as a source of materials to consume but also as a sink to hold waste – whether it be in the air, water, land or ocean, there is only so much space. The mass of all man-made materials on Earth (which are produced as a result of consuming natural materials) now outweighs the mass of all natural materials (Elhacham et al. 2020). Pushing planetary boundaries in such a way is compromising the integrity of all natural systems, including ecosystems and biodiversity (Steffen et al. 2015). Often these natural systems are pushed to the point where restoration and recovery, much less sustainability, are no longer an option.

We are already witnessing significant detrimental changes to the environment occurring on all continents and into all corners of the ocean. This chapter explores several of the key indirect drivers and the primary direct agents of environment change, all stemming from human actions (see Figure 2.2.1 summarised in Table 2.2.1) and influencing sustainability choices. In closing, we highlight strong reasons to maintain hope for a sustainable future and illustrate how individual actions can impact meaningful and positive change.

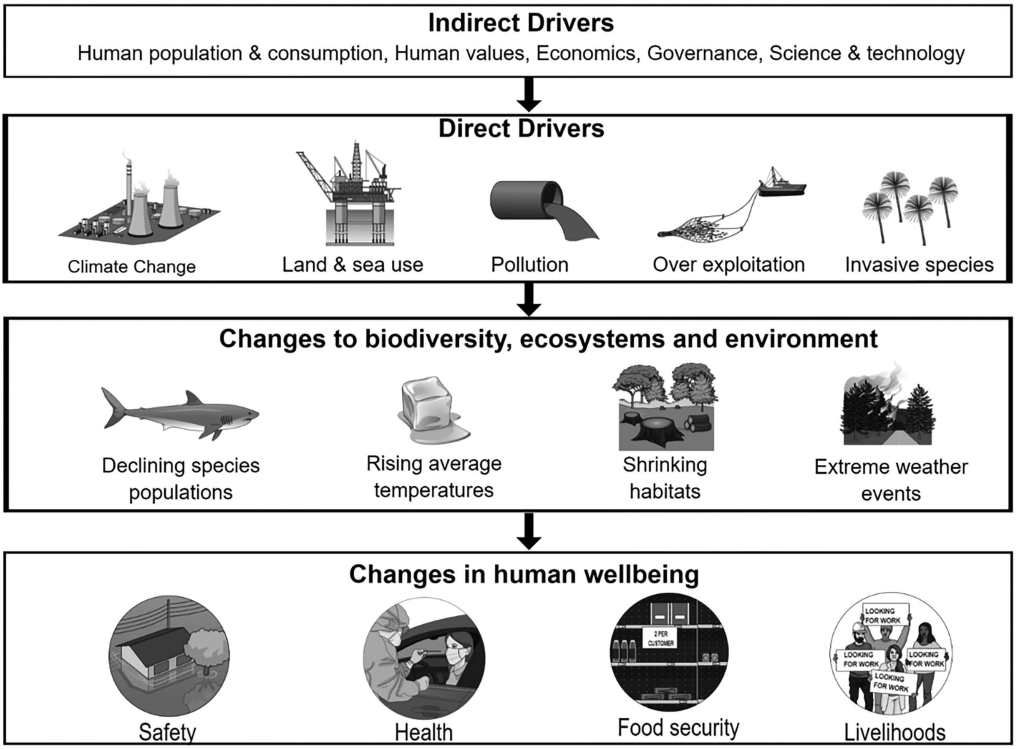

Figure 2.2.1 The process of environmental change, where indirect drivers like the economy drive more direct actions like over-exploitation and land and sea use. In turn, these drivers work together to undermine the natural environment. In turn, these changes affect the functioning of planetary systems that humans rely on, producing changes to human wellbeing.

Throughout, it is important to remember the societal, geographic and temporal complexities of environmental change and the impact on sustainability decisions. Nature's provisioning, human use patterns, ecosystem services and biodiversity are all unequally distributed across the planet, creating a complex mosaic across the Earth and often unpredictable change through time. In this regard, there will always be exceptions to the general trends highlighted throughout this chapter.

People, consumption and demography

The human population has doubled in size since 1950 (now quickly approaching 8 billion in 2022) and will continue to grow, albeit at reduced rates of around 1% per year (Balvanera et al. 2019). In fact, the biomass (total weight) of all humans on Earth (~0.6 Gt, or roughly 3.6 million blue whales!) is now thought to exceed that of all other living mammals by an order of magnitude (Bar-On et al. 2018). Population growth rates are variable in space and time, however. In many developed countries, like some in Europe, rates are now declining following historical peaks, while in some developing countries, for example, in Africa and Asia, population growth rates are increasing (Balvanera et al. 2019). Yet the

Table 2.2.1 Key examples of the magnitude of different drivers on the global environment and their combined effects on the natural world

Driver	*Example*	*Effects*
Climate change	The global temperature has already increased, on average, by 0.8 degrees Celsius (1.4 degrees Fahrenheit) in the past 100 years (IPCC 2021a).	Native species populations have declined by at least 20% since 1970 (Purvis et al. 2019).
Land and sea use	Over a third of all land on Earth has been converted into cropping or animal agriculture (Balvanera et al. 2019).	Around half the world's live coral reef cover and 75% of wetlands have been lost (Balvanera et al. 2019).
Pollution	An estimated 60,000 particles of microplastic are present for each square kilometre of ocean (Balvanera et al. 2019).	In coasts around the world, pollution has created more than 400 dead zones (Balvanera et al. 2019).
Over-exploitation	There are around 3.7 million fishing ships in the world, each catching as much as 200 tonnes of fish per day (Rousseau et al. 2019).	Around 1 million plant and animal species are estimated to be threatened with extinction (Purvis et al. 2019).
Invasive species	Around the globe, ships transport between 3,000 and 7,000 different invasive species per day (WHO 2011).	

role of population growth in environmental degradation is difficult to disentangle from the role of human consumption and lifestyle. Every person on the planet needs to consume food and resources provided by ecosystems to survive, and as our consumption grows, we approach the boundaries of what can safely be extracted from the environment (Steffen et al. 2015). Between 2005 and 2015, the amount of fossil fuels, living biomass, metal ores and minerals extracted from the Earth by humans doubled (Balvanera et al. 2019). Of course, consumption varies geographically as well, where affluent regions often show slower population growth rates but much higher consumption rates per capita – much greater consumption of food, water, energy, materials and greater production of waste (Balvanera et al. 2019). Human population growth is a challenging and contentious issue, with some arguing that managing population growth is the key to planetary wellbeing and sustainability (see Chapter 2.3 in this volume), while others consider that factors like consumption and variation in growth across locations complicate potential solutions (Weber and Sciubba 2019). The reality of managing population growth also has many potential negative societal impacts, such as gender preferencing and ageing populations.

Climate change

Anthropogenic climate change (hereafter, climate change) refers to changing climates induced by human activity rather than natural climate variability (UNFCCC 1992). Climate change is a key driver of environmental degradation, whose effects are projected to outstrip and exacerbate other drivers like pollution and exploitation (Balvanera et al. 2019). The industrial revolution in the mid-1700s triggered a significant increase in the burning of fossil fuels (oil, gas and coal) by humans. Fossil fuels have traditionally been used to power vehicles like cars and planes, to produce electricity and heat and cool buildings and to facilitate the production of goods. Burning fossil fuels emits greenhouse gases, particularly carbon dioxide (CO_2), into the atmosphere. In addition, carbon and methane emissions are also produced through agriculture, livestock, building development and deforestation (IPCC 2021a).

Greenhouse gases are accumulating in the atmosphere in quantities far higher than their natural volume, driven by the scale and magnitude at which we burn fossil fuels. Excessive greenhouse gas levels increase the absorption of infrared radiation from the sun and drive higher temperatures throughout the Earth (IPCC 2021a). The average global temperature has already increased by about 0.8 degrees Celsius (1.4 degrees Fahrenheit) over the past 100 years (IPCC 2021a). Atmospheric warming triggers a much wider variety of climate impacts across the globe. Some direct impacts include the shrinking of polar ice sheets and glaciers, rising sea levels, severe heat waves and droughts (IPCC 2021b). Extreme weather events are increasing in frequency and intensity, including more severe tropical storms, floods, blizzards and wildfires (Balvanera et al. 2019). These impacts and events can vary by location, creating additional stresses on land and human supplies such as water and energy resources and exacerbating existing risks to livelihoods, wildlife, biodiversity, human and ecosystem health, infrastructure, agriculture, food systems, cultural heritage and human health (IPCC 2021b).

Ocean climate change

Climate change is commonly described in terms of its impact on the land; however, its impact on the ocean is significant. As global warming persists, the ocean is absorbing excessive heat and carbon dioxide (CO_2), leading to changes in chemistry and temperature from its surface to the deepest trenches. In addition to ocean warming, the increased level of CO_2 is making the ocean more acidic and less oxygenated, putting many marine organisms, particularly reefs, shellfish and crustaceans, at great risk (Heinze et al. 2021). Changes in ocean temperature and chemistry are also accompanied by rising sea levels and shifting ocean current patterns, both locally and globally (IPCC 2021a; Peng et al. 2022).

Changing the temperature, chemistry and physics of oceans has important ramifications for ocean biodiversity and function. As species and ecosystems evolve according to their physical surroundings, changes to these factors can disrupt the reproduction, location, abundance and survival of marine species (Bindoff et al. 2019). Coastal ecosystems like coral reefs, for example, are under stress from ocean warming, sea level rise and ocean acidification. The Great Barrier Reef, a world heritage site, has experienced exceptional heatwaves in multiple recent years, resulting in widespread coral bleaching and mortality (Cresswell et al. 2021). These changes also affect the people relying on these ecosystems for food, tourism, culture and recreation. As a result of climate change, 45% of important fish stocks like tuna have been projected to move to other countries by the end of the century, with impacts felt most severely in tropical countries (Palacios-Abrantes et al. 2022). A recent State of the Environment report for Australia states that 198 species have undergone changes to their original range since 2003 (Cresswell et al. 2021).

Most countries in the world have agreed that without a significant reduction in emissions, climate change poses a fundamental threat to humanity (UNFCCC 1992). Marine ecosystems and their resources are an important component of the global climate, and maintaining their integrity is essential to the physical, economic and food security of local communities, as well as resources for global businesses. A low-carbon emissions trajectory is an essential element to preserving the remaining health of the ocean and its ecosystems and species. More can be learned about climate change in Chapters 1.2, 1.3 and 2.1 in this volume.

Indirect drivers of global environmental impact

Understanding the causes ('drivers') is essential in sustainability education and required to slow or stop environmental change. Drivers are commonly separated into two categories: direct and indirect. Direct drivers have a physical impact on ecosystem processes, the five most influential being climate change, land and sea use by humans, direct exploitation of organisms, pollution and invasion of alien species (Balvanera et al. 2019). Indirect drivers occur at a broad scale and include diffuse societal processes that influence multiple, if not all, direct drivers. In addition to population and demography, discussed earlier, the four most influential indirect drivers are considered to be people's values, the economy, technology and governance (Balvanera et al. 2019).

Human values

The way people perceive and value the environment throughout the world varies significantly (Pascual et al. 2017; Nelson et al. 2006) and is tied to their interpretation of sustainability. People's values have a strong influence on the way they interact with and use nature (Pascual et al. 2017). There are many ways of perceiving the value of nature, which range from intrinsic (the environment is valuable in its own right, regardless of people), to instrumental (the environment is valuable because of its function and contribution to human lives), to relational (people have a social and moral responsibility for nature) (Pascual et al. 2017). Recent evidence suggests that the most dominant viewpoint is that humans value the environment most often for the functional contributions it provides – the instrumental view (Balvanera et al. 2019). Despite this dominant use-centric perspective, it appears that attitudes may be shifting to more intrinsic-based and moral-based values, highlighting the possibility of a paradigm shift away from consumption-based views (Balvanera et al. 2019) to a more sustainability-focused lens.

Economics

In many parts of the world, economic growth is considered the main determinant of human health and wellbeing, yet is often at odds with sustainability values. Economic growth relies on extracting raw materials and land from nature and turning them into products that can be sold (like food, timber or clothing), while also using the environment as a sink to absorb waste and by-products, such as rubbish, CO_2, fertilizers and plastics. Greater economic affluence is therefore linked to sustained use of the environment over time, often at high environmental cost (Nelson et al. 2006). Over the last 50 years, global gross domestic product (GDP), a key measure of economic growth, has grown nearly five-fold, now worth well over $100 trillion (Balvanera et al. 2019; Roser 2013). This increased productivity, along with associated growth in worldwide trade, is influencing how and where environmental costs – in terms of lost biodiversity and ecosystem services – are felt, as high-income countries import raw materials like wood and coal from lower-income countries (Balvanera et al. 2019; Nelson et al. 2006).

The natural environment does not have the capacity to sustain this long-term economic growth and associated environmental costs (Doring and Aigner-Walder 2022; Meadows et al. 1972; Balvanera et al. 2019). While economic growth could alleviate inequalities of living conditions in the short term, the long-term effects on the environment are expected to have catastrophic implications for human wellbeing (Steffen et al. 2015). The Earth doesn't have infinite resources to extract, nor infinite capacity to absorb waste, and ecosystems cannot bounce back from these disturbing forces in perpetuity. Ongoing economic growth, as it works today, would therefore eventually reach a point where finite resources like fossil fuels are gone, and ecosystems have been altered to the extent that they can no longer provide vital ecosystem services like clean air and water (already occurring in some cities like Beijing and Adelaide).

Governance

Governance refers to the way nations govern themselves and their environment, the quality of public engagement in policies, judicial systems and education. Ecosystem services, such as local access to the ocean for subsistence fishing, are typically considered common resources shared among many people or communities and frequently spanning multiple jurisdictions (see Chapters 7.4 and 8.3 in this volume on 'Tragedy of the Commons'). In these cases the individual often does not immediately experience the full implications of their actions (e.g., overfishing), with these indirect impacts instead being felt by individuals and communities in different locations or in the future (Nelson et al. 2006). This makes governing nature and ecosystem services in an equitable way exceedingly difficult (Nelson et al. 2006). Throughout much of the world, natural resources are governed through a centralised or top-down system. We are now recognising, however, that more bottom-up and community-based management or indigenous governance, where users are directly involved in decision making, can result in better environmental outcomes (Balvanera et al. 2019; Nelson et al. 2006). Governance related to natural resource use and environmental change is inherently complex, context and culturally dependent and dynamic in time, yet plays an enormous role in determining (or limiting) the pace and type of environmental change experienced across the planet.

Science and technology

Over the last century, we have witnessed extreme advances in all areas of science, including physics, chemistry, biology and ecology. These advances have fundamentally changed how we interact with our natural environment. This advancement and innovation in science and technology have powered significant economic growth and is responsible for approximately 5% annual growth in GDP in Organisation for Economic Co-operation and Development (OECD) countries (OECD 2022). Of course, there have been positive social and environmental outcomes from these advances, as well as negative outcomes. For example, the technology developed to support the expansion of agriculture vastly increased food production and reduced pressures on wild harvesting. The same technology also comes at an environmental cost through greater nutrification of freshwater and nearshore marine ecosystems

(Balvanera et al. 2019). On the other hand, more recent scientific breakthroughs to increase crop yields and build natural pest defence have reduced land and pesticide requirements, easing the stress on downstream environments (Nelson et al. 2006). While technology will be essential for building further efficiencies and sustainability in food and goods production to meet the demand of a growing population (see Chapters 2.3 and 2.5 in this volume), it is also unlikely to recover collapsed ecosystems or bring back extinct species (Hooper et al. 2005).

Direct drivers of global environmental impact

Land and sea use

Humans have been modifying the land and sea for at least 12,000 years (Ellis et al. 2021; Fletcher et al. 2021). Over the last century, however, these modifications have become increasingly destructive, often harming biodiversity, altering the natural functions of ecosystems and releasing greenhouse gases (Balvanera et al. 2019; Fletcher et al. 2021; IPCC 2021a). Land and sea use typically refers to activities that convert natural ecosystems to human-dominated systems, such as clearing forest or grasslands for crops and cities (urbanisation) or dredging the seabed to deepen ports for ships. The scale and magnitude of land conversion accelerated significantly around the turn of the 19th century, particularly in North America and Europe (Balvanera et al. 2019). More recently, land and sea change has been rapidly increasing in the tropical regions of the world, nearly tripling in rate between 2010 and 2020 (Balvanera et al. 2019). While humans use landscapes and seascapes in very different ways (e.g., land clearing for human developments vs. fishing for food), our alterations to, and impact on, marine ecosystems are still substantial and increasing. For example, in 2019 there were around 6,500 oil and gas structures in the ocean supporting a large proportion of human energy needs. The rate of shipping for global trade (90% of global trade is over water), and its nearshore and onshore infrastructure, is projected to triple by 2050 (OECD 2022). In Australia, marine-related sectors of the economy are growing at 2–3 times the rate of other sectors (Cresswell et al. 2021).

Some of the impacts of land and sea habitat conversion are apparent immediately, while others emerge slowly. Plants store carbon and are often the first organisms removed during landscape conversion. When they are removed from the land or ocean, they release carbon dioxide into the air, contributing significantly to climate change, alongside the burning of fossil fuels (IPCC 2021a). In addition, habitat conversion affects biodiversity directly, for example, deforestation directly removes and kills most plants and many small animals and displaces the more mobile species to new and often marginal habitat (Fahrig 2003). The habitat that remains is often poor quality and highly fragmented, often patches separated by great distances or impenetrable barriers such as major roads or developments. The remnant populations of species living in these fragmented land and seascapes are less resilient and more vulnerable to disturbance events like fires or cyclones, increasing their risk of local extinction (Fahrig 2003). Generally, the reduced area of habitat, the compromised quality and the fragmentation leave these populations incredibly vulnerable to climate change, unable to adapt or move (De Chazal and Rounsevell 2009).

On land, conversion of natural habitat for human use is considered the biggest driver of biodiversity loss to date. For example, conversion for agriculture has led to one-third of all land and 75% of all freshwater on Earth being altered. Unsurprisingly, the geographic area used for urban environments doubled just between 1992 and 2019 (IPBES 2019). Land conversion is not distributed evenly, but rather is concentrated around the coasts and other highly desirable areas (IPBES 2019), with more than 40% of the people in the world living within 100 kilometres (62 miles) of the coast (Millennium Ecosystem Assessment 2005). As a result, certain ecosystems experience more habitat loss than others, including old growth forests, wetlands and coastal ecosystems like coral reefs and mangroves (IPBES 2019). Australia has seen 47–78% of area previously occupied by saltmarsh and mangrove lost since European arrival in the late 18th century (Cresswell et al. 2021). The concentration of urban areas on the coasts also has indirect effects on the surrounding freshwater and marine ecosystems, from associated marine infrastructure like ports but also through increased pollution runoff. In addition to these direct human impacts, many of these coastal areas are also under increased pressure from a rapidly rising sea level (Stojanovic and Farmer 2013), now approaching 0.37 mm per year (IPCC 2021a).

Around 87% of the ocean is experiencing some level of human impact from things like fishing, climate change, industrialisation and pollution. While unaffected places still exist, most are in the remote ocean of the Southern Hemisphere (Jones et al. 2018). Ocean areas most affected by industrialisation (including shipping, offshore infrastructure like oil rigs and tourism) include Western Europe and North America, reflecting the high levels of urbanisation along the coasts of these locations (Stojanovic and Farmer 2013). Seabed mining may spread as far as the Arctic and Antarctic regions as ice melts (Balvanera et al. 2019), and the development of legislation for deep sea mining to commence in the remote ocean, beyond national jurisdictions, has begun. More recently, large-scale destruction of ocean floor ecosystems has occurred in Asia and the Middle East to make way for tourism infrastructure and islands (Balvanera et al. 2019).

Nature plays an important role in people's health, wellbeing and safety. The patchy nature of land and sea conversion means that people in some places experience benefits from conversion, like increased housing availability, while people in other locations are more likely to feel negative effects, like the pollution that makes its way downstream after a river passes through intensive agriculture or urban areas (IPBES 2019). Managing the trade-off between benefit and harm is a tricky balancing act, and no single approach is likely to meet the needs of everyone (IPBES 2019). Part of this management includes protected areas. Fifteen percent of all land and seven percent of oceans are currently under protection (IPBES 2019). Protected areas can help secure remaining nature from conversion and over-exploitation if placed in the right locations, but can also negatively impact those who rely on the local area for food, shelter and livelihoods (Balvanera et al. 2019). Strict, fortress-style protected areas are not the only option. Indigenous and local community land and sea management practises are increasingly recognised to have beneficial outcomes for the local communities and the local environment (IPBES 2019). Currently, nearly 25% of land globally is owned, managed, used or occupied by indigenous communities (Ellis et al. 2021; Fletcher et al. 2021). Biodiversity and biomass in many of these areas are increasing, yet local and global threats also continue to rise (IPBES 2019).

Pollution

Pollution occurs when humans allow harmful substances, most commonly chemicals, gases and plastic, to enter the environment. Pollution is a by-product of human consumption and is accelerating (Balvanera et al. 2019). Many pollutive substances are easily spread by humans, wind and waterways. This means that the impact of pollution is often felt at a great distance from where it was released, including in the ocean, the destination to which all rivers and stormwater eventually lead. The health effects of air and water pollution disproportionately affect low-income people (Balvanera et al. 2019). At least 300 million tonnes of heavy metals and toxic sludge are discharged into waterways each year, and 80% of global wastewater goes directly into waterways without being treated (Balvanera et al. 2019). Fertiliser and pesticides washed from agricultural land into the ocean can remove oxygen from the water, creating dead zones along the coast where few plants and animals can live. Currently, there are more than 400 identified coastal dead zones throughout the world, covering nearly 250,000 km (Balvanera et al. 2019).

More recently, plastic products (traditionally derived from fossil fuels) and plastic fragments have been accumulating in coastal and marine ecosystems across the world (Bhuyan et al. 2021). These plastic fragments can be from microscopic to large in size, while adding to the pollution problem and altering the functionality of the natural environment in various ways. Plastic can injure or kill large numbers of wildlife, like seabirds, through plastic entanglement or ingestion, upsetting the balance of ecosystems in which these birds participate. Larger pieces of plastic can transport invasive species to new locations, and they can ruin the aesthetic value of culturally, economically or recreationally important locations (Thushari and Senevirathna 2020). It is estimated that every square kilometre of ocean contains over 60,000 particles of microplastic (Balvanera et al. 2019). Microplastics have been found accumulated in animal tissues, which in turn can have negative health implications for other animals ingesting them, including humans (Smith et al. 2018). As an example waste management pollution is discussed in more detail in Chapter 2.4 in this volume.

Over-exploitation and consumption

Humans have always exploited land, animals, plants and other resources in terrestrial, freshwater and marine ecosystems. The first form of terrestrial over-exploitation can even be seen in the fossil records over the past 250,000 years. A recent study by Dembitzer et al. (2022) suggests that, due to long-term human hunting, the average size of hunted animals has declined over time, with each new generation of humans hunting progressively smaller prey as the larger were targeted and eliminated by earlier generations. This form of hunting of wild game was the primary form of over-exploitation by humans until the development of agricultural practices – the large-scale cultivation of plants and livestock – some 12,000 years ago. This triggered one of the most significant transformations of civilisation, and the environment, in history (Nelson et al. 2006). In recent history, the proportion of meat in human diets has been increasing rapidly (González et al. 2020), driving significant expansion of agricultural practices, land and impacts (IPBES 2019). The production of meat for human consumption requires significantly more land than plants, with 77% of global farming land being used for livestock grazing and to grow crops to feed that livestock (Poore and Nemecek 2018). The production and consumption of meat also contribute to higher carbon emissions than vegetarian diets (González et al. 2020). Meat also requires more water to produce – producing 1 kg of beef requires 10 times more water than 1 kg of kidney beans (González et al. 2020).

In the marine environment, overfishing (analogous to overhunting in terrestrial environments) presents a significant threat to ecosystems and food security. Global fishing catches have increased by 50% over the past 50 years (Brauman et al. 2019), particularly highly regarded species such as tuna and other finfish. This pattern has resulted in a drastic decline in higher-order fish species, a phenomenon known as fishing down the food web, where humans are over-exploiting higher-order marine species until they are exhausted before moving down to the next level (often the previous target species' prey) in a similar way to large terrestrial organisms were hunted to extinction (Pauly and Palomares 2005).

Fishing provides an important source of protein for billions of people around the world and is the principal livelihood for millions. Global fishing catch peaked in 1996 at 130 million tonnes and has steadily declined ever since (Pauly and Zeller 2016). These rising catches are not a result of growing fish populations, but rather technological advancements that have allowed fishing fleets to fish for longer, in deeper waters and take more fish, even when their numbers dwindle (Rousseau et al. 2019). The number of fishing ships on the ocean has doubled to 3.7 million since 1950. These ships have evolved into highly refined machines, with some individual vessels capable of pulling out 200 tonnes of fish per day – the equivalent weight of 20 buses (Rousseau et al. 2019).

Increased fishing ability has coincided with poor fisheries management and illegal, unreported and unregulated (IUU) fishing. In 2011, IUU fishing represented up to one-third of the world's reported catch (Balvanera et al. 2019). Managing fisheries effectively, and preventing IUU fishing, is an incredibly complex task, spanning multiple national jurisdictions and often out of sight in the deep sea. As a result, an increasing proportion of marine fish stocks are overfished (33% in 2015), while 60% are at capacity, and only 7% are underfished (Balvanera et al. 2019).

Much like other ecosystem services, wealthy nations are responsible for taking most of the fish within their own jurisdictions and the waters of lower-income countries. In fact, 78% of industrial fishing in lower-income countries is done by wealthier nations, who supply financial and technological assistance in exchange for the right to fish in their waters (McCauley et al. 2018). This pattern results in a reduction of fish being available for local fishermen and prevents the development of associated local economies, such as canneries, resulting in lost livelihood and subsistence opportunities.

To meet the ever-increasing demand for fish, many nations have turned to aquaculture (fish farming), which surpassed wild fisheries production for human consumption in 2016 (Boyd et al. 2022). The aquaculture industry has had its own issues, however, with a large proportion of wild-caught fish being used to feed farmed fish. In 1997 to produce 1 kg of farmed fish approximately 2 kg of wild-caught fish were required. By 2015 this was reduced significantly to 0.28 kg. However, there are still many species such as salmon, trout and most marine fish that still require between 1.2 and 1.9 kg of wild-caught fish (Naylor et al. 2021). The challenges around agriculture and food production are covered in more detail in Chapter 2.5 in this volume.

Invasive species

Invasive species have a significant impact on biodiversity and ecosystems worldwide (Purvis et al. 2019). Species are considered invasive when they are introduced into a new area, where they successfully survive and reproduce, often significantly altering their new home. Most invasive species introductions are the result of human activities. Some are accidental, stowing away on planes, vehicles, ships or marine debris, such as the European green crab, which stowed away on boats and ended up in Australia, South Africa and the United States, where it is devastating native shellfish and crab populations, as well as damaging eel grass and salt marsh habitats. Some others are intentional introductions by people, such as cane toads, brought to Australia to eat the sugar cane beetle, but instead are eating and outcompeting native species and are poisonous to native predators. Developed countries have a significantly higher number of recorded invasive species than developing countries due to population size, trade and more resources dedicated to detecting invasives (Seebens et al. 2017). Invasive species span many different groups of organisms; they can be insects, birds, crustaceans, mammals, amphibians and everything in between. Some examples of damaging invasive species include the European green crab (*Carcinus maenas*), common myna (*Acridotheres tristis*), killer algae (*Caulerpa taxifolia*), Asian tiger mosquito (*Aedes albopictus*), stoats (*Mustela erminea*) and the cane toad (*Rhinella marina*).

Invasive species often share similar characteristics that help make them invasive. One of these is a fast reproduction rate, as they mature early and produce many offspring. Invasive species often have significant dispersal abilities too. Invasive species generally experience less pressure from predators, competitors, diseases and parasites in their new environments. It is estimated that between 3,000 and 7,000 different species are transported by ballast water in ships every day (WHO 2011). Over the last 200 years, the introduction rate of invasive species has been increasing steadily and shows no sign of slowing down (Seebens et al. 2017).

Invasive species have negative ecological, economic, social and cultural impacts on their introduced environments because of their detrimental impact on local biodiversity. The traits which make them very successful invaders also make them very successful at crowding out local native species by consuming resources such as food, shelter or suitable habitat. In addition, some also eat native species. Ecosystems previously rich with many different types of local species can be transformed (see Figure 2.2.2) – for example, in south-eastern

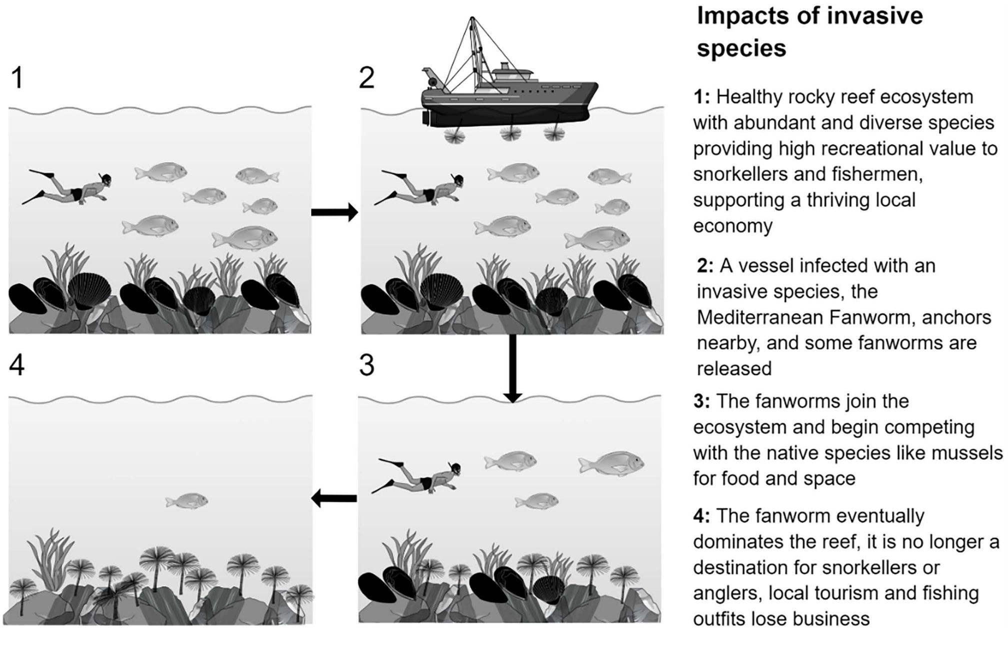

Figure 2.2.2 Example of how an invasive species can alter an ecosystem and affect nature, people and the economy.

Australia, invasive sea urchins have devoured underwater seaweed forests, displacing their inhabitants and leaving only a vast blanket of urchins in their place (Johnson et al. 2011). Invasive species can also change ecosystem functions. Examples include nutrient cycling – invasive zebra mussels can increase the transfer of nitrogen from the water to the bottom – and fire regimes where invasive plants alter fuel conditions to promote fire, allowing subsequent dominance for the species. Invasive species can also introduce parasites and diseases which impact environmental and human health.

Climate change can increase the spread of invasive species, further reducing the resilience of ecosystems and biodiversity, making them more susceptible to climate change. With the increase of extreme weather events, such as marine heatwaves, native ecosystems will become more stressed, making it easier for invasive species to establish. With increased ocean temperatures causing sea ice to melt, new shipping lanes can be established, creating new pathways for invasive species being transported on ships. Cold winter events often limit the range of invasive species (Osland et al. 2021). However, with increased temperatures due to climate change, new habitats will become available for invasive species, such as within the Arctic and Antarctic. With the positive feedback loop between invasive species and climate change projected to grow stronger, the resultant impacts on biodiversity and ecosystem functioning are also expected to be more severe.

The transformation of ecosystems by invasive species can devastate fisheries, tourism, cultural values and liveability of these places. The economic costs are significant, with funds either lost from reduced production or spent on managing these species. The annual estimated damage from invasive species globally is 5% of the world's economy, larger than the GDP of 179 countries (Stanley and Adrianna 2010). Biosecurity, the management of invasive species, is becoming increasingly important. There are many possible solutions to help reduce the spread and impact of invasive species. Prevention of introduction by pathways, such as commercial shipping vessels and aeroplane luggage, is key, along with the prevention of intentional introductions. Early detection is crucial to successful management, as once invasive species begin to spread, particularly within the marine environment, they are extremely difficult to eradicate and control. Education and awareness can play an important role for the public to aid in biosecurity. Nevertheless, of all possible solutions, prevention is the most important.

Biodiversity change

Throughout the world, these indirect and direct driving forces are translating to visible changes to biodiversity and subsequently to important ecosystem functions. While human populations continue to grow in many places, the opposite is true for many other species, with native species' populations declining by at least 20% since 1970 (Purvis et al. 2019). At least 680 species have been driven to extinction since 1500, mostly by land use change (Balvanera et al. 2019). For our remaining species, the combination of declining numbers, the shrinking availability of suitable habitat, increased fragmentation and climate impacts means that an estimated 1 million plant and animal species are threatened with extinction (Ceballos et al. 2020; Purvis et al. 2019).

Because species diversity and ecosystem health are closely tied to patterns in the climate, climate change has and will continue to exacerbate the effects of other drivers (Purvis et al. 2019; IPCC 2021b). Generally, there are a limited number of options for species to respond to climate change: species can adapt genetically to the changes, species can move or shift locations to more amenable climates or species can go extinct. In the most biodiverse parts of the world, between 2% and 10% of species are predicted to currently be at a very high risk of extinction due to climate change (IPCC 2021b). Many species already appear to be shifting their home ranges toward locations where the climate is more suitable to their needs. For example, many marine species are moving into deeper, cooler waters – often toward the poles (Arias et al. 2021). We are also seeing large-scale mortality events as a result of heat extremes, in some cases to the point where entire local populations of species have been lost from a place (IPCC 2021b). Scientists have estimated what proportion of species will be threatened with extinction under different potential warming scenarios – at 2°C of warming, 5% of species will be at risk of extinction, at 4.3°C, 16% of species will be at risk (specifically from climate change, excluding other causes) (Purvis et al. 2019).

Healthy ecosystems are required to maintain important natural functions, including the carbon and water cycles, food systems and coastal protection. While land conversion has a very clear effect of removing portions of an ecosystem, the biodiversity change described earlier is highly destabilising to ecosystem services, even if the ecosystem appears to remain largely intact (Hooper et al. 2005). The most threatened ecosystems from climate change impacts include tropical forests, temperate kelp forests and seagrass beds, Arctic sea ice ecosystems, tundra regions and warmwater coral reef systems (IPCC 2021a). Approximately half of the world's live coral cover has been lost since the 1870s, and 85% of wetlands have been lost in this time (Balvanera et al. 2019). Unfortunately, biodiversity hotspots with a high proportion of rare species are experiencing a disproportionate amount of ecosystem degradation and subsequent loss of species (Balvanera et al. 2019).

Conclusion

People are altering the natural environment at extreme spatial scales and magnitudes, with the majority of our ocean, freshwater and land experiencing some level of human impact. In particular, habitats such as coral reefs, wetlands and forests are being removed at exceptional rates, while those that remain are at risk of becoming severely degraded due to changing climates and invasions from non-native species. As a result, many species and ecosystems around the world are threatened with extinction or collapse. In turn, essential ecosystem services such as access to clean air and water, food security, safe livelihoods and culture is diminishing. Together, these global environmental impacts resulting from human use and exploitation are having a massive impact on wellbeing and compromising hope for a sustainable future.

To prevent significant further environmental devastation, we need to completely transform the way humans interact with the environment. The solution starts with effective and science-driven sustainability education, incorporating social, ecological, and environmental complexities. The required transformational change will only be possible if meaningful education and change occur at every societal level – governments, businesses, institutions, communities and individuals. An environmental focus in education is an essential factor enabling this kind of global transformation – understanding ecosystem and species dynamics and the impacts of environmental change must be an essential part of motivating change. Finally, empowering this transformational change through science-based evidence and logic will help ensure we reduce our environmental footprint and mitigate existing and future global impacts.

In considering how we can reduce the current and future impacts and build a sustainable world, it is important to also consider where the responsibility for change lies. Some significant impacts can be made at the individual level – small changes include biking or walking as an alternative to driving, choosing to eat lower on the food web, reducing our reliance on non-recyclable products and reusing items when possible. By changing our eating and consuming behaviours, as well as becoming more active advocates for a more sustainable, equitable and balanced future, we can become catalysts for positive change for the planet.

Many impacts are outside the direct control of the individual, however, and require organised effort and management at higher levels – governments and corporations need to regulate their impact, such as through reduced greenhouse gas emissions and achieving more sustainable fisheries catches (Nelson et al. 2006). It is widely agreed that transformative change will be required to secure a sustainable future of the planet, an aspiration that cannot be achieved without widespread and enthusiastic buy-in from everyone.

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2.3
POPULATION, ENVIRONMENT AND WELFARE
A difficult conversation

Theodore P. Lianos[1]

Key concepts for sustainability education

- Population growth, which implies an increasing demand for limited resources, is predicted to continue to increase and reach 10.9 billion at the end of the century.
- Environmental as well as social problems will intensify as population growth increases the demand for resources in a world of finite resources.
- The need to feed a growing population has increased the global ecological footprint to 21.2 billion global hectares, which now exceeds the estimated world's biocapacity by 65%.
- Reduction and stability of population size are critical to ensure an essential balance between population resource demands and the ability of the world to provide for those demands.
- Reduction of population size would be associated with an increase in the well-being of global citizens and ensure better intergenerational equity of global resources.

Introduction

Fifty years after the publication of Ehrlich's "The Population Bomb" (1968), Meadows et al.'s "The Limits to Growth" (1972), H. Daly's paper "On economics as a life science" (1968) and Ehrlich and Holdren's "Impact of Population Growth" (1971), the growth of population as a crucial factor in shaping the present problematic condition of the Earth is beginning to be widely recognized. In a recent paper, O'Sullivan (2020) stresses the need for paying greater attention to population growth and the ensuing social and environmental influences. In 2019, Sandra Diaz and 27 (2019) co-workers include in a list of leverage points the "lowering total consumption and waste, including by addressing both population growth and per capita consumption differently in different contexts". In January 2021, Corey J. A. Bradshaw, together with 17 colleagues[2] (2021), emphasizes the continuing loss of biodiversity, the danger of a sixth mass extinction, climate disruption and the ecological overshoot due to population size and overconsumption. In the same year, Dasgupta (2021) gave a very readable account of the economics of biodiversity.

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The evidence for the crucial condition of the environment is here and it is undeniable. What is missing is the political will to take proper action. The situation is really frightening. Scientists from all relevant scientific disciplines predict that in the next decades, if we remain inactive, dramatic changes with tragic consequences, such as natural catastrophes, famines, wars, local conflicts, social unrest and even extinction of the human race (Fenner, reported by Firth, 2010) will take place within the next 100 years. Also, Schade and Pimentel (2010) have warned us of “a painful population crash”.[3]

Can catastrophe be avoided? Various groups of people and some international organizations (Organisation for Economic Co-operation and Development [OECD], United Nations [UN], World Bank) believe it can, or so it is implied by their suggestions and/or actions. Degrowth theorists, advocates of green growth and green economy, eco-socialists and eco-modernists present models of social and economic changes that according to their claims would bring humanity back to a course that would avoid catastrophe and lead to economic and social prosperity. It is really surprising that in these models the population is absent or it is mentioned only incidentally. Technological solutions, such as carbon dioxide removal (CDR), exclude by definition the causes of greenhouse gas emissions and they ignore population completely.

In this chapter I discuss the following aspects of population: (a) population growth and projections, (b) its relationship to the social and environmental problems, (c) a suggestion for population control and (d) the long-run equilibrium of the economy when the desired level of population is reached.

Population growth

There is no doubt that humans are the fastest-growing population on the Earth, particularly during the 20th century when the world population increased from 1.55 billion in 1900 to 6.14 billion in 2000, which is an increase of 296%. During the first 20 years of this century another 1.65 billion have been added. The highest rates of growth occurred during the 1950–1990 period when population increased by 20% per decade. During the last two decades the rate of growth has declined to 13.2% for the 2000–2010 period and to 12% for 2010–2020 period.

Of course, the decline of percentages offers no comfort because it is due to the increasing denominator of estimating the rates of growth and not to decline in the absolute values. It can be seen from Table 2.3.1 that the absolute increase of population in the 2010–2020 decade was greater than that of the 1960–1970 decade, which had the highest rate of growth. It is a frightening fact that a new city is created every day and 238,000 additional people have to be provided with food, housing, medical care, etc., every day. If you plot the data of Table 2.3.1 on a diagram, you will see that population follows an exponential curve; therefore the decline in the rate of growth offers no real comfort.

According to a recent study from the International Institute for Applied Systems Analysis (Lutz et al., 2014), world population is likely to peak at 9.4 billion around 2070 and then decline to about 9 billion by the end of the century. According to a UN study (Gerald et al., 2014), the world population can be expected to grow to 9.6 billion in 2050 and to 10.9 billion in 2100. Bradshaw and Brook (2014), on the basis of a “business as usual” scenario, predict a world population of 9.23 billion for 2050 and 10.42 billion for 2100. Despite their differences, all three studies predict a substantial increase in world population in the next 80 years. The 2019 revision of the UN prediction for the world population is

Table 2.3.1 World population 1900–2020

Year	*Population (millions)*	*Population change (millions)*	*Growth rate of decade (%)*
1700	600		–
1800	813		–
1900	1,550		–
1910	1,750	200	12.9
1920	1,860	110	6.3
1930	2,070	210	11.3
1940	2,300	230	11.1
1950	2,536	236	10.3
1960	3,035	499	19.7
1970	3,700	665	21.9
1980	4,458	758	20.5
1990	5,327	869	19.5
2000	6,143	816	13.3
2010	6,957	814	13.2
2020	7,795	838	12.0

Sources: US Census Bureau, UN Population Division, World Population Prospects.

9.7 billion for 2050 and 10.9 billion for 2100 (UN, 2019). In brief, we should not expect the world population to stabilize in the near future.

Although the world population continues to grow (it reached 8 billion in November 2022), a few developed countries have slightly declining populations. Japan's population declined by 1.1% in the 2010–2021 period, Italy's by 1.7% in the 2014–2021 period and Portugal's by 2.7% in the 2010–2018 period. In developing countries, the population continues to grow. Thus, India's population increased by 11.5 million in 2022, Indonesia's by 2 million and Brazil's by 1.1 million. It is interesting to note that China's population fell in 2022 by 850,000.

Is the world overpopulated?

This is an old question to which there is not a single answer (Cohen, 1995), but it is also a question that must be answered, explicitly or implicitly, in any civil society that cares about the quality of life of its members. This makes necessary the adoption of a criterion on the basis of which the question of overpopulation can be answered. The first criterion in history that was practically used was the ability of the land to provide an accepted standard of living. As early as the 8th century B.C., Greek cities had begun to create colonies in the Mediterranean Sea as a result of overpopulation in the metropolis. In 347 B.C. Plato wrote in his *Laws*:

> The number of citizens can only be estimated satisfactorily in relation to the territory and the neighboring states. The territory must be sufficient to maintain a certain number of inhabitants in a moderate way of life – more than this is not required; and the number of citizens should be sufficient to defend themselves against the injustice of their neighbors, and also to give them the power of rendering efficient aid to their neighbors when they are wronged.
>
> *(Laws,737, C, D)*

Thus, for Plato the accepted standard of living was a moderate way of life. For his student Aristotle, the relationship between population and land is determined by the notion of a "best life" which presupposes wealth of material goods and virtue:

> But a better definition would be "to live temperately and liberally" (for if the two are separated a liberal mode of life is liable to slip into luxury and a temperate one into a life of hardship), since surely these are the only desirable qualities relating to the use of wealth.
>
> *(1265a 33–38)*

The attribute of a best life refers both to individuals and to the state:

> For the present let us take it as established that the best life, whether separately for an individual or collectively for states, is the life conjoined with virtue furnished with sufficient means for taking part in virtuous action.
>
> *(1323b40–1324a2)*

Thus, Aristotle uses the same criterion as Plato but instead of a moderate way of life he suggests a comfortable but not a wasteful life.[4]

Cohen's definition of the quality of life can be seen as a modern version of Aristotle's "best life". Cohen writes:

> The real crux of the population question is the quality of people's lives: the ability of people to participate in what it means to be human; to work, play, and die with dignity; and to have some sense that one's own life has meaning and is connected with other people's lives.
>
> *(2017, p. 42)*

Clearly, Cohen relates the size of a population, and consequently of overpopulation, to a criterion that involves, in some way, the measuring of the standard of living, among other things.

No serious objection can be raised against using income as a variable for material welfare and also as a proxy for a good life. People's material welfare differs greatly among individuals and among countries, and it is difficult to find a level of income which we would all accept as providing enough for a comfortable but not wasteful life. To get a sense of the magnitudes involved, let us examine three alternatives, that of Australia, the European Union and Greece. In 2020 the world gross domestic product (GDP) was 84.7 trillion USD and per capita GDP of Australia in the same year was 51,812 USD. If everyone in the world were to enjoy as high an income as the Australian citizen, the world population would be 1.64 billion. If everyone in the world were to enjoy as high an income as the average person in the European Union with 33,927 USD per capita income, the world population would be 2.5 billion. In my opinion, the Australian citizen and the average citizen of the European Union have incomes that provide more than is needed for a comfortable life. Let us try Greece's per capita income, which was 17,676 USD in 2020. It is my experience that a family of four with an income of approximately 70,000 USD can have a comfortable life.[5] If everyone were to have Greece's per capita income, the world population should be 4.8 billion.

The conclusion to be drawn from this arithmetic is that the present size of the world population exceeds by 62% the size that would make possible a comfortable life for everyone, and therefore if we accept economic well-being as a criterion, the tentative answer to the question we discuss in this section is that the Earth is definitely overpopulated.[6]

However, this is not the end of the story because the world GDP[7] 84.705 trillion USD is not sustainable. The calculations presented earlier could have provided an answer if we knew the sustainable level of world GDP. Let us try to do that.

Sustainable world GDP

Roughly speaking, a sustainable level of production is that which does not reduce the ability of the productive system to reproduce itself. In order to have a magnitude of the sustainable level of production, we need a variable or an index that measures sustainability, and it is related to production. For the purposes of this chapter the ecological footprint (EF) in relation to biocapacity (BC) seems to be proper. To estimate sustainable GDP, I make the assumption that the sustainable GDP is the same proportion of the actually produced GDP as BC is to EF.[8] If sustainable GDP is denoted by GDP*, then

$$\frac{GDP^*}{GDP} = \frac{BC}{EF}$$

and

$$GDP^* = \frac{BC}{EF} GDP$$

The most recent data we have for BC and EF are BC = 12.17 bn GH (global hectares) and EF = 20.51 bn GH for 2016, and the world GDP of that year was 76.42 trillion USD. Thus, the sustainable world GDP for 2016 was GDP* = 45.34 trillion USD.

Obviously, the sustainable world GDP is not a given quantity, as it depends on the changes of BC and EF as well as the level of real production. The previous estimate may be an approximation of the real sustainable GDP, but it is in congruence with all scientific evidence that has been accumulated over the last decades and leads to the conclusion that we are using resources at higher rates than those at which resources can be reproduced.

Yes, the world is overpopulated

We can repeat the arithmetic we did in the previous section and divide the estimated sustainable world GDP with the per capita GDP of the three countries. If we accept Australia's per capita GDP as an acceptable standard of living, the size of world population should be 875 million (45.34 trillion divided by 51,812 USD). If we prefer the European Union per capita GDP, the size of the world population should be 1.336 billion (45.34 trillion divided by 33,937 USD) and if we are happy with Greece's per capita GDP, 2.57 billion people can live happily on the Earth.

It is interesting that three earlier studies have found estimates of optimum population size in the same neighborhood. Daily, Ehrlich and Ehrlich (1994), using a per capita energy criterion, estimated the optimum population size to be 2 billion people. In the same year Pimentel et al. (1994), using the size of land needed for supply of food as a criterion, estimated the optimum population size to be 3 billion people. More recently, Pimentel et al. (2010) estimated that under certain reasonable assumptions about land inputs and also a European standard of living for everyone, the optimum population size is 2 billion people. More recently, Lianos (2013), using the data for EF and BC, estimated the world's optimal population to be 2.5 billion.

Clearly, even allowing for a wide margin of error, say 100%, the previous estimates show that the present population size of 7.8 billion people exceeds by far the carrying capacity of the Earth. Our planet is undoubtedly overpopulated.

Figure 2.3.1 gives an informative picture of the estimates given earlier. The SS line represents the sustainable world GDP of 45.3 trillion USD. Actually, it is the budget constraint of the world economy. It shows that for every population size the maximum sustainable per capita GDP. Point A shows that if Australia's per capita GDP were to be universal, the corresponding size of the world population should be 0.9 billion if sustainability was to be maintained, and similarly for points EU, G and W, which correspond to the European Union, Greece and the world, respectively. Points to the right of SS are not admissible because they belong to combinations of per capita GDP and population that are not sustainable. Point WN, which shows the current situation of 10.9 thousand USD per capita and a world population of 7.9 billion people, is not admissible but it is possible because of the extensive exploitation of the Earth's resources that makes the existing situation unsustainable.

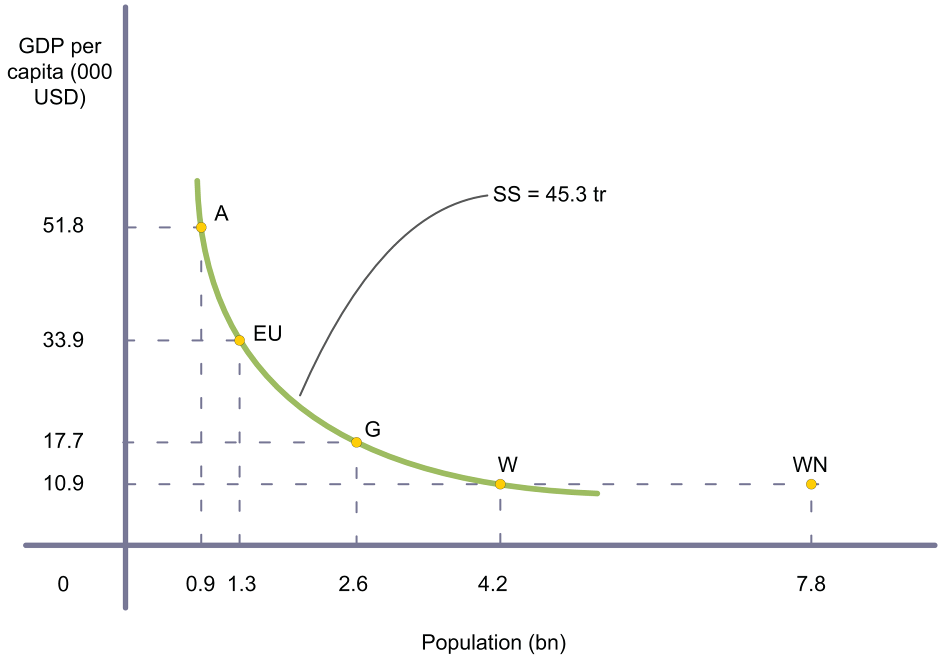

Figure 2.3.1 Informative representation of the estimates for world population. If we accept Australia's per capita GDP as an acceptable standard of living, the size of the world population should be 875 million. If we prefer the European Union per capita GDP, the size of the world population should be 1.336 billion and if we are happy with Greece's per capita GDP, 2.57 billion people can live happily on the Earth. The SS line represents the sustainable world GDP of 45.3 trillion USD.

Why is the world population growing?

There are several factors to which the growth of the world population can be attributed. Perhaps the most important is the worldwide increase in the average length of life, which was 46 years in the 1950–1955 period and increased to 71 years in the 2000–2013 period. This was a result of the development of drugs, particularly for the treatment of infectious diseases, and of improvements in health care, as well as to improved conditions of life due to economic development. Also significant is the contribution of unintended pregnancies, which are close to 120 million every year and of which approximately 60% are terminated. This is a result of a lack of family planning, ignorance due to lack of education about sexual reproduction issues and in many places, lack of contraceptives and societal and partner coercion.

Further, a part of new births can be attributed to the lack of female empowerment. Education and the ability of women to earn incomes are crucial in allowing women to decide the number and spacing of their births or to opt out of motherhood altogether.

Also, in many developing countries with inadequate social security systems children are security for the old age and at the same time cheap labor for agriculture and small family businesses.

Religious, political and military factors may also be important. Some religious dogmas favor the large family model and discourage attempts to control the number of children. A large population is often considered a factor that increases the political influence of a country in international politics, particularly when it is accompanied by military power.

Finally, there is a general cultural element that a large family is a good thing. This is probably related to the recent past of North America and Europe when the number of children per family could be as high as six or even more.

We should also mention four ideological factors that act against any suggestion for population reduction. First, anyone who dares speak for the need of population reduction or stabilization is automatically accused of Malthusianism,[9] mainly by Marxists and leftists, following Marx's antipathy for Malthus. Second, suggesting population control makes one a racist simply because population control is taken to be mainly needed in African and Asian countries. This reaction ignores that the intensity of the need for population control is equally needed in all countries: in those with large per capita consumption but also in those with low per capita consumption which however aspire to reach a high per capita consumption.[10] Third, in some quarters it is believed that technological progress will solve the environmental problems and therefore population controls are not needed, ignoring the fact that resources are limited and people must be fed. Fourth, generally speaking, it is a common observation that there is a taboo on discussing issues related to population, which prevents the development of awareness of one of the major causes of today's environmental problems.[11]

It is not only population that is a problem, it is also consumption

The total anthropogenic negative impact on the environment is a result of total production and the technology used.[12] It is informative to express total production by the product of total production per capita times the size of population, as is done in the well-known equation

$$I = PAT$$

where I is the environmental impact, P is population, A is affluence measured by total production per capita or by total consumption per capita and T represents technology. This formulation has three advantages. First, it draws attention not only to population but also to per capita consumption as a factor directly related to the environmental impact. Second it can be applied on a country level and thus can be used to stress the difference in the impact of various countries on the global environmental deficit. In fact, it is well known that the EF (a measure of environmental impact) is much higher in the wealthy countries relative to the less developed and poor countries. For example, the per capita ecological footprint of the United States, Canada, Great Britain and Australia is 8.22, 8.17, 7.93 and 9.31 global hectares, respectively, whereas for Mauritania, Uruguay, Bolivia and Guyana it is 2.54, 2.91, 2.96 and 3.07, respectively. The third advantage of this equation is that it proposes various ways of measuring the environmental impact as the EF, the carbon dioxide emissions, etc.

In other words, our impact on the environment depends on how many we are and on how much we consume. Therefore, there are two ways to reduce the negative impact on the environment: we can reduce the size of population or of per capita consumption (or GDP), or both, of course. But it makes a great difference which one we choose. Reducing per capita consumption means ipso facto reduction of people's welfare, whereas reduction of population will increase people's welfare as is discussed later in this chapter. This is the reason that our emphasis is on population rather than on per capita consumption.

Some people put the emphasis on technology (T) hoping that with technical progress the world economy can continue to grow without producing negative results for the environment. This is the idea of absolute or relative decoupling, and it does not seem to be valid. The equations that follow present the results of three regressions where the EF measured in millions of global hectares is the dependent variable and the gross world product in billions of US dollars at constant 2010 prices is the independent variable. The first equation is estimated for the 1970–1985 period, the second for the period 1986–2000 and the third for the period 2001–2016.

$$EF = \underset{(16.7)}{6.523} + \underset{(13.0)}{0.202}\,GWP \qquad R^2 = 0.91 \qquad d.f. = 16 \tag{1}$$

$$EF = \underset{(24.9)}{8.168} + \underset{(19.5)}{0.154}\,GWP \qquad R^2 = 0.98 \qquad d.f. = 15 \tag{2}$$

$$EF = \underset{(6.3)}{6.888} + \underset{(10.7)}{0.186}\,GWP \qquad R^2 = 0.93 \qquad d.f. = 16 \tag{3}$$

The coefficient of GWP shows the effect of a unit change in GWP on EF. It appears that over the 1970–2016 period, the coefficient is declining but not to a considerable degree.

Are there solutions without population reduction or stabilization?

There are at least five theories which answer "yes" to this question. The answer is implicit in the sense that population is not considered in their analysis, although they might agree that population reduction could be helpful. These theories carry the names green economy or green growth,[13] degrowth, eco-socialism, eco-modernism and simpler way. They include the following proposals: reduction of fossil fuels, limits on carbon emissions, downscaling affluent economies and material flows, home and commercial insulation, renewable heating, relative or absolute decoupling, reducing work hours and sharing available jobs without reducing wages, a "simpler way" society, getting rid of market forces and, finally, transforming the capitalist system to a socialist one. Some of these policy suggestions are consistent with others, some are contradictory, some are imaginative but obviously unrealistic, some are promising, some are being proven wrong (decoupling), some (eco-socialism, degrowth and the simpler way) may have a chance of success in a non-capitalist economy and two of them (the green economy and eco-modernism) are dependent on technical progress and its application to production.

In contrast to these theories, in the steady-state economy (SSE) model, population is required to remain constant. Herman Daly, the best-known advocate of this model, defines the SSE as an economy with a constant population, constant capital stock and use of resources at a rate which is within the regenerative and assimilative capacities of the ecosystem.[14] This sounds perfect but serious questions immediately arise: how population can be constant and at what level, and how capital stock can be kept constant? Daly has answers for these and other questions, some of which are convincing and some are not.

In my view the SSE model requires only stability of population at a level which satisfies the condition for ecological equilibrium, given an accepted standard of living. This model can function in a capitalist system with price flexibility or in a command system.[15] If the population size is determined, all other variables of the economy will adjust to that.

Can population be reduced?

The world population is already at unsustainable levels. The estimates we presented earlier show that if everyone should have a comfortable standard of living, ecological equilibrium cannot be achieved with the present size of the world population. Therefore we should not talk about stabilization, but rather about its reduction. The answer to the question is easy: yes, population can be reduced. The difficult question is how.

To keep the population in check, Plato and Aristotle had suggested admonition and guidance to the young. Malthus had suggested moral abstinence. Apparently, these did not work. Family planning services have given good results in some countries (Thailand, Colombia, Iran). Also general education may appear to give good results since women with a higher educational level are associated with fewer births. Probably, this is because they enter the labor market. In the economic literature the positive relationship between years of education and rates of labor participation of women is a common result. It may also be because education makes people more able to develop skills to take better care of themselves in general. Availability of contraceptives at low prices may also have good results, as in Brazil, North America and Europe. Economic motives may also be effective. In many countries large families are given economic assistance in various ways, and this seems to have a positive effect on the number of children per family. It may also work in the opposite direction if economic motives are given for small families. Disincentives for large families should be of a negative tax type, i.e. to subsidize families, mainly with limited incomes, if they abstain from having more than two children. The subsidy can be either monetary or in kind, e.g. free education throughout the entire educational ladder. Taxing large families may create difficult administrative problems, and it may also be unfair to the less privileged.

Coercive policies for reducing population have been applied in China with the one-child policy from 1980 to 2015 and in India with the sterilization policies of S. Gandhi in 1975.

Non-coercive policies may or may not produce the expected results, but they do not create additional problems. Coercive policies may have the expected results, but in addition to the ethical problem they create practical problems as well. In China, for example, the traditional preference for boys and the possibility of early diagnosis of the child's biological sex have resulted in millions of abortions and a large deficit of women.[16] Also, the big fines on the family for having more than one child have resulted in many new births to remain unregistered.

Should coercive policies be completely excluded?

It is true that coercive policies for population reduction seem offensive to human rights and may reduce the welfare of the individual affected by these policies and possibly of all citizens. However, not all coercive measures are equally abusive and do not equally affect the individual and general welfare. We are coerced to follow general rules every day. Some are forced to do military service, pay sales and income taxes every day and every year, to drive on one side of the road, to send our children to school and in some countries mandatory COVID vaccination, etc. We accept these rules because we realize that the benefits from following them exceeds the disutility involved. Also, if a coercive measure has general applicability, people may not perceive it as binding their choices.[17]

Fifty years ago, Ehrlich and Holdren (1971, p. 1219) ended their essay with these words:

> To ignore population today because the problem is a tough one is to commit ourselves to even gloomier prospects 20 years hence, when most of the "easy" means to reduce per capita impact on the environment will have been exhausted. The desperate and repressive measures for population control which might be contemplated then are reason in themselves to proceed with foresight, alacrity and compassion today.

Unfortunately, in the years to follow, humanity proceeded neither with foresight nor with alacrity, but rather with complete indifference with regard to the environment, and consequently we are faced today with an explosive situation. We are facing an extreme situation, and if the other non-coercive policies fail, we may need to take unpopular but effective measures.

Stability of population or reduction?

In thinking about the world population size, one may suggest stability in the short run and reduction in the long run. It is definitely easier to achieve stability of a population by designing tax and/or incentive policies that would bring results than to reduce it. For example, a governmental program that will finance education and medical care for families with one or two children (as in the past in China) may be a strong incentive for avoiding having a third.[18] If a tax is added for the third child, this plan would very likely have the intended results. Of course, such a policy would be costly for the government and also for the families that decide to have more than two children. Recently, Ortaga (2021) has proposed the imposition of a yearly natality levy for every person in the world who decides to have a child. This proposal, in addition to being coercive and unequal, may involve substantial administrative costs.

The problem with this and other similar suggestions is that we do not have the luxury of waiting for the long run. The environmental problems made their appearance around 1970 when the world population was less than half of its present size. Technological progress helped, but not enough, and there is no reason to believe that more can be done now. The predictions of population for 2050 give sizes exceeding 9 billion. The environmental and the related social problems are pressing. It seems that we do not really have a choice but to consider undesirable ways of regulating the size of the world population.

Almost half a century ago, in 1964, Boulding (1964, p. 135) had suggested a transferable birth license scheme which allows license transfer between families. The effect on population would depend on the number of child-units allocated to each license. At that time population decline talk was very unpopular, and Boulding's scheme fell under the stricture of political correctness and therefore did not receive much attention. Hadavand and Almasi (2012) compared Boulding's scheme with China's one-child policy and came to the conclusion that from the point of view of welfare, Boulding's plan is preferable.

A mildly coercive plan for reducing the world population would be to give every woman when she reaches the age of reproduction three shares issued by the government. Each share gives the right to give birth to half a child. Each share represents her right to participate in the creation of the next generation. These shares are tradable in an international market at prices that may fluctuate freely depending on demand and supply. Thus, a couple, e.g. in Australia, that wishes to have two children will be able to buy a share from someone anywhere in the word who wants to have one child. To have three children, a family should have to buy three shares, etc. Every woman (or every couple) will have to weigh up very carefully the costs and benefits of having children, and giving birth to a child would not be an accidental event but the result of careful thinking. Depending on the desire for children and the market price of each share, substantial incomes may be received by those who sell.[19]

This plan has four advantages and three important disadvantages. The advantages are that it gives some choice, that it is essentially free of cost, that it treats everybody equally and that it is certain that it will give results. The disadvantages are that it favors those who do not want children and the relatively rich, it is coercive and its implementation worldwide would be questionable. Many people would be very skeptical about introducing laws that force families to reduce the number of their offspring. For example, Conly (2016), who rejects the claim that people have a right to have as many children as they want, refuses to accept enforcements on the number of children a family may have.

In principle, coercive measures should be avoided because they violate human rights and people's freedom of choice, but when a situation becomes critical, they should be weighed against the alternatives.

In the history of the world, social problems have been solved or were limited to manageable proportions by command and by incentives (economic or otherwise) and by a combination of both.[20] Of course, monetizing the overpopulation problem by creating a market for reproduction rights is not the best solution, although it does offer some choice. However, nothing else seems to have worked in reducing the size of population, and our time is up.

What would be the effects of population reduction?

The effects of declining population would depend on the extent and the speed of decline. It is useful to examine the effects of considerable population reduction in the short run, in the long run and in final stages when the desired reduction has been realized and the economy works with a constant population.

In the short run, e.g. the first 20 years after births begin to fall, the main effects will be a fall in the demand of goods and services related to the young generation (medical services, education, entertainment, clothing, etc.). This fall in demand may act as a negative multiplier and affect all sectors of the economy. This fall in aggregate demand may also increase unemployment level. These effects may not be serious because the part of incomes that was previously spent for the needs of the young can now be spent on other goods and services. The speed of the adjustment to these changes will depend on the flexibility of the process. The positive effects include a halt to the negative environmental impacts and an improvement in population density, particularly in crowded cities and households. Of course, stabilization of population size will not have any of the results listed earlier, but it will prevent any further environmental deterioration.[21]

The long run is the period between the present time and the time when the desired population size is reached. This period may last several decades depending on the rate of population decline and its final size. For example, if the present size is to be reduced to 5.5 billion with a one-child policy, approximately four decades will be required, and with a one-and-a-half-child

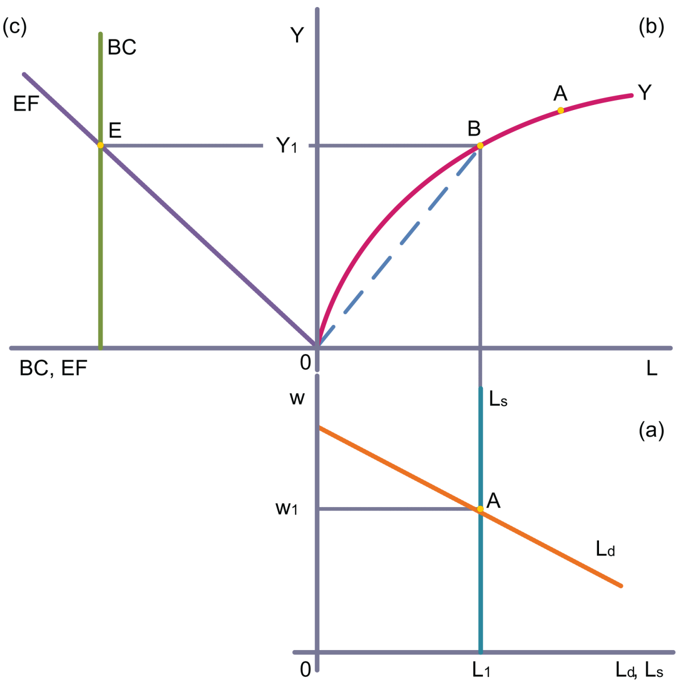

Figure 2.3.2 Final steady-state position of the economy. Part (a) shows the labor market with constant supply of labor and declining demand for labor and market equilibrium at the intersection of the two lines. Part (b) shows the production function and the level of output produced when the labor market is in equilibrium. Part (c) shows the ecological footprint and biocapacity. The labor supply and biocapacity are drawn as straight lines for simplicity. The ecological footprint is linearly and positively related to total product. Product per capita is shown by the slope of the dotted line in part (b).

policy, six decades will be needed. During this period, total product will decline together with a declining aggregate demand and may reach a sustainable level, with the EF falling to the BC level. The declining total product does not mean a fall in per capita product because the decline in population precedes the decline of total product. During this period, labor may tend to be scarce relative to capital and wages may increase at the expense of profits, thus contributing to an improvement in income distribution. Of course, total consumption levels, but not consumption per capita, will also decline unless the propensity to consume rises. Also, in the long run the dependence ratio will be restored to normal levels.

The final steady-state position of the economy is best described with the help of Figure 2.3.2. Part (a) shows the labor market with a constant supply of labor and declining demand for labor and market equilibrium at the intersection of the two lines. Part (b) shows the production function and the level of output produced when the labor market is in equilibrium. Part (c) shows the EF and BC. The labor supply and BC are drawn as straight lines for simplicity. The EF is linearly and positively related to total product. Product per capita is shown by the slope of the dotted line in part (b). The functional distribution of income is shown in part (a) where labor's share is the area $0L_1Aw_1$ and capital's share is the triangle. Point A in part (b) shows a level of total product associated with an ecological deficit ($BC - EF < 0$) and a large population. The long-run equilibrium is reached when the level of employment is such that, given the production function and the available technology, total production is at a level at which the EF is equal to BC (or less).

The equilibrium position shown in Figure 2.3.2 is unique because there is only one level of total product which corresponds to equality of EF with BC. Of course, with respect to sustainability, any level of total product can be at equilibrium as long as EF is less than BC.

Conclusion: only he who inflicts the wound can heal it

In Greek mythology, there is a prophesy that was given by the Oracle of Apollo to Telephus about how to heal his wound caused by Achilles. Apollo said

> Only he who inflicts the wound can heal it.

We are in a similar situation today. The Earth's wounds are caused by excessive production of goods and services for the benefit of humans who have grown in numbers, and their needs exceed the limits of the planet. Ecological equilibrium requires that total production be reduced. But reduction of production without reduction of population would be economically disastrous. Therefore, it is the size of the world population that must be reduced. Finally, it is important to understand that population growth raises issues that concern all disciplines as well as government policies and that it is an important concept in sustainability education.

Notes

1 The author expresses his gratitude to Professor Anastasia Pseiridis and to Professor Michele John for valuable comments and suggestions.
2 The number of co-workers and colleagues for the last references are given with the intention to emphasize that the concern about population growth is gaining momentum.
3 Also, see Acemoglu et al. (2017), Klare (2020).

4 For Plato and also for Aristotle the protection of the city's boundaries was an important factor in deciding the size of a population.
5 An individual in a family of four can enjoy more goods than a single individual with the same per capita income because there are substantial economies of size in the family. Of course, what is considered "comfortable" is a personal affair.
6 The calculations we did here are *grosso modo* for at least three reasons. First, from GDP we need to subtract capital depreciation, which is 10–15%. Second, disposable income is less than the GDP. Third, material welfare may depend on a variety of local factors.
7 World Bank.
8 For more on this subject see Lianos and Pseiridis (2021).
9 Of course, there is nothing wrong with Malthusianism and one may very well be a Marxist and also see value in the Malthusian arguments.
10 To illustrate this point, the ecological footprint of a child born in the United States is 8 times that of a child born in an African country.
11 O'Neill et al. (2018).
12 For an extended discussion of these issues see Dasgupta (2021) sections 6–9.
13 For representative references for these ideas see OECD (2011), Kallis (2010), Kovel and Lowy (1991), Asafu-Adjaye et al. (2015), and Trainer and Alexander (2019).
14 Daly (2008).
15 Lianos (2021).
16 According to the UN World Population Prospects, in 2019 the male and the female population of China was 732.25 and 701.08 million, respectively. The deficit is bigger for age groups below 35 years of age.
17 It is interesting to mention that an opinion poll published by the Pew Research Center (located in Washington, DC) in August 2008 said that the one-child policy of China was overwhelmingly accepted by the Chinese public with a 76% approval rate.
18 Michele John has made this suggestion to me in a private communication.
19 For a more complete discussion of this plan see Lianos (2018).
20 A recent case in point is the command and incentives used for dealing with the COVID pandemic.
21 Gotmark et al. (2018) discuss some of the issues related to an aging population, but they seem to ignore the negative effects on total product. Also, it is not clear what the time period is in which the effects are discussed.

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2.4
WASTE(D) VALUES

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Key concepts for sustainability education

- Waste is a significant externality from human production and consumption activities, and poor waste management practices have created serious global, social and environmental problems.
- In a world with finite (scarce) resources, waste recovery and reuse are critical elements in providing solutions to resource scarcity and a circular economy in sustainable waste management.
- Sustainability values and waste management values are important in anchoring our understanding of and behaviour change towards sustainability and waste management.
- Sustainability education should provide an understanding of waste management principles in order to inculcate a normative understanding of sustainability behaviour and responsibilities in the 21st century.
- Religious groups (80% of the world population) can provide a strong ethical framework on the related issues of environment and waste that is directly relevant to their adherents and sustainability education development.

Introduction

Waste has been a product of human activity throughout history. The production of waste has significantly increased in recent years as the global population has grown and industrialisation has become increasingly widespread (Zaman and Ahsan 2020). Increasing living standards and population growth across the globe are key drivers for waste generation, where people tend to consume more goods and services as economic conditions improve. The relationship between consumerism and waste is particularly evident in high-income countries, which are home to just 16% of the global population but are collectively responsible for around one-third of the world's waste (Kaza et al. 2018).

Based on current production and consumption patterns, waste production is set to increase, as products are increasingly designed to have shorter lifespans and are commonly packaged in disposable materials (de Wit et al. 2019). This poses a significant challenge for

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waste management, particularly in urban areas, which are projected to house 68% of the world's population by 2050 (United Nations 2018).

Waste pollution: a significant challenge

According to the World Bank report by Kaza, Shrikanth, and Chaudhary (2021), up to 83% of global waste generated is said to be residual waste, which was landfilled, incinerated, or otherwise disposed of without being diverted for productive use. In Table 2.4.1, the Global Waste Index 2022 presents a comparative analysis of waste management by the Organisation for Economic Co-operation and Development (OECD) nations, considering the quantity of waste that is recycled, incinerated, landfilled, openly dumped, or otherwise unaccounted for.

Traditional waste management practices in higher-income countries have favoured the 'out of sight, out of mind' approach that has seen waste transported great distances for disposal in landfills, resulting in greater traffic impacts, energy use, and emissions (Cirrincione et al. 2022). Landfills are the third-largest source of methane emissions originating from human activity (Environmental Protection Agency 2022). The release of this harmful greenhouse gas into the atmosphere has serious implications for climate change, having a global warming potential that is 28 times more potent than carbon dioxide (CO_2) (Clean Energy Regulator 2022). The current atmospheric concentration of methane is more than two times greater than pre-industrial levels, an issue which was high on the global agenda at the 2022 UN climate summit in Glasgow (IEA 2023). Here, world leaders signed on to the Global Methane Pledge which will address emissions from municipal solid waste (MSW)

Table 2.4.1 Global Waste Index 2022

Rank 2022	*Rank 2019*	*Country*	*Recycled Share %*	*Final Score*	*Rank 2022*	*Rank 2019*	*Country*	*Recycled Share %*	*Final Score*
01	↔ 01	South Korea	60.8	100.0	20	↓ 12	Czech Republic	22.0	71.0
02	↑ 11	Denmark	35.6	94.9	21	↑ 24	Slovenia	45.0	69.7
03	↑ 06	Germany	47.8	90.4	22	NEW	Colombia	16.0	69.6
04	↔ 04	Switzerland	29.8	89.3	23	↓ 22	Spain	18.9	69.3
05	↑ 07	Finland	28.2	89.3	24	↓ 18	Portugal	12.7	64.6
06	↑ 09	Norway	35.3	88.5	25	↔ 25	USA	23.4	60.2
07	↓ 03	Japan	19.6	86.9	26	NEW	Costa Rica	3.0	60.0
08	↓ 05	Netherlands	27.7	86.5	27	↑ 28	Slovak Republic	28.6	59.8
09	↓ 02	Sweden	20.2	84.8	28	↓ 26	Greece	16.0	57.9
10	↑ 15	Luxembourg	29.4	83.5	29	↑ 34	New Zealand	32.7	54.8
11	↓ 08	Belgium	35.3	83.1	30	↓ 14	Iceland	16.7	54.0
12	↑ 21	Ireland	29.3	79.7	31	↓ 29	Canada	25.9	53.3
13	↓ 10	Poland	26.6	79.5	32	↓ 30	Estonia	28.2	46.3
14	↑ 17	France	22.5	78.9	33	↓ 27	Israel	6.3	42.6
15	↑ 16	Hungary	22.3	75.1	34	↓ 31	Italy	30.0	36.6
16	↑ 23	Lithuania	27.5	74.5	35	↓ 33	Mexico	3.6	35.4
17	↑ 19	Austria	26.2	74.2	36	↓ 32	Chile	0.5	23.3
18	↑ 20	United Kingdom	27.2	73.4	37	↓ 35	Latvia	32.4	18.5
19	↓ 13	Australia	26.8	72.9	38	↓ 36	Turkey	11.0	0.0

Source: Adapted from (Sensoneo 2023).

landfills, presenting an opportunity to capture, convert, and utilise a significant energy resource (Environmental Protection Agency 2022; Kumar and Samadder 2017). Although China, India, and Russia are the world's biggest methane polluters, none of these countries are signatories to the pledge (IEA 2023).

Figure 2.4.1 shows that in low-income countries, open dumping and open burning are the main MSW strategies, accounting for 93% of solid waste (Kaza et al. 2018). The gases emitted from open burning are detrimental to the environment, harming air quality through the release of toxic gases and heavy metals (United Nations Environment Programme 2021). The impacts to human health have been reported to include an increased risk of developing neoplasia, reproductive issues, and diseases such as hypertension or reduced lung function (Tait et al. 2020). Openly dumped waste streams frequently pollute nature, where their impacts are transmitted via several pathways that eventually lead to aquatic environments (United Nations Environment Programme 2021). Littered plastic has been rapidly accumulating in the marine environment, accounting for at least 85% of ocean waste (see Section 7 – Thomas). Certain industries such as fishing and aquaculture make the largest contribution by volume of marine plastic waste. Figure 2.4.2 illustrates the flow of land-based plastic waste streams that can become ocean-bound pollutants (United Nations Environment Programme 2021).

The sheer scale of plastic ocean pollution is overwhelming; a dump truck's worth of plastic is flowing into the ocean every minute, adding up to 11 million tonnes each year (World Wildlife Fund 2021). The slow degradation of ocean plastics impacts over 800 species in the marine ecosystem through ingestion, entanglement, toxicity, and bioaccumulation (Ostle et al. 2019). The presence and degradation of plastic in nature have been shown to contaminate precious ecosystems for hundreds of years as the particles break down into microplastics and nano-plastics (United Nations Environment Programme 2021). Research estimates that a plastic water bottle takes 450 years to biodegrade because the microorganisms responsible for biodegradation are unable to efficiently break down plastic effectively in saltwater (World Wildlife Fund 2021).

A paradigm shift is needed to encourage greater accountability and the decoupling of economic growth from overconsumption that wastes Earth's resources and creates significant pollution problems. Underpinning this paradigm change towards zero-waste thinking is the important role of values in framing sustainability education.

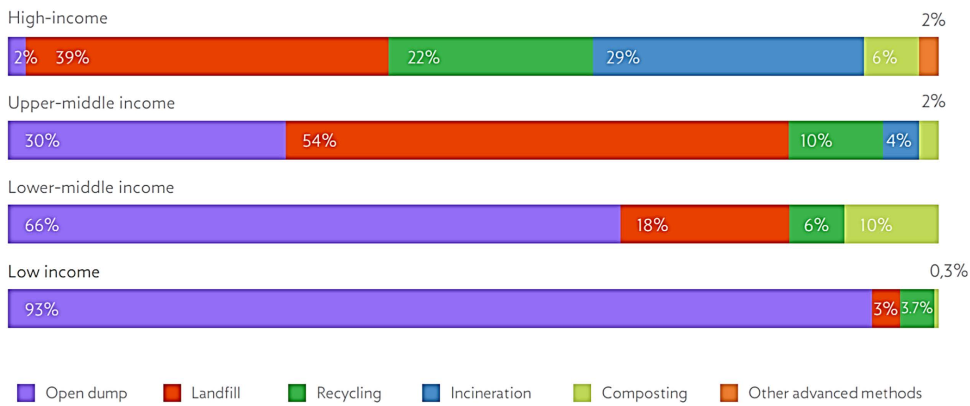


Figure 2.4.1 Worldwide variation in waste disposal methods by income (Kaza et al. 2018).

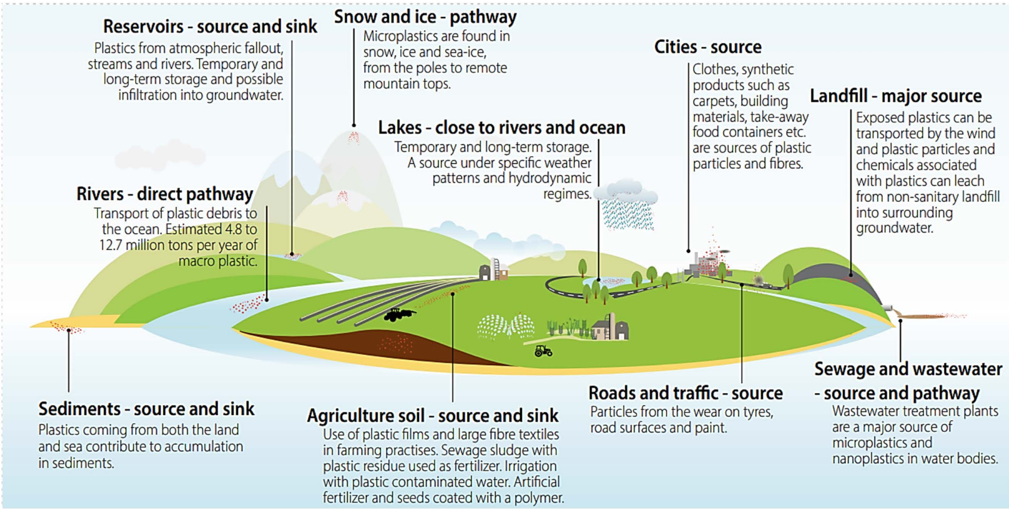
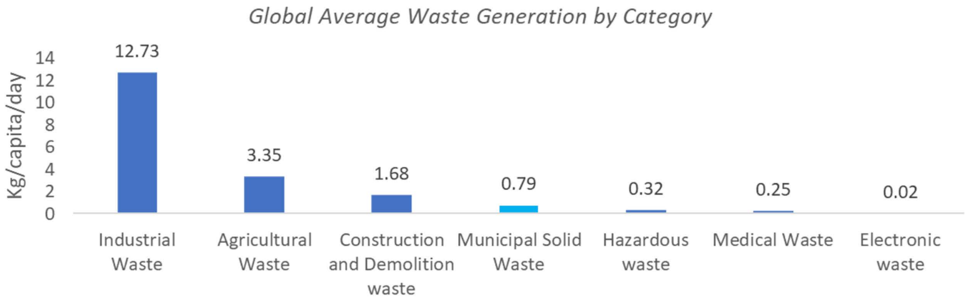


Figure 2.4.2 Major pathways of plastic waste pollution in marine environments.
Source: (United Nations Environment Programme 2021)



Note: kg = kilogram.

Figure 2.4.3 Daily per capita production of global waste.
Source: (Kaza, Shrikanth, and Chaudhary 2021; Kaza et al. 2018)

The origin and scale of global waste production

Every nation faces unique and significant challenges to manage waste locally. Wasteful production and ‘conspicuous consumption’ patterns have encouraged waste generation to increase in both intensity and diversity of sources, whilst the infrastructure, technology, and governance managing outputs and practices have remained lacklustre (Garske et al. 2020).

Dominant waste streams include industrial waste, agricultural waste, construction and demolition waste, municipal solid waste (MSW), hazardous waste, medical waste, and electronic waste (Kaza et al. 2018). Figure 2.4.3 presents a global perspective for the per capita generation of each waste stream on a daily basis.

Municipal solid waste

The solid waste generated by household, institutional, and commercial sectors is collectively known as MSW. It comprises a wide range of waste streams, with the largest share coming from food, followed by green waste, plastic, paper, cardboard, glass, and metal (Kaza et al. 2018). The management of each waste stream directly affects the resulting greenhouse gases (GHGs) that are released as a by-product of waste production. By accounting for the volume and composition of waste generated, Kaza et al. (2018) estimated that the treatment and disposal of solid waste produced 1.6 billion tonnes of carbon dioxide equivalent ($CO_{2\text{-}e}$) in 2016, which accounted for approximately 5% of global GHG emissions. Of this, it was reported that nearly half of the GHG emissions were due to food waste. In 2020, the global average generation of solid waste amounted to 0.79 kilograms per capita, per day (Kaza, Shrikanth, and Chaudhary 2021). Figure 2.4.4 shows that waste generation rates vary significantly across the globe, with the highest growth in the near term expected in East Asia and the Pacific.

Kaza, Shrikanth, and Chaudhary (2021) predict that without immediate action, global solid waste generation may increase by 73% over the next 30 years, reaching 3.88 billion tonnes annually by 2050. Although many high-income countries are approaching peak waste generation rates, projections indicate that global waste generation will continue to increase until at least the end of the century (Hoornweg, Bhada-Tata, and Kennedy 2015).

Industrial waste

Global industrialisation has spurred the rapid growth of industrial waste, with a yearly volume approximately 18 times higher than the household, institutional, and commercial sectors combined (World Bank 2018). The scale of industrial waste is a key challenge, with the volume of primary waste produced by the mining and quarrying industry alone amounting to over 100 billion tonnes of solid tailings and rock waste per year (OECD 2019c). Forecasts show that the global market for industrial waste management is likely to grow by

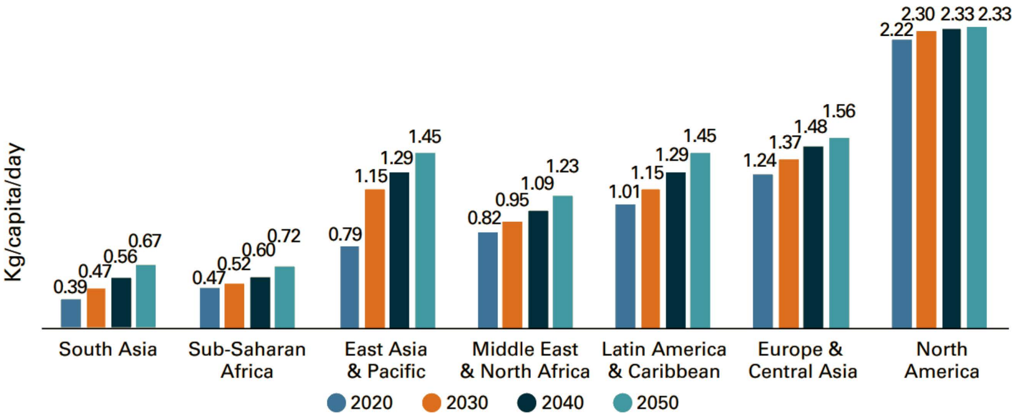


Figure 2.4.4 Global MSW generation per capita for each region.

Source: (Kaza, Shrikanth, and Chaudhary 2021)

10.4% p.a. between 2021 and 2031, when it will reach a value of US $2.3t (Transparency Market Research 2022). However, in developing countries where regulations and enforcement are lacking, industrial waste is commonly mismanaged due to the prohibitively high cost of safe disposal (Ferronato and Torretta 2019). The illegal dumping of untreated toxic and hazardous waste still occurs both on land and in waterways, where environmental pollution can spread far from the point of origin (Transparency Market Research 2022). The stockpiling of industrial waste by-products is common where manufacturing operations are highly concentrated, with stockpiles in China reaching between 60 and 70 billion tonnes in 2017 (Zhang et al. 2021). Here, the risks to environmental and human health are created from fugitive dust pollution or as hazardous elements infiltrate and erode the soil, harming vegetation and polluting underground water (Han 2019).

Agricultural waste

The agricultural sector is estimated to generate 3.35 kg per capita of waste per day through industries such as farming and forestry (Kaza et al. 2018). Agricultural production has increased more than three-fold in the last 50 years to feed an increasing global population, driving rapid changes in land use and habitat loss (Duque-Acevedo et al. 2020; WWF 2021). Obsolete waste chemicals such as fertiliser, herbicide, and pesticide have contributed to biodiversity loss and the degradation of soil quality and freshwater resources (WWF 2021). Unused crop residues and animal manure could be used as energy resources and fertiliser but often remain unutilised, resulting in ongoing methane emissions and a continued dependence on agrichemicals.

In 2011, the UN Food and Agriculture Organization (FAO) estimated that one-third of all food produced within the global supply chain was lost or wasted (WWF 2021). More recent estimates suggest that food waste within the global supply chain may be significantly higher than one-third of all food produced, conservatively estimated at 2.5 billion tonnes per year, with an average of 15.3% being wasted at the farm stage alone (WWF 2021; United Nations 2019). Figure 2.4.5 illustrates the high agricultural losses experienced by emerging nations through to the food processing stage, while highlighting the typically higher levels of food waste seen at the consumer level for developed nations.

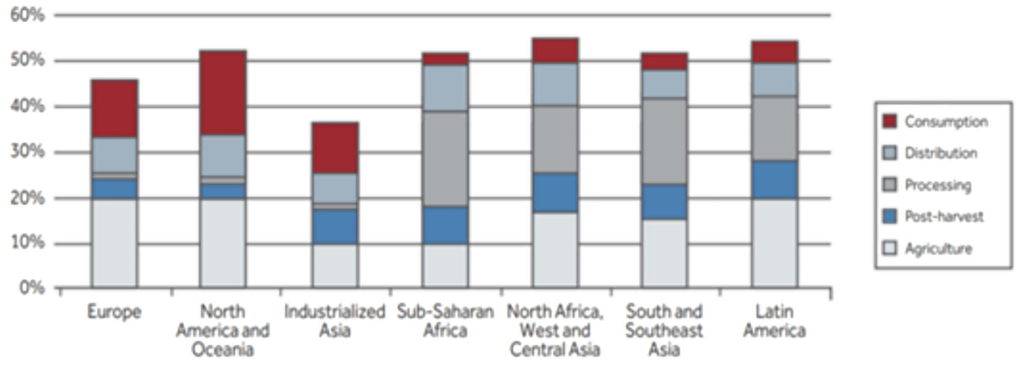


Figure 2.4.5 Food waste as a percentage of regional supply chain production.

Source: (Rezaei and Liu 2017)

Construction and demolition waste

Waste material generated by the construction and demolition (C&D) industry includes debris from construction, renovation, and demolition activities across a range of structures such as bridges, roads, and buildings (Environmental Protection Agency 2018). Rapid urbanisation has led to the global C&D industry generating more than twice as much solid waste as the household, institutional, and commercial sectors worldwide (Kaza, Shrikanth, and Chaudhary 2021). Around 35% of global C&D waste is directed to landfills, contributing significantly to resource depletion through the continued need for virgin materials (Menegaki and Damigos 2018). For example, the disposal of hazardous C&D asbestos waste continues to represent a health threat throughout the world, claiming 250,000 lives annually despite being banned in most countries (Cook, Velis, and Black 2022).

C&D reclamation rates varies greatly between countries, with Japan and South Korea achieving 97% reuse of C&D waste, while the figure for China is less than 10% (Menegaki and Damigos 2018). Similarly, some members of the European Union (EU), including the United Kingdom, Germany, Denmark, Estonia, and the Netherlands, reach between 80% and 90% reclamation, whilst others such as Spain, Portugal, Greece, and Hungary each fall below 15% (Menegaki and Damigos 2018).

In their report on C&D waste in the United States, the Environmental Protection Agency (EPA) found that 86% of asphalt shingles were dumped in landfills in 2018, representing a lost opportunity to reutilise a material that is present on approximately three-quarters of US and Canadian homes and can take up to 300 years to decompose (Assadollahi et al. 2020). The end-of-life management for C&D waste can be improved by identifying next-use markets where waste can become a resource. One example is the repurposing of materials such as concrete, brick, clay, and asphalt into an aggregate mixture used to produce concrete (Environmental Protection Agency 2018). However, C&D wastes that can potentially be recovered and used in infrastructure projects globally still experience institutional and regulatory challenges in their reuse applications.

Electronic waste

The global uptake and rapid advancement of technology have given rise to significant electronic waste (e-waste) streams, composed of discarded electrical and electronic equipment (Baldé et al. 2022). Figure 2.4.6 shows that in 2019, the global generation of e-waste grew to 53.6 Mt, translating to an average of 7.3 kg per capita (Forti et al. 2020).

E-waste production is forecast to grow by 39% by 2030, making it the fastest-growing waste stream globally (Forti et al. 2020; Olla and Toth 2009). The composition of e-waste can include up to 60 elements on the periodic table, including many precious metals (Zaman and Ahsan 2020). Considering the average global e-waste recycling rate of 17% in 2019, Baldé et al. (2022) estimated the secondary raw material potential from e-waste as being worth up to US$57 billion. According to Hewlett-Packard (2018), while e-waste may only represent 2% of landfilled waste in the United States, this amounts to approximately 70% of overall toxic waste in landfills.

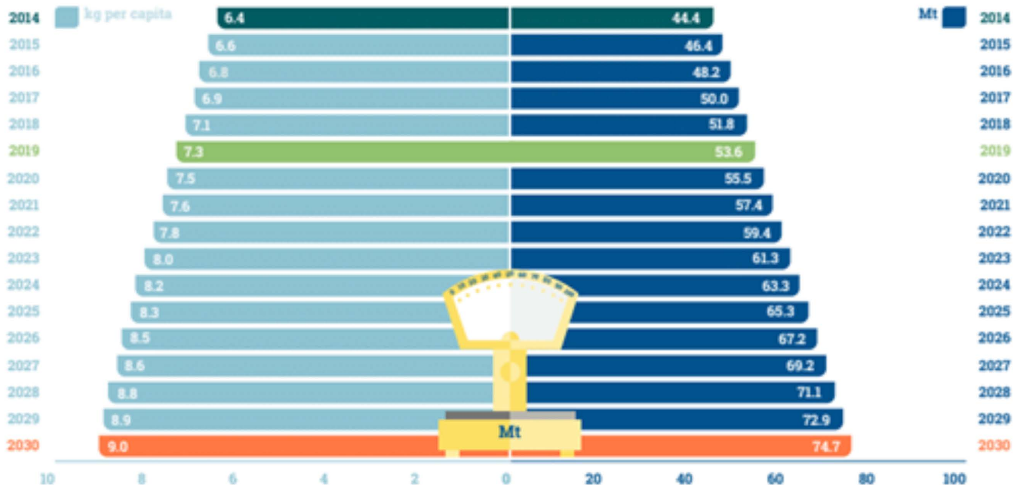


Figure 2.4.6 Global E-waste Monitor's 2020 forecast for e-waste production to 2030.

Source: (Forti et al. 2020)

Humans have been found to be exposed to e-waste through direct contact, inhaling toxic gases during open burning of e-waste, and consuming contaminated water and food (Lundgren 2012). The impacts of e-waste are also beginning to spread beyond our planetary boundaries, with space e-debris becoming a growing concern (Shittu, Williams, and Shaw 2021). Through a lack of regulation, the debris orbiting Earth is estimated to have reached up to 19,124 tonnes, with a projected recovery value of up to US$1.2 trillion (Leonard and Williams 2023). The inherent risks include collision with satellites and other spacecraft, as well as the increase in debris falling back to Earth and predominantly landing in the so-called 'Spacecraft Cemetery' in the Pacific Ocean (Leonard and Williams 2023; Shittu, Williams, and Shaw 2021).

Hazardous waste

Hazardous waste streams include those that have flammable, toxic, explosive, or corrosive properties that can cause harm to humans and the environment (Hyder 2011). The production of chemicals, coal, and petroleum are together responsible for the majority of hazardous waste generated by industry around the world each year (Rosenfeld and Feng 2011). The Basel Convention seeks to regulate the widespread global trade of toxic wastes, with 190 countries signing on to the treaty (Yang and Fulton 2017). However, Lucier and Gareau (2015) discuss that much of the governance is co-created with industry, and redefining toxic materials as 'resources' instead of 'wastes' has led to the acceleration of toxic flows to less developed countries, further manifesting the global environmental injustice of waste.

In the household, some common examples of hazardous waste products are aerosols, batteries, flammable liquids and solids, paints, and pesticides (Latimer 2021; Hyder 2011). The unregulated disposal of hazardous waste into household sinks, stormwater drains, and landfills inevitably results in contamination that is harmful to humans and the environment (Rosenfeld and Feng 2011).

Plastic waste

Whilst the large-scale production and use of plastics only began in the early 1950s (Ostle et al. 2019; Plastics Europe 2021), global plastic production has since grown to a reported 390 million tonnes in 2021 alone (Statista 2022), where China (32%) and North America (18%) collectively produced half of the world's plastic production (Statista 2022). Production levels were exacerbated by the global COVID-19 pandemic through the production of single-use medical waste, as the health care industry had an increased need for plastic-based rapid antigen tests and personal protective equipment (United Nations Environment Programme 2021). Over 99% of this plastic is made from fossil hydrocarbons, which are non-renewable resources and are rapidly depleting given their increasing demand by other economic sectors (de Wit et al. 2019).

Globally, approximately 7 billion tonnes of plastic waste have been produced to date, with the world's thirst for convenience leading to almost 1 million single-use plastic bottles becoming waste every minute of the day (Euromonitor International 2019). Figure 2.4.7 pictorially presents one month of global polyethylene terephthalate (PET) bottle waste against the size of the Eiffel Tower.

Estimates based on 2019 data suggested that 49% of plastic waste was directed toward landfill, 9% to recycling, and 19% toward incineration, with the remaining 22% mismanaged by the end user (OECD 2022). The throw-away attitude that our society has developed needs to be reversed. In a world where 99% of new plastic is made from fossil hydrocarbons, decreasing virgin fossil-based plastic production should be made a sustainability priority (de Wit et al. 2019).

The annual ReSource plastic report (World Wildlife Fund 2021) predicts that by employing impactful reduction and substitution strategies within their supply chain, as few as 100 global companies could reduce plastic waste by up to 10 million tonnes each year. Bioplastics made from plant-based materials are a viable substitute, as these can have a smaller carbon footprint and biodegrade within months without releasing toxic residues into the environment (Kwon 2023). Limitations to the physical properties and cost-effectiveness of production need to be improved to increase the estimated 1% share of bioplastics within the global market.

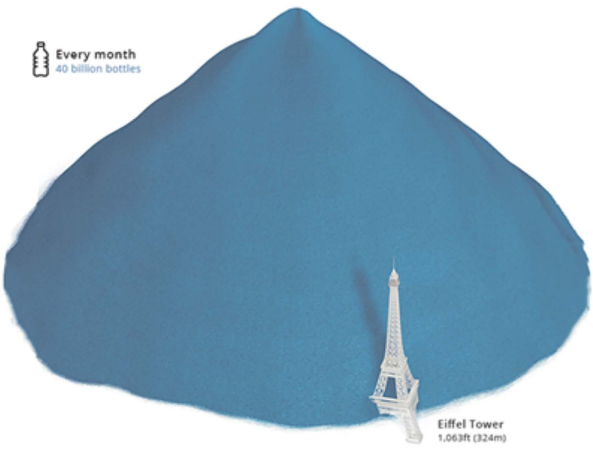


Figure 2.4.7 Global waste accumulation of 40 billion plastic bottles every month from (Visual Capitalist 2019), original source: (Reuters Graphics 2019).

The source of our sustainability values

Sustainability values are a critical link in understanding the challenges of sustainability management. In the 21st century how do we frame the discourse for growth without the now-critical reference to ecosystem health and intergenerational equity? Many cultures across the world have a normative understanding of the importance of the environment and its critical role in maintaining human health and wellbeing.

Values are idealised attributes that are rooted deeply in our culture, ideologies, and belief systems (Civil Society Reflection Group on Global Development 2011). By subscribing to certain values, we create sincere aims and commitments that drive us to improve our current way of life (Neog 2019). Progress is accelerated when values are collectively realised, and education provides the necessary medium to develop widespread understanding. Principles are a guide to practice. They help to connect values thinking with behaviours that correspond to desired outcomes.

Sterling (2012) suggested the possibility of discussing ethics and different philosophical stances to provide students with an opportunity for reflective inquiry into areas such as animal rights, the place of humans and animals within ecosystems, the intrinsic worth of nature, the importance of future generations, and social and environmental justice.

Sterling noted that higher education institutions tend to "skirt around the issues of values, preferring the language of quality assurance and skills to that of ethics and purpose" and "society needs new values, to counter excessive consumerism, individualism, inequity and materialism and help a more peaceable, equitable and sustainable culture to emerge".

Sterling (2012) presented a number of key sustainability values, noting that exploration of these values involves relating them to real-world situations and to personal interests and values:

–sufficiency (living lightly)
–equity and justice (intragenerational and intergenerational)
–social inclusion and meeting basic human needs
–participation and empowerment
–eco-efficiency (in resource use)
–biodiversity and green space
–human rights and needs
–ethical investment and fair trade
–sustainable consumerism
–animal and biocentric rights and needs
–democracy and participation
–resource conservation and efficiency
–community and mutuality
–meeting needs locally
–resilience and durability
–system health and wellbeing
–futurity (taking the future into account today)

Within this context, we now briefly review the contribution of some of the main world religions to sustainability and waste-related values, noting that 80% of the world's population identifies with a religious group (Pew Research Center 2017). Faith communities are very active in waste reduction, as shown by a recent global review (Zamri et al. 2020), and theologians are deeply engaged with its ecological implications (Öhlmann and Swart 2022; Yoreh and Scharper 2020). A helpful overview of key documents from many religious and faith traditions can be found in the UN Faith for Earth Initiative (2021). A valuable practical resource for religious communities on climate change and waste reduction has been developed by the Australian Religious Response to Climate Change (2023). Five world religions are provided with tailored action kits of around 30 pages which are particularly focused on the Australian context, but much of the content can be translated to other contexts.

Approaches to environmental and waste values of the three Abrahamic religions (Judaism, Christianity, and Islam) as well as Buddhism, Hinduism, and atheism will now briefly be summarised.

Judaism: The Jewish tradition emphasises the importance of the Earth and the environment. Jews are called to protect and preserve the environment, as well as to practice sustainable living. The concepts of *tikkun olam,* or repairing the world, and *bal tashḥit,* the prohibition against wastefulness and destruction, are important in Jewish environmentalism and encourage environmental stewardship (Neril 2012; Yoreh 2014). Hundreds of rabbis released a Rabbinic Letter on the Climate Crisis (Rabbi Arthur Waskow et al. 2015) approaching COP26.

Christianity: The Christian tradition encourages good stewardship of the environment and its resources. The idea is that God has given us the responsibility to care for the Earth and to be good stewards of His creation. Therefore, Christians are called to reduce waste, recycle, and promote sustainable living. Of the many traditions within Christianity, one of the most significant contributions on waste values is the encyclical letter by Pope Francis (2015): Encyclical Letter *Laudato Si'* of the Holy Father Francis: On Care for Our Common Home. While the letter is primarily addressed to all people living on this planet, including non-Catholics, it is also specifically directed to the world's 1.3 billion Roman Catholics and highlights the urgent need for global action on climate change and environmental degradation, calling for an integral ecology that recognises the interconnectedness of all creation and advocates for sustainable development and social justice.

The World Council of Churches (WCC) brings together churches, denominations, and church fellowships in more than 120 countries and territories throughout the world, representing over 580 million Christians. The WCC (2022) has extensive resources and statements on environment and waste. Within the Protestant tradition there is an extensive Christian literature in this area which cannot be reviewed here, but good references include living environmentally responsibly (Valerio 2019) and living to reduce waste (Bookless 2012). Organisations with an evangelical origin include A Rocha (n.d.), which is a global network of Christian conservation organisations based in the UK, and the US-based Evangelical Environmental Network (nd) that educates and mobilises Christians in their effort to care for God's creation.

Islam: The Islamic tradition emphasises the importance of cleanliness and purity. Muslims are called to avoid wastefulness and to conserve resources. The concept of *mizan*, or balance, is also emphasised, encouraging Muslims to live in harmony with the environment. Two further relevant Islamic concepts of *khalifa* and *tawhid*, highlight the role of humans as stewards of creation and the unity of all creation, respectively. A helpful discussion of Islamic environmental ethics where the six principles are associated with environmental actions Muslims can take can be found in Iner (2013). Suggested actions include minimising waste, conserving water, and respecting all creatures. There are many grassroots Islamic waste reduction groups, including the Green Muslims (2023) and others (Zamri et al. 2020). On the global stage in the lead-up to the COP26 in Glasgow, the national Muslim organisations in the United Kingdom and Ireland released a joint statement on climate change and waste (COP26 Statement 2021). The global Islamic Relief agency has been very active in promoting waste reduction as part of its relief activity (Islamic Relief 2023).

Buddhism: The Buddhist tradition emphasises the concept of interdependence and the importance of reducing suffering. Therefore, Buddhists encourage reducing waste and consumption to minimise the negative impact on the environment. The concept of mindfulness (emphasis on awareness, attention, and responsibility) also plays a significant role in waste reduction and is connected to the wider movement of 'engaged Buddhism'. Two important Buddhist statements, both endorsed by the Dalai Lama, come from One Earth Sangha (2022), which is a global community that aims to integrate ecological awareness and spiritual practice in order to foster a sustainable, compassionate, and just society, and Buddhist Climate Change Statement to World Leaders (2015). A more critical approach has been taken by Brox et al. (2022) in their analysis of Buddhism and waste, exploring ways waste can be reduced in religious practice.

Hinduism: In Hinduism, the concept of *ahimsa* (non-violence, also relevant in Buddhism) leads to the idea of the interconnectedness of all things. This leads to an emphasis on minimising waste and living in harmony with nature, as waste and pollution are seen as harmful to the environment and all living beings. Furthermore, the concept of karma emphasises the importance of taking responsibility for actions and their consequences. Therefore, waste reduction and sustainable living are encouraged to avoid negative karma. While Hindus take the Vedas as a sacred text with authority, unlike some other world religions, Hinduism generally does not have a central authority or bureaucratic structure and therefore does not have centralised documents such as *Laudato Si'*. However, it is interesting to note that India, the origin of Hinduism, has the largest environmental movement in the world (Findly, Chapple, and Tucker 2002). There are many examples of spiritual ecology and activism arising among today's Hindu communities (Dwivedi 2009), including the developing (e.g. in Bhutan see Allison (2019)) and the developed world (e.g. Bhumi Global (2023), whose mission is to engage, educate, and empower people, and communities to address the triple crisis of climate change, biodiversity loss, and pollution). (See also Shaji et al. Chapter 9.5 in this volume.)

Atheism: Atheism does not have a specific set of religious beliefs or practices. However, many atheists are concerned about the environment and advocate for sustainable living and waste reduction. The focus is often on the scientific evidence for the negative impact of waste on the environment and the need for action to protect the Earth.

These historical values are strongly underpinned by a sustainability ethic and play a formative role in their cultural representation of sustainability and waste management challenges. Though they start from very different positions, the religious traditions discussed earlier all provide an ethical basis for responsible action on the environment and waste. The opportunities for world religions to influence and motivate their followers and others in the interrelated areas of environment, waste, and climate change are evolving rapidly. They are likely to play an increasing role towards making our planet more sustainable into the future.

Waste management values and principles

Important waste-related values, principles, and practices can be attributed to range of factors, including but not limited to cultural, religious/societal norms, economic considerations, technological developments, political/legal frameworks, and environmental awareness. The relative influence of each of these factors varies depending on the local context. It is important to consider a range of factors when analysing waste-related values and practices and to recognise that there may be significant individual and community-level variations. We also acknowledge the role and value of a secular approach to ethics and values, drawing from religious teachings but transforming them into universal sustainability principles. This way, values emerge naturally and rationally from our shared humanity, equally acceptable to those with faith and those without (Lama. 2012).

The pathway to tackling the global waste problem is underpinned by the need for educators to effectively communicate the values and principles that can drive meaningful change to current waste management practices. Approaching waste management from a first-principles approach can strengthen the cohesiveness of global efforts to improve sustainability performance across all disciplines (Neog 2019). The following values in Table 2.4.2 are fundamental to sustainability within the waste context.

Table 2.4.2 Waste management values

Value	**Goal**
Minimise waste generation	Avoid unnecessary consumption and ensure that less waste is being produced.
Protect the environment from waste pollution	Ensure that waste products do not enter and deteriorate our ecosystems.
Promote waste stewardship and self-regulation	Recognise that we have a set of common but differentiated responsibilities in the war on waste. Lead by example – we are raising the next generation to be more acclimatised to waste than we are.
Circular economy thinking	Eradicate the linear consumption and disposal model by using materials in continuous cycles.

Sustainable waste management education and practices need to consider a number of important waste management principles in the framing of sustainable waste management practices. These waste principles adapted from (Gertsakis and Lewis 2003; Zhang et al. 2022; Gharfalkar et al. 2015; Yan and Feng 2014; Sihvonen and Ritola 2015; Potting et al. 2017; ZWIA 2022) are presented in Table 2.4.3 and discussed next.

Table 2.4.3 The 5 Rs of waste management

Principle	*Outcomes*
Rethink	Most desirable
Reduce	
Reuse	
Recycle	
Recover	Least desirable

1. Rethink

Rethinking is the preferred route in the waste hierarchy, as this encourages us to consider how to break away from unnecessary material consumption (ZWIA 2022). It means that we need to be more cautious of our consumption habits to reduce the impact on the environment. For example, putting recyclables in the bin is not enough; we should rethink about what we can do to avoid the root causes of waste creation as part of a sustainability mindset. For this particular example, we need to bring our own shopping bag to the store instead of use a single-use plastic bag provided by the store. People can also look for recycled content in products that they are purchasing or building.

Many negative environmental impacts (like waste) from our industrial production can only be influenced by a limited number of people with the capacity to redesign/reconsider the production and therefore waste model. However, every person consuming products and services has a part to play in waste management.

(Re)design for the environment

For engineers working in product design, rethinking means that they should consider the environmental impact in their engineering design. Waste has traditionally been inherent in the design of products. To combat the growing waste problem, engineers need to address waste at the design stage with precautionary resource management and innovation. Living within the regenerative capacity of the planet involves minimising the use of non-renewable resources and preventing the degradation of renewable resources (Meadows, Randers, and Meadows 2004). Design for the environment (DfE) emphasises the reduction of environmental and health impacts by modifying the physical design of a product, such as the improvement of materials (Olla and Toth 2009). This can be achieved through promoting the use of recycled or environmentally friendly materials. Examples of this include products from Apeel and Ecovative. Apeel designed a plastic-free alternative to seal fresh products for longer using an edible, plant-based coating that mimics the natural defence from plants' cuticle layer (EMF 2022b). Ecovative created an alternative to polystyrene packaging using agricultural by-products which renders the product compostable at the end of life (EoL) (EMF 2022a).

DfE also means 'design for disassembly', as most of R strategies (i.e., reuse, recover, repair, remanufacturing) can be implemented if the EoL product can be disassembled. For example, a compressor has been designed in a way that it can be completely disassembled. More than 90% of the EoL parts can be recovered, reused, and repaired to make a remanufactured compressor, which provides the same durability as a new compressor with a carbon footprint reduction of more than 90% (Biswas and Rosano 2011). Apart from saving CO_2 emissions and preventing EoL items going to landfills, a significant amount of virgin materials can be conserved for the future generation. Plus, this remanufactured compressor is one-third of the cost of a new compressor (Biswas and Rosano 2011).

Eco-design is an approach that promotes 'quality over quantity' and seeks to ensure the continued use of a materials through mechanisms such as repair or recovery at the EoL (OECD 2019b). Designers and manufacturers bear the responsibility of ensuring efficient materials utilisation; the reduction/elimination of hazardous materials; improved recyclability; minimised material diversity; remanufacturing; and reverse logistics design for disassembly, repair, and remanufacture (OECD 2019b, 2021).

Waste generation is not isolated to the end of the life cycle. Life cycle thinking (LCT) requires an understanding of the entire life cycle of a product or service to enhance sustainability decision making (Biswas and John 2022). Traditionally, the life cycle considered is limited to the useful life of a product, neglecting EoL considerations, which adds to our current waste dilemma. LCT is commonly used in industry through the life cycle assessment (LCA) to facilitate a product or service's environmental evaluation (Gheewala and Silalertruksa 2021; Biswas and John 2022). It is important to account for the whole life cycle when making decisions, as singling out the optimisation of individual components can lead to suboptimal solutions (Gheewala and Silalertruksa 2021; Biswas and John 2022).

Extended Producer Responsibility - positive waste stewardship

A global citizen acknowledges that through ecosystem interconnectedness, linkages exist between all components of the ecosystem and for every action there is a reaction (Pae 2003). Recent action by China and other countries has restricted international waste imports, presenting the need for stronger domestic waste management infrastructure and an enhanced market for recycled materials (OECD 2019a).

Extended producer responsibility (EPR) is viewed as a rational expansion of the 'polluter pays' principle, arguing that potential impact on the environment and society can be determined in the design phase (Olla and Toth 2009). The principle proposes that those responsible for producing waste should bear the financial responsibility at the EoL (WWF 2022). The Zero Landfill scheme from Fuji Xerox provides an example of product stewardship to address the generation of waste by designing products suitable for disassembly, remanufacturing, recovery, and reuse after the EoL.

2. Reduce

Waste hierarchies produced by organisations such as the Zero Waste International Alliance (ZWIA) aim to reduce the amount of materials that become waste (ZWIA 2022). This 'Reduce' not only implies the reduction of materials and energy but also reduction of the use of harmful, wasteful, and non-recyclable products. For example, by printing a document double-sided, it will cut waste output in half. This R strategy in fact gave birth to the concept of 'dematerialisation'. It is defined as the reduction of the quantities of materials needed to serve an economic function, or the decline over time in the mass of materials used in industrial end products (Pacheco-Torgal et al. 2017). Online shopping, video conferencing, and reading online are a few real-world examples that avoid the use of material resources as well as the wastes generated due to use of material resources to serve the economic functions.

Reduce the impact of waste pollution on the environment (pollution prevention)

The two most common ways that waste can be minimised are through the reduction of sources and by recycling. Source reduction reduces or eliminates the generation at the source where the waste is generated. Some examples of source reduction are the purchase of more durable products and replacement of certain materials to reduce toxicity and improve operating practices. For example, the substitution of 40% cement with fly ash in concrete has been found to increase the service life by 1.6–1.75 times more than the conventional concrete (Nath, Sarker, and Biswas 2018). The use of fly ash as a partial replacement for cement delays quarrying and can help minimise waste generation, cost, land use changes, toxicity, waste generation rate, deforestation, fuels, GHG emissions, embodied energy, and the loss of biodiversity.

The example of recycling can be the use of C&D wastes in the road base. The diversion of this waste from the landfill to the infrastructure project not only reduces waste generation and land use changes at the landfill site but also reduces land use and waste generation at the limestone quarry site, as these non-renewable materials are replaced by the C&D wastes.

Maximise resource efficiency

Resource efficiency refers to the utilisation of Earth's finite resources in a way that minimises environmental impact, essentially "doing more with less" (EC 2022; OECD 2019b). The key is reduction: less raw material and energy usage translates into financial savings, lower emissions, and less waste. Resource productivity is a term that refers to how effectively a production process utilises its natural resources (OECD 2019b), and this is used to create a quantitative measure for the value added. Waste can be minimised by using natural resources more efficiently and effectively, supported through resource efficiency incentives that can lead to higher material productivity (OECD 2019a). Resource efficiency is linked to eco-efficiency, which is often represented in the terms of Factor X. Here, 'X' is the technological factor. For example, Factor 4 means doubling the production or outputs, while halving the resources or inputs (i.e., 2/0.5 = 4). It means that recycling carpets consumes less energy than manufacturing new carpets but offers the same services. Also, a new carpet made from recycled carpet materials require less virgin material by a factor of 4 as the same material used to make two carpets. Also, the waste carpet materials diverted from landfill saves land use for landfills by a factor of 4.

'Delinking' is another indicator of resource efficiency, where the economic growth increases with the decrease of wastes and other environmental impacts. Alternatively, growth of welfare is delinked from the use of nature and the generation of waste. For example, in Sweden, the economic growth was delinked from the generation of GHGs. There was an increase of gross domestic product (GDP) by 58% but a decrease of GHG emissions by 23% during 1990–2013 (Biswas and John 2022).

3. Reuse

Industrial symbiosis involves an interconnected network of continuous energy and material exchanges, where the wastes and by-products from one industry's production process become the raw material inputs for another industry's process, eliminating waste (see Korevaar Chapter 3.8 in this volume). Companies from different industrial sectors encourage resource efficiency through sharing and reusing resources including materials, by-products, energy, water, and infrastructure, leading to improved accountability. There are many successful examples of industrial by-product and waste reuse programs including:

Kwinana Regional synergies: https://kic.org.au/industry/synergies/).
NISP UK: https://www.nispnetwork.com/
See Chapter 4.2 in this volume: Biswas and John
Kalundborg Symbiosis: https://www.symbiosis.dk/en/

Kwinana Industrial Area (KIA) is referred to as one of the world's most popular examples of industrial symbiosis. Knowing what product and by-product exchanges are possible within an industrial area or a cluster of industries helps the locational decision process for a prospective new entrant/industry/participant (Kwinana Industrial Council 2023). Each new entrant that participates in the exchanges increases the overall strength of the cluster itself. For example, the cement industry is one of the entrants, as the lime kiln dust that it produces is utilised in the residue area of the neighbouring refinery for soil amendment purposes, where the exchange is known as a by-product synergy (Biswas and John 2022). There also exists utility synergies as the heat that is recovered from the exhaust gas in the oil refinery in Kwinana is used in the neighbouring co-generation plant for electricity generation.

Refurbish/repair

All the 'R' strategy options including reuse, reduce, recycling, recovery, remanufacturing and refurbish/repair need to be incorporated into the design process of a product to prevent the end of life (EoL) product going to landfill.

Refurbish/repair is considered the most sustainable 'R strategy' option for the management of EoL products as it helps to significantly reduce waste generation, minimises the uptake of natural resources, and offers economic benefits through waste and material purchase reduction.

Refurbish/repair can potentially totally reduce waste production from a product. For the same durability, refurbished/repaired products (e.g: product has had minor changes made to reinstate it as a 'new product) have been found not only to be cheaper than remanufactured products (eg: EoL product needing to be completely disassembled for remanufacturing into an as 'new' product) and recycled products (e.g: product has new replacement parts only), but very importantly also enhance intergenerational environmental and social equity by conserving scarce materials and non-renewable resources. Biswas et al. 2013).

Repurpose

Repurposing is different from remanufacturing in that the former is converted to another product, while the latter is turned into the same product. In some instances, where EoL products cannot be remanufactured, reused, or repaired, they are repurposed to make different products or components of another product. For example, the wood from around the house can be reclaimed and turned into many things such as fuels and furniture.

Depending on the type of materials, EoL waste can be either 'upcycled' or 'downcycled'. The conversion of post-consumer plastic to toys is a type of downscaling activity, while their conversion to useful products (e.g., gears, impellers) is known as upcycling. Repurposing waste can be a cost-effective opportunity to transfer or add value to resources that would otherwise remain unproductive sitting in landfills or polluting the environment (Cheung and Pachisia 2015; Saber et al. 2022).

4. Recycle

Recycling is the process of converting waste materials into new materials and objects. It is an alternative to 'conventional' waste disposal that can save material resource depletion and help lower GHG emissions by avoiding upstream processes such as mining, processing and manufacturing. For example, the steps taken to recycle plastic include waste collection and delivery to a material recovery facility (MRF), sorting, bundling, shredding, washing, melting, and reorganisation (Goodship 2007). Plastic pellets and aluminium sheets require between 93% and 95% less energy when made from recycled material compared with virgin raw materials (Morris 2005). Here, the recyclability of the material depends on its ability to regain the properties it possessed in its original state (Villalba et al. 2002). In some cases, such as recycled aggregates from C&D waste, issues like high porosity and excessive water absorption may limit the application of the recycled material (Mistri et al. 2021).

Recycling however is no silver bullet for waste management, as it is also limited to those resources which can be cost-effectively collected and processed into useful materials and products (ISO 2016). The capital and energy intensity of recycling becomes more significant if the EoL product is complex and made of composite materials. The market value for recycled materials ranges from close to parity with the raw material down to a negative value when the costs of landfill or incineration are accounted for (Runnel et al. 2017). Table 2.4.4 describes materials that are commonly recycled into products to save energy and reduce emissions.

In high-income countries, these common recyclables make up around half of all MSW, while in low-income countries, the solid waste composition is approximately 16% recyclable (Kaza et al. 2018). However, this does not account for organic wastes. Composting is nature's way of recycling organic materials that are rich in carbon and nitrogen through an aerobic decomposition process that creates a nutrient-rich mulch/compost alternative to fertiliser (EPA 2022). Every effort should be made to recover and recycle all materials that will not retain their product properties or create more significant environmental impacts (Runnel et al. 2017).

5. Recover (waste as a resource)

The value and definition of a products waste changes based on the availability and abundance of the resources involved in their production (Madurwar, Ralegaonkar, and Mandavgane 2013; Reno 2009). As global reserves of scarce minerals become depleted, waste recovery presents the opportunity to extract valuable resources contained within waste stockpiles such as landfills (Hogland, Marques, and Nimmermark 2004). The finite nature of many landfilled materials has incentivised the up-and-coming practice of urban mining to recover wasted resources (Eisenstein 2022). E-waste is one such example, where the valuable elements (e.g. copper, gold, silver, palladium, cobalt) present in e-waste can be physically or chemically separated from materials that are toxic or have low recovery value (Xavier et al. 2021; Eisenstein 2022). Similarly, the recovery of critical metals and minerals from mining and metallurgical waste tailings is an opportunity to recover value from one of the largest global waste streams (Bellenfant et al. 2013). (See Chapter 2.7 in this volume)

Recovery can happen with and without treatment or pre-processing. For example, waste engine oils cannot be refined for use in cars, but they can be directly burnt to produce energy in other applications to avoid dependence on coal and imported oil. On the other hand, maximum recoveries of 91.45%, 93.64%, and 87.92% for Co, Li, and Mn, respectively, were achieved from the cathode active materials of spent lithium-ion batteries via the electrokinetics process (Huang, Liu, and Zhang 2019). The recovery of critical materials not only reduces the volume of toxic and hazardous wastes but also significantly assists in

Table 2.4.4 Relative impacts of common recycling practices

Recycling Facts and Figures			
When this material is recycled	*It can be turned into*	*Energy saving from recycling*	*Greenhouse gas emission reductions from recycling*
Aluminum	New aluminum cans, pie pans, house siding, small appliances, lawn furniture – in fact, almost everything aluminum	Recycling one aluminum beverage can could save enough energy to run a 100-watt bulb for 20 hours, a computer for 3 hours, or a TV for 2 hours.	Recycling 10 tonnes of aluminum saves as much greenhouse gas emissions as preserving more than 1.1 acres of forest from deforestation.
Glass	Glass jars and bottles, fiberglass insulation, tiles, countertops, glass pavers, sand for ashtrays and sand, traps, pavement (pulverised glass)	The energy saved from recycling one glass bottle will operate a 100-watt light bulb for 4 hours.	Recycling 10 tonnes of glass saves as much greenhouse gas emissions as preventing the use of more than 8 barrels of crude oil.
Paper	Newspaper, tissue products, paper towels, notebook paper, envelopes, copy paper and other paper products, insulation, hydro-mulch, moulded packaging, gypsum wallboard, and kitty litter	By recycling 1 tonne of paper, we save enough energy to heat an average home for 6 months.	The greenhouse gas emission reductions from recycling 10 tonnes of mixed paper are comparable to preventing the use of 94 barrels of crude oil.
Plastic	Fibrefill (for ski jackets, cushions, sleeping bags. etc), plastic containers and bottles, recycling bins, fleece, carpet, car parts, tennis ball felt, pallets, benches, fences, building materials, twine, and thermoformed parts	The energy saved by recycling one plastic bottle will power a computer for 25 minutes.	Recycling 10 tonnes of PET plastic saves as much greenhouse gas emissions as removing more than three cars from the road for 1 year.
Steel	Steel cans, building materials, tools – in fact, almost everything steel	By recycling steel, the steel industry saves enough energy in 1 year to electrically power 18 million homes for 1 year.	Recycling 10 tonnes of steel saves as much greenhouse gas emissions as growing 470 tree seedlings for 10 years.

Source: (EPA 2007)

the conservation of scarce non-renewable resources required for running the green economy (e.g. batteries for solar panels and electric cars).

Waste-to-energy (WtE) or energy-from-waste (EfW) processes such as combustion, gasification, and pyrolysis utilise the thermo-chemical conversion of solid waste to produce fuels, heat, and energy (Ram, Kumar, and Rani 2021). Incineration with energy recovery is widely used across the EU and serves a growing market in China, Japan, and the Southeast Asian region (Tun et al. 2020; Tait et al. 2020). The process involves recovering the electrical energy and heat produced as a by-product from the combustion of primarily non-recyclable waste materials (Donahue 2018). Improvements to emission reduction technology coupled with stricter regulations can ensure that this practice does not simply substitute solid waste pollution for harmful airborne emissions. The biochemical conversion techniques of fermentation and anaerobic digestion are considered to be an eco-friendly approach for future energy generation, as these can produce biohydrogen and biogas, respectively, from organic wastes (Ram, Kumar, and Rani 2021).

Conclusion

Waste is an increasing challenge in the 21st century. Waste management responsibility falls on all of society including corporations, governments, individuals, and educators. Greater accountability must be taken for the production, treatment, and disposal of waste. Inculcating sustainability and waste values is essential in sustainability education as a much-needed catalyst for behaviour change and the development of circular economy and zero-waste thinking and innovation for a cleaner and more resource-efficient future.

Increasing the understanding and acceptance of important waste management values and principles is essential in the development of the knowledge, attitude, and behaviours required to promote both circular economy thinking and sustainable development.

These sustainability values should also promote lifelong learning and behaviour change in our move towards a zero-waste society and one that is focused on regenerative sustainable development (see Chapter 7.6 in this volume) and encourages more life cycle thinking (see Chapter 4.2 in this volume) and stewardship in the design of our modern lives (see Chapters 3.2 and 3.7 in this volume).

Sustainability education that is not founded on the virtues of sustainability and waste management values is a waste(d) opportunity in sustainability education, to effectively establish critical norms that help to reduce both waste production and the environmental impacts from waste production and improve resource efficiency in our production and consumption decision making. Resource efficiency that future generations will need to count on.

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2.5
SUSTAINABILITY CHALLENGES IN AGRICULTURE AND FOOD PRODUCTION

Ross Kingwell

Key concepts for sustainability education

- Sustainability challenges are impacting agriculture and food production, both in terms of production sufficiency, production impacts from climate change and agricultural greenhouse gas emissions.
- The global demand for food is increasing due to population and per capita income growth.
- Food security is resurfacing as an important social and political issue.
- Sustainable agricultural production must address the need to satisfy the social and political challenge of ensuring adequate, affordable supplies to local consumers whilst safeguarding national sovereignty and political stability.
- The social licence to operate is challenging agriculture and food production, especially in wealthier nations on issues including low-emission agriculture, agricultural chemical use, animal welfare, food safety and agricultural labour wages.

Introduction

The global population is set to increase to 9 billion by 2050 (United Nations 2011), which implies global food production must also increase (Godfray *et al.* 2010), despite most of the available arable land already being used for agriculture or other land uses such as natural ecosystems (Tilman *et al.* 2001). Moreover, not only is the world becoming more populous but on average people are growing richer, and the richer people become, the more calories, nutrient rich and diverse their diets often become, which serves to fuel further demand for a wide range of agricultural products. Hence, as populations and per capita incomes increase, additional agricultural production is required, drawing on finite resources of land, water and air.

Yet the required increase in agricultural production in coming decades needs to occur against the backdrop and challenge of a changing climate. In many agricultural regions across the globe, adverse rather than beneficial climate change is underway. Various climate models are projecting that these unfavourable changes in climate will continue and

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worsen (IPCC 2023). For example, Pokhrel *et al.* (2021) outline that the proportion of the globe's land area exposed to drought is likely to increase steadily until the mid-21st century, with millions more people increasingly being exposed to drought. Of particular concern, Pokhrel *et al.* (2021) point out that extreme droughts are expected to become more frequent in many main agricultural regions.

World agriculture's sustainable production challenge

The effects of adverse climate change will cause some current agricultural land eventually to be lost to desertification and salinization (IPCC 2007). The yields of some plants will be reduced, and the severity and array of plant and animal pests and diseases will alter and complicate agricultural production. Many of the main regions of agricultural production are acknowledged to be likely adversely affected by projected climate change. For example, the Food and Agriculture Organization (2016) state that if the current trajectory of greenhouse gas (GHG) emissions continues, then by the year 2100 there will be a likely decline in the production of major cereal crops (20–45% in maize yields, 5–50% in wheat and 20–30% in rice). Hence in the near future, crop losses and yield reductions may be more commonplace, contributing to reduced food availability and higher food prices. Food shortages could become more pressing geopolitical issues in regions or countries with low per capita incomes and rapidly increasing populations.

Amid these serious difficulties imposed by a changing climate, agricultural production, and ideally the productivity of agricultural land, must be further increased (Godfray *et al.* 2010) to meet the increased demand for food that will arise from population increases and per capita increases in income. Increased agricultural production can occur via allocating more land to agriculture, but that is likely to mean loss of areas of natural vegetation, deforestation and conversion of grazing land, with the risk of species loss, reduced biodiversity and irreversible changes in landscapes.

Increased agricultural production also can occur via intensification. Yet enhanced land productivity generated by intensification can have undesirable on- and off-site environmental impacts, so honouring society's need for affordable, nutritious food, produced safely and sustainably, will be an increasing challenge (Rausser *et al.* 2019).

As economies grow and gross domestic product (GDP) per capita increases, a lesser proportion of household expenditure goes towards food purchases (Figure 2.5.1), creating greater employment opportunities in sectors other than food and agriculture. Although it may seem from Figure 2.5.1 that the economic importance of agriculture and food diminishes as nations' per capita wealth increases, in fact, expenditure on food increases (Figure 2,5.2). As per capita wealth increases, more is spent on food. Often more calories are consumed; more dairy products, fruit and vegetables are consumed; and where culture and religion permit, meat production (e.g., pork, chicken, beef) and their production often increasingly become based on feed grains.

Much of the increase in population towards 2030 increasingly and in subsequent decades will occur in Africa and the Middle East (Figure 2.5.3). However, most of the increase in wealth towards 2030 will occur in already populous Asia (Table 2.5.1), especially in China, India and Indonesia. These three countries are the source of 45% of the world's projected middle-class income in 2030. This regional growth in middle-class income will affect trade flows of agricultural products, especially feed grains.

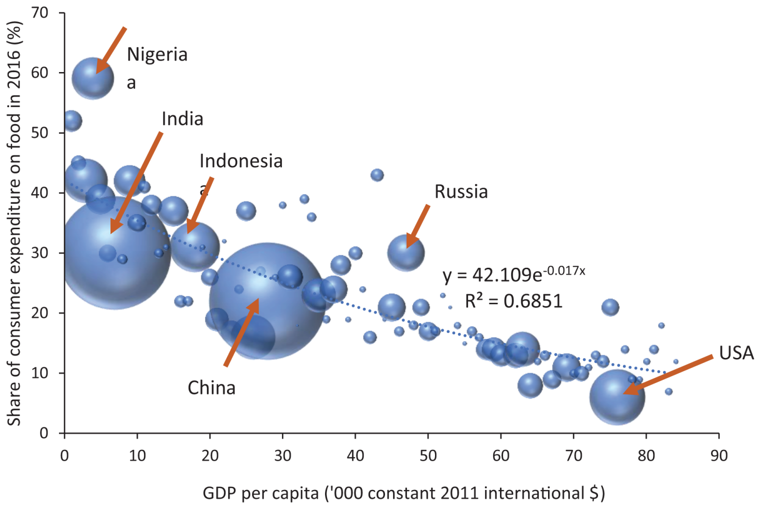

Figure 2.5.1 Share of consumer expenditure on food versus GDP per capita in various countries

Note: The size of each bubble is that country's population.

Source: Derived from World Bank data publicly available at: https://databank.worldbank.org/source/icp-2017

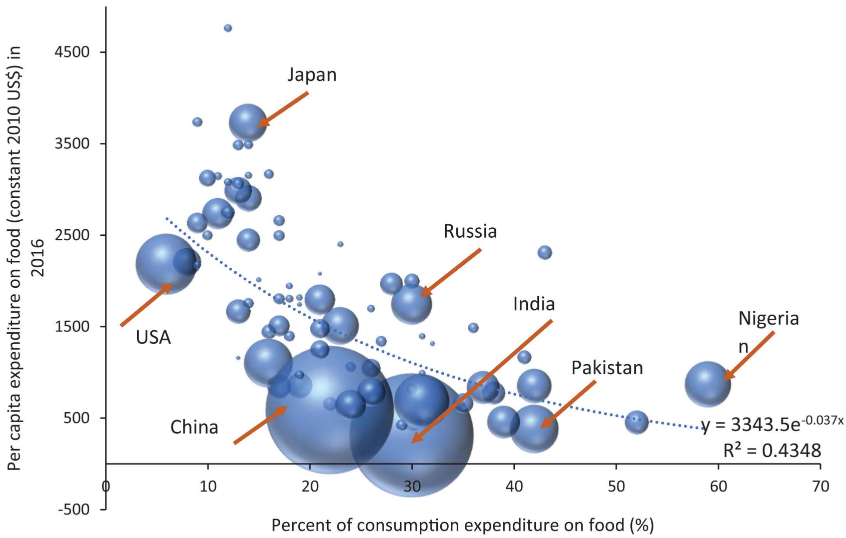

Figure 2.5.2 Per capita expenditure on food versus the percentage of consumption spent on food in various countries.

Note: The size of each bubble is that country's population.

Source: Derived from World Bank data publicly available at: https://databank.worldbank.org/source/icp-2017

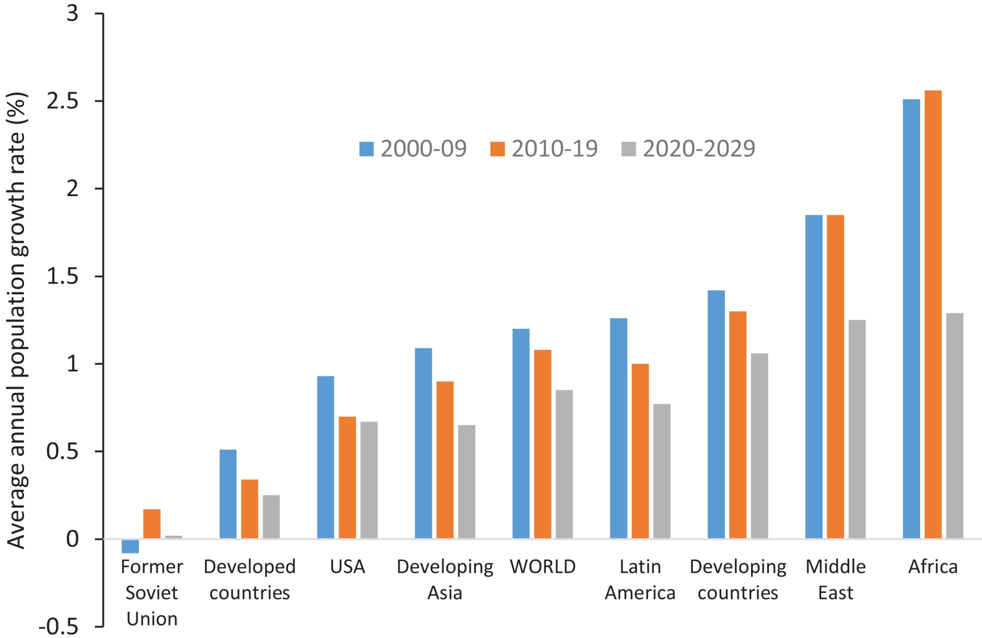

Figure 2.5.3 Regional increases in population.

Source: Based on USDA (2021)

Table 2.5.1 Top ten countries ranked by their middle-class consumption expenditure in 2020 and 2030

	2020			*2030*	
Country	*Middle-class consumption expenditure (2005 PPP$ billions)*	*Share of global middle-class consumption expenditure*		*Middle-class consumption expenditure (2005 PPP$ billions)*	*Share of global middle-class consumption expenditure*
China	4468	13%	India	12,777	23%
USA	4270	12%	China	9985	18%
India	3733	11%	USA	3969	7%
Japan	2203	6%	Indonesia	2474	4%
Germany	1361	4%	Japan	2286	4%
Russia	1189	3%	Russia	1448	3%
France	1077	3%	Germany	1335	2%
Indonesia	1020	3%	Mexico	1239	2%
Mexico	992	3%	Brazil	1225	2%
United Kingdom	976	3%	France	1119	2%

Larger populations, and often richer populations, will place increased demands on agricultural and trade systems to deliver the required volumes and qualities of food products. Already China imports massive volumes of feed grains, and Indonesia has become the world's second largest importer of wheat. India's ability to be self-sufficient in agricultural products may be challenged in coming decades as its population grows in size and wealth and climate change impacts unfold to weaken the reliability of its agricultural production. In the late 2020s India is projected to surpass China as the world's most populous nation, although rates of increase in population will be the greatest in Africa and the Middle East (Figure 2.5.3).

The great main challenge facing global food production systems is how to produce the required increasing volumes of food products sustainably, especially after noting that food purchases already represent a sizable share of per capita consumption expenditure in the world's most populous countries (India, China, Pakistan, Nigeria). The increase in agricultural production needs to take place against the backdrop of a worsening or more volatile climate in many main agricultural regions of the globe, as already mentioned. However, there are several other sustainability challenges for future agricultural production.

Food versus fuel

One of the global challenges, described as causative of climate change (IPCC 2023), is the continuing upward trend in GHG emissions. According to the IPCC (2023), total anthropogenic GHG emissions have continued to increase, despite a growing number of climate change mitigation policies and activities. Anthropogenic GHG emissions in 2010 reached 49 ± 4.5 GtCO2-eq/yr. Emissions of CO_2 from fossil fuel combustion and industrial processes contributed about 78% of the total GHG emissions increase from 1970 to 2010. By 2018, 83% of anthropogenic CO_2 emissions originated from fossil fuel combustion. Accordingly, many governments have enacted and supported changes to lessen fossil fuel combustion, such as encouraging the use of agricultural crops (e.g., corn, canola, sugar cane, soy oil, palm oil) for use in biofuels.

For example, in the United States, corn production is supported by government-direct payments, subsidised crop insurance payments and mandates to produce ethanol. In the United States, the Renewable Fuel Standard, administered by the Environmental Protection Agency, mandates the use of biofuels in the country's fuel supply. Every year, the Environmental Protection Agency directs how much biofuel has to be blended. The mandate's intention was to expand the nation's renewable fuel sector, lessen GHG emissions and reduce reliance on imported oil.

To support the mandate, corn subsidies totalled roughly $90 billion between 1995 and 2010 – not including ethanol subsidies and mandates – which helped drive up the price of corn. Foley (2013) points out that roughly 40% of US corn is used for ethanol whilst around 36% is used as animal feed for meat and dairy cattle, pigs and chickens. Much of the rest is exported as a feed grain. Only a tiny fraction of the national corn crop is directly used for food for Americans, much of that as high-fructose corn syrup.

In the United States, corn is regularly grown on at least 90 million acres (USDA 2020) and is associated with over 5.6 million tonnes of nitrogen being applied to corn each year through chemical fertilisers, along with nearly a million tonnes of nitrogen from manure. Some of this fertiliser leaches into waterways, contributing to the dead zone in the Gulf of Mexico. The

2019 area forecast for the dead zone was close to the record size of 8,776 square miles in 2017 and was larger than the five-year average of 5,770 square miles (NOAA 2019).

Between 2006 and 2020, the corn area in the United States increased by 12 million acres, mainly in response to rising corn prices and the increasing demand for ethanol. Most of the new corn acres came at the expense of wheat plantings, with wheat grown in the United States mostly being used for human consumption and feed grain purposes. The shift into corn production to principally serve animal feed and energy markets raises the thorny question of the wisdom of using scarce farmland to grow energy crops for transport fuel when the world faces the burgeoning issue of feeding 9 billion people in the coming decades.

It could be argued, for example, that biofuels based on corn, sugarcane, palm oil, soy oil and canola are a transition energy source for transport. In the next few decades low-emission sources of electricity are likely to increase in affordability, and electric vehicles and battery technologies seem destined to become more popular, reliable and price competitive. For example, in the first four months of 2020, plug-in car sales in France, Germany, Italy and the United Kingdom were about 90% higher than in the same period in 2019 and plug-in car sales have surged in the EU during the fourth quarter of 2020. In 2020 total plug-in car registrations in the EU passed the 1 million mark for the first time ever, totalling 1,364,813 units, up 144% from 2019. Registrations of fully electric cars totalled 745,684 units, up 107% from 2019, and plug-in hybrid cars a total of 619,129, up 210% from 2019. The region's plug-in market share achieved a record 11.4% in 2020. If these increased sales of plug-in vehicles and increased market shares are a portend of the future in other developed economies, then, despite increasing populations, the demand for biofuel may eventually lessen, freeing up farmland for feed and food crops rather than energy crops. Thus, the current anxiety and concern over the seeming unsustainability of committing farmland to energy crops rather than feeding people may abate due to technological innovation and associated market price signals.

Low-emission agriculture

Earlier in this chapter was commentary on the rise in global GHG emissions and the threat posed by further adverse climate change. Accordingly, one of the sustainability challenges for agriculture is to lessen its GHG emissions and thereby help contribute to minimising the likelihood of further adverse climate change. However, the history of agricultural production to-date is that as agricultural production increases so do agricultural emissions (Figure 2.5.4). The inference is that growth in agricultural production, required to feed the world's growing population, is only exacerbating the problem of excessive GHG emissions. Although the emissions intensity of agricultural production may be improving, helping agriculture's share of global emissions to decline, nonetheless, in aggregate, GHG emissions from global agriculture continue to increase (Figure 2.5.4).

Noting that many governments have pledged to reduce their countries' emissions or even achieve carbon neutrality, the task facing many countries' agricultural sectors is how to increase agricultural production whilst reducing agricultural emissions. Taking land away from agriculture to provide forestry sequestration to abate emissions is unlikely to be a viable option in many cases due to the value of farmland and the need to increase agricultural production. Science- and technology-based innovation may be increasingly needed to lessen emissions whilst increasing agricultural output. If no technology solutions are available, then perhaps policy or regulation changes are required to cause some emissions-intensive agricultural products to increase in price to lessen their consumption (and therefore associated

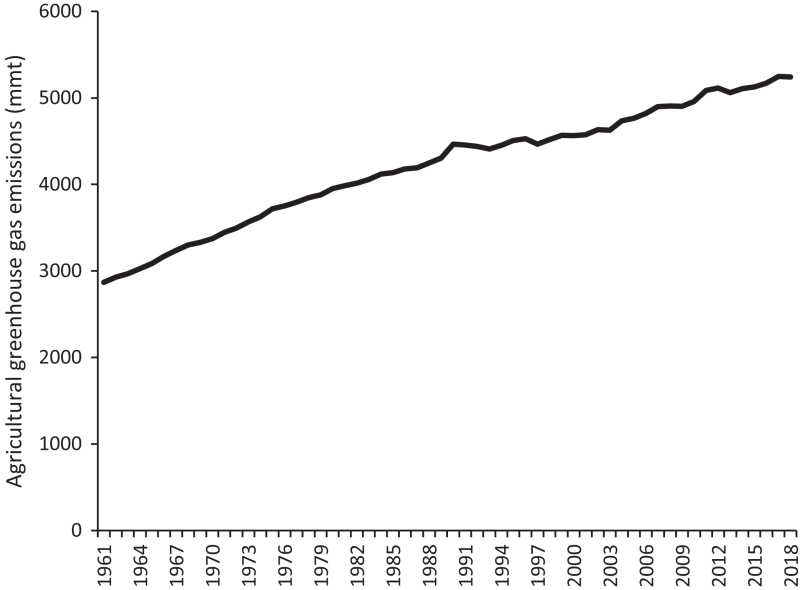

Figure 2.5.4 Greenhouse gas emissions from global agriculture: 1961–2018.

Source: Based on FAOSTAT data publicly available at: https://www.fao.org/faostat/en/#data/GT

emissions), but this is often politically unpalatable. At the very least it is foreseeable that food products may be required to be labelled by their embedded GHG emissions or some other sustainability metrics or certificated environmental branding.

In many agricultural systems often the main source of emissions are animal enterprises, especially ruminants such as dairy and beef cattle, goats and sheep. Their digestion systems produce methane, a particularly potent GHG with respect to its global warming potential. Lessening emissions from these enterprises is challenging for various reasons. Firstly, where these animals graze extensively there is no simple way of capturing their methane output before it enters the atmosphere, unlike what is technically more feasible when animals are raised intensively in facilities that support the capture and subsequent use of the methane produced by these animals. Secondly, the milk, meat and fibre products that are produced by these animals often increasingly feature in the diets and purchasing behaviour of people as their per capita incomes increase. As people become wealthier, they tend to consume more dairy and meat products and wear fibres perceived to be luxury fibres such as wool or cashmere. Hence as people's individual wealth grows, so does their demand for these products of ruminant animals. Moreover, as the demand for these products increases, farmers supplying these products are incentivized to spend more on feeding these animals, increasing herd sizes and intensifying production by financing higher stocking rate systems that often are underpinned by increased use of nitrogenous fertilisers to grow more feed. The end result is more animals and more emissions, not fewer emissions.

To lessen emissions, especially from extensively grazed ruminants, requires introducing anti-methanogenic feed sources whilst simultaneously endeavouring to use genetic selection to lessen the emissions intensity of ruminant production. If technological and management innovations cannot lessen emissions and emissions intensity associated with ruminant-based agricultural production, then the power of pricing and regulation may eventually curb those emissions.

Explaining further, although in general people increase their meat and dairy consumption as their incomes increase, the relative prices of different meats, dairy and dairy equivalents are important influences on the purchasing behaviour. This can be illustrated with reference to the meat-eating behaviour of Australians, noting that Australia is already a country with a high per capita income and high per capita consumption of meat. As indicated in Figure 2.5.5, for several decades the per capita consumption of meat in Australia has ranged from 96 to 111 kilograms per year with no significant time trend being evident. However, the composition of the meat in Australians' diets has changed greatly. Back in the late 1970s beef and lamb were the most popular meats consumed. Fast-forward to the late 2010s and the most popular meats are chicken and pork. The per capita consumption of beef and lamb has declined substantially over the last three decades, whilst conversely pork and particularly chicken per capita consumption has grown strongly.

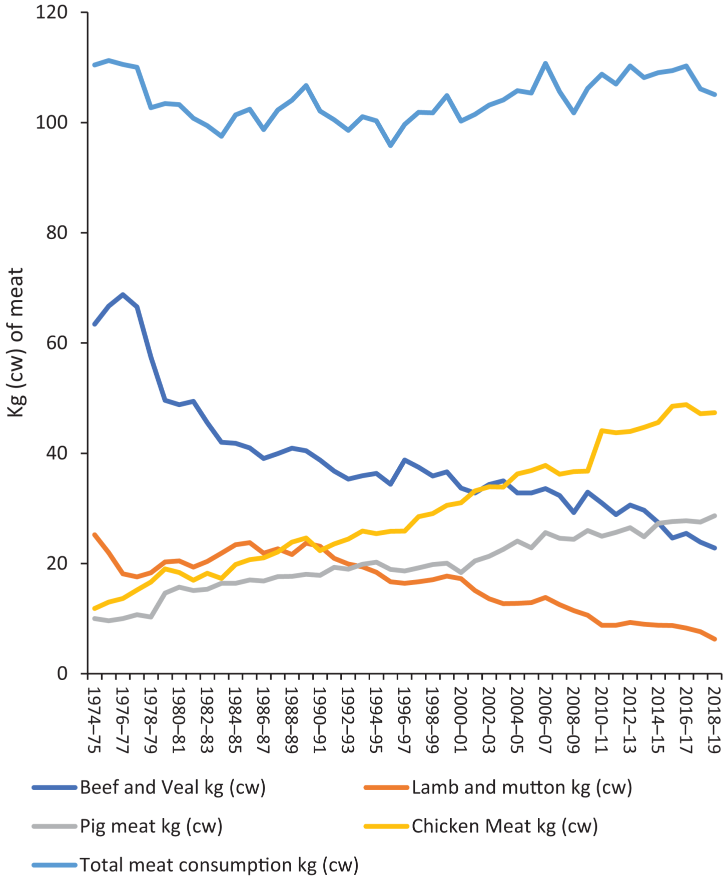

Figure 2.5.5 Per capita meat consumption in Australia: 1974–2018.

Source: Based on ABARES data publicly available at: https://www.agriculture.gov.au/abares/research-topics/agricultural-outlook/data#_2022 (Rural Commodities Meat General)

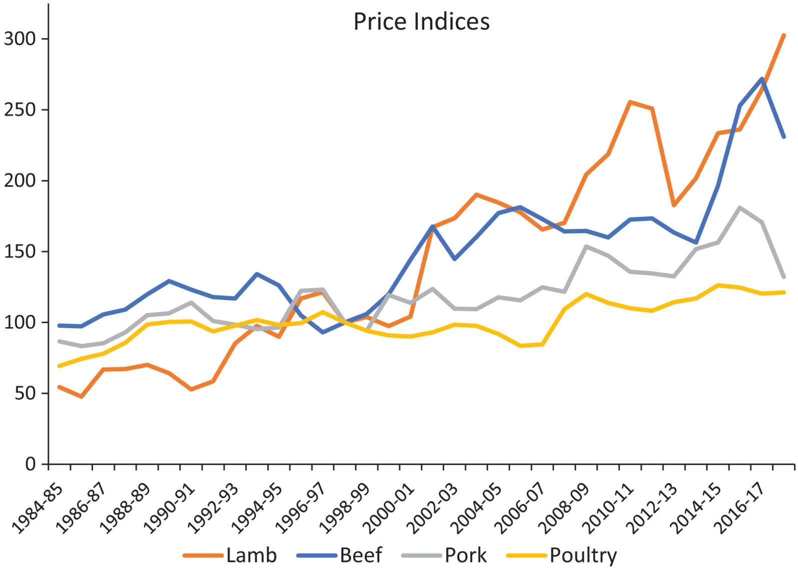

Figure 2.5.6 Relative prices of main meats consumed in Australia.

Source: Based on ABARES data publicly available at: https://www.agriculture.gov.au/abares/research-topics/agricultural-outlook/data#_2022 (Rural Commodities Meat General)

Lamb was once the cheapest among the main meats consumed in Australia. It is now the most expensive (Figure 2.5.6). Poultry prices have increased the least since the mid-1980s, making chicken the most affordable type of meat, followed by pork. The price gap between lamb and beef versus poultry has been widening, encouraging greater consumption of chicken. Lamb and beef production in Australia are historically extensive grass-fed enterprises, whereas pork and chicken production are intensive industries. Moreover, the feed conversion ratio for chicken and pork production is far greater than that for sheep and beef production, resulting in the emissions per kilogram of meat produced being far less for chicken and pork production. Hence, although Australians continue to consume per capita over 100 kg of meat, the methane emissions associated with their meat consumption has declined. The alteration in the composition of the portfolio of meats eaten has almost solely been due to the relative affordability of each type of meat (Figure 2.5.6). This example of Australia shows that the relative prices of different meats does affect their consumption. Hence, emissions associated with meat production can be simultaneously affected whenever relative prices change and market forces can drive consumption behaviour towards lower-emissions foodstuffs.

Fewer chemicals in farming

Often the intensification of agricultural production is associated with higher rates of application of inputs. One frequently increased input is chemicals that bolster or safeguard agricultural production. For example, fertilisers, herbicides, pesticides and fungicides often support the intensification of cropping. Yet as commented upon earlier, with the example of the dead zone in the Gulf of Mexico caused by the leaching of fertilisers into waterways, sometimes there are detrimental off-site impacts from use of certain chemicals.

Sometimes the overuse of a chemical leads to local and potentially widespread problems such as weeds, pests and fungi developing a resistance to the chemicals used to control them. Sometimes end products become contaminated by chemical residue limits being exceeded. Sometimes human health concerns surround the overuse of certain pesticides or weedicides. Such has been the case concerning the popular herbicide glyphosate.

Regarding glyphosate, in 2015 the International Agency for Research on Cancer, part of the World Health Organization, released a report classifying glyphosate as "probably carcinogenic to humans" (IARC 2015). Since the release of that report, public concern about the safety of glyphosate has grown, despite the US Environmental Protection Agency (USEPA 2016) deeming the herbicide safe to use when used in accordance with the instructions. Some subsequent epidemiological studies have found that frequent use and exposure to glyphosate are linked to an increased risk of non-Hodgkin's lymphoma (Myers *et al.* 2016; Zhang *et al.* 2019) or a subtype of non-Hodgkin's lymphoma, diffuse large B-cell lymphoma (Leon *et al.* 2019). However, the EPA (2020) has reviewed and criticised these studies and reiterated its own view that glyphosate should be categorised as "not likely to be carcinogenic to humans". Nonetheless, media and legal furore surrounding the use of glyphosate has ensued, mostly in the United States.

In June 2020, Bayer announced it would spend up to $US10.9 billion to settle approximately 95,000 lawsuits brought by individuals in the United States who claimed their non-Hodgkin's lymphoma was due to their exposure to glyphosate (ABC 2020). Up to $US 5 billion was to be paid out in 2020 and $US5.1 billion of the remainder paid in 2021. Bayer has said no agreement had yet been reached for about 25,000 remaining claims. In June 2020 Bayer also filed a class action in San Francisco to settle all future claims of individuals who use Roundup (i.e., glyphosate) but have not yet manifested non-Hodgkin's lymphoma. Bayer also announced the creation of a special science panel which, over the next four years, would study Roundup and render a decision on whether or not the herbicide caused non-Hodgkin's lymphoma.

Glyphosate use in public spaces has now been banned in countries such as the Netherlands, France and Italy (Tosun *et al.* 2019). Luxembourg has banned the use of glyphosate since December 31, 2020, and the French government has announced the cessation of the use of glyphosate by 2021. In Australia, many local councils have banned or are phasing out use of glyphosate as a weed control option. In 2020, Kellogg announced that in its supply chains, it will phase out by 2025 wheat and oats treated with glyphosate as a drying agent.

Yet in global agriculture, use of glyphosate remains important. Glyphosate-tolerant (GT) crops have become very popular in several key grain-producing regions of the world (Brookes and Barfoot 2014). GT crops such as RoundUp Ready corn and RoundUp Ready soybean are now grown on over 191.1 million hectares globally, mostly in the United States, Brazil, Argentina, Canada and India. Application of glyphosate on GT crops accounts for 56% of global glyphosate use (Benbrook 2016).

Loss of access to glyphosate, if a global phenomenon, would make countries that rely on either the production or importation of GT crops to be especially vulnerable (Brookes *et al.* 2017). Noting that most of the world's main traded feed grains, corn and soybeans, are GT crops, a global ban on glyphosate would cause feed grain prices to increase as feed grains like corn and soybeans, whose production is mostly via GT technologies, would become more expensive to produce. Higher international grain prices in turn would trigger higher prices of agricultural commodities and food stuffs (e.g., eggs, dairy, poultry, pork) dependent on grain-feeding. Global regions greatly dependent on GT crops, either as producers or consumers, would be particularly disadvantaged. Those regions include much of Asia, North America and South America.

Hence, as illustrated by the case of glyphosate, removal or reducing chemical use in agricultural production can lead to a wide range of impacts, affecting producers and consumers. Consumers' desire for agricultural production to be underpinned by less use of chemicals with unpalatable side effects or off-site effects will trigger a cascade of consequences, including development of safer and more effective chemicals and application practices. However, it is likely to make intensification of agricultural production more difficult and expensive, challenging agriculture's ability to feed affordably growing and wealthier populations.

Food security versus self-sufficiency

One social and political challenge that will accompany this desire to sustainably increase agricultural production is the extent to which each nation or region, as part of its sustainability agenda, will choose to embrace either self-sufficiency in food production or trade-based food security, or some combination of the two. Explaining further, some governments view self-sufficiency in food production as a national imperative to support national sovereignty and independence. Accordingly, many governments maintain food stockpiles or economic measures to ensure their populations have sufficient access to locally produced food rather than being reliant on food imports. This is especially true of populous countries like China, India and Indonesia who maintain policies to protect and bolster their national agricultural production, particularly regarding food crops.

However, not all countries have sufficiently small populations relative to their agricultural areas or have the latitudinal spread in their agricultural production to be capable of supplying a broad range and sufficient volume of food products. Moreover, even where local production is feasible, sometimes by relying on international trade in agricultural products, certain food products can more affordably be imported rather than supplied locally. In short, in some situations it is more cost-effective to import food products rather than pursue a policy of being self-sufficient in a broad range of food products.

The principle of comparative advantage that underpins the gains from trade identifies how nations can mutually benefit from agricultural trade. Capturing those gains, however, requires protecting and encouraging the freedom to trade. Yet history reveals that whenever there is serious disruption to international trade or reduced availability of food supplies, then consumers in food-insecure countries can readily experience food price inflation and in the extreme, civil unrest can arise over the affordability and availability of food. Hence, because food is a constant necessity for living, many countries are loath to overly rely on importation of food products, as it potentially exposes national governments to political instability and occasional food insecurity.

Hence, the future for sustainable agricultural production must address the need to satisfy the social and political challenge of ensuring adequate, affordable supplies to local consumers whilst safeguarding national sovereignty and political stability.

Social licence issues

As nations grow in wealth and per capita incomes increase, then increasingly these societies become urbanised and their individuals express concerns not only about the safety and nutritional value of the food products they consume, but they also voice concerns about how their food is produced. Broadly, these latter concerns are called 'social licence' issues. Increasingly, it is urban voters, food consumers and major food retailers who determine the acceptable means of agricultural production. Their concerns are revealed in the label adjectives applied to food products (free range, dolphin-friendly, hormone-free, grass-fed, non-GM) and are embedded in the contractual arrangements between food producers and major retailers.

Issues of animal welfare, chemical use, food safety, labour wage and price fairness and environmental protection all feature as social licence issues. The increasingly wealthy consumer is concerned not only about the availability and price of the foods they purchase but also the manner of food production. Social media campaigns can readily be mounted to expose and oppose production methods viewed as socially or environmentally unacceptable. The shift of political power to urban areas means that increasingly politicians and lawmakers will respond to the clamour from urban groups rather than rural groups, with urban groups being increasingly divorced from a practical experience of food production, particularly large-scale agricultural production. Marrying what is desired by urban groups with what rural groups may feel is technically and practically feasible is possibly a further challenge for the future sustainability of agricultural production.

Conclusion

Noting all these trends and challenges that face the sustainability of agriculture and food production, what should educators emphasise in their teaching programs for sustainability? In my view, to assist discussion and reactions to these challenges, it is important to start with the facts as we currently know them:

Fact 1: The fundamental drivers of food consumption are population and per capita income growth. Understanding how these drivers change over time and differ between countries helps clarify the nature and urgency of the sustainability challenges facing agricultural production.

Fact 2: Climate change will mostly restrict the growth prospects for agricultural production. There will be spatial differences in climate's impact on agricultural production, and different agricultural crops and industries may be differently affected. Spatial 'winners and losers' may emerge, yet growth in overall agricultural production is likely to be constrained by unfolding climate change.

Fact 3: Increasingly governments, industries and societies across the globe are endeavouring to reduce their emissions. The task facing many countries' agricultural sectors is how to increase agricultural production whilst reducing agricultural emissions. Taking land away from agriculture to provide forestry sequestration to abate emissions is unlikely to be a viable option in many cases due to the value of farmland and the need to increase agricultural production. Science, policy and technology-based innovation will increasingly be needed to lessen emissions whilst increasing agricultural output.

Fact 4: As nations grow in wealth and their per capita incomes increase, then increasingly their citizens will express concerns not only about the safety and nutritional value of the food products they consume, but they also will voice concerns about how and where their food is produced. Issues of chemical use in agriculture, animal welfare and worker exploitation will arise, and debates about food self-sufficiency versus food security will ensue.

The ramifications of these facts are worth highlighting in any sustainability educational program. After stating the facts of the sustainability challenges affecting agricultural production, the next priority for educators will be to outline the likely implications of those facts. For example, if increased food production is required whilst conserving natural areas, then greater investments in science and technology and careful policy design are likely to be required to ensure effective and affordable sustainable systems for agricultural production are generated in coming decades.

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2.6
MOVING BEYOND PEAK OIL
The importance of renewable energy in the sustainability transition

Kelvin Say

Key concepts for sustainability education

- Understanding the historical context of the global energy system, its relationship with energy conversion technologies, and society's demand for energy.
- Understanding the scale of the global energy system and comparing it with the amount of renewable energy resources on the planet.
- Recognising the source of renewable energy resources, its locational and temporal dependencies, and physical limits.
- Developing knowledge on conversion technologies used to extract energy from renewable energy resources, along with their broader social, environmental, and economic impacts.
- Identifying pathways to decarbonise the energy systems in each energy sector and the degree to which it transforms the current global energy system.

Introduction

To teach renewable energy, sustainability educators have to first understand the role of energy in society. All societies require energy to function, from rotating machines to generate electricity, internal combustion engines to power transport, to natural gas for heat, society's use of energy relies on the extraction and conversion of energy from other energy resources. Today's global energy system is a by-product of technologies societies use to convert energy from primary (i.e. raw) energy resources into secondary energy resources (such as electricity, fuel, and thermal energy) that can be consumed. Energy technologies have played key roles in our history, with the use of coal and steam engine technology leading to the industrial revolution and innovations such as electricity and railways to the use of (higher energy density) petroleum and internal combustion engine technology enabling a new era of mobility with cars, trucks, and planes. These technologies rely on the high energy density found in fossil fuels, and their widespread use has made fossil fuels the largest source of energy today (IEA, 2021a). However, as extracting fossil fuel energy relies on combustion

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processes that emit carbon dioxide and nitrous oxide, the planet's balance of greenhouse gases (GHGs) has been altered.

The energy sector is currently the biggest contributor (73%) to global anthropogenic GHG emissions (Ritchie & Roser, 2020), as it is largely powered by fossil fuels. For reference, the world extracted 606 exajoules (EJ) of energy in 2019 to satisfy an annual energy consumption of 418 EJ (IEA, 2021a). The majority (80.9%) of primary energy resources were sourced from fossil fuels and a much lesser extent from renewable energy resources (14.1%) and nuclear energy (5%). These primary energy resources are transformed into secondary energy resources to be used by society, namely electricity and heat, petroleum and fuel gas products, and biofuels that are then consumed in the end-use sectors of (i) transport, (ii) industry, (iii) building, and (iv) agriculture, forestry, and other land use. For the global energy system to transition away from fossil fuels, it has to make use of renewable energy resources available in the natural environment and develop pathways for society to use it. This transition is further complicated since today's fossil fuel–powered energy system needs to develop, manufacture and deploy the non-GHG-emitting energy systems of tomorrow. A synthesis of the energy system transition literature by Clarke et al. (2022) highlights that the electricity system is capable of incorporating a wide range of renewable energy technologies that are primarily used to produce electricity. The lowest-cost pathways to net-zero emissions rely heavily on the electricity sector to rapidly decarbonise and provide its energy into other (end-use) sectors. This is not simply replacing technology, but a broader reconfiguration of the global energy system, from one reliant upon extracting geological energy to one extracting energy from its natural environment. This transition, however, does not solely depend on technical and economic factors but also a broader understanding and acceptance of its social, environmental, and political repercussions, since it will fundamentally affect how society itself functions.

What is renewable energy?

Renewable energy resources can be broadly defined as "energy derived from natural resources that replenish themselves in less than a human lifetime without depleting the planet's resources" (REN21, 2019). Non-renewable energy resources on the other hand are finite, and as they are consumed cannot be replenished (Table 2.6.1). As a planet, the Earth has a finite range of forces that act upon it, namely (i) gravitational energy from the Sun

Table 2.6.1 Fossil and uranium reserves and resources

Finite resource	*Reserves [EJ]*	*Resources [EJ]*
Conventional oil	4,900–7,610	4,170–6,150
Unconventional oil	3,750–5,600	11,280–14,800
Conventional gas	5,000–7,100	7,200–8,900
Unconventional gas	21,100–67,100	40,200–121,900
Coal	17,300–21,000	291,000–435,000
Conventional uranium	2,400	7,400
Unconventional uranium	–	7,100

Source: (Edenhofer et al., 2011).

and Moon that provide tidal energy, (ii) thermal emissions from radioactive decay within Earth's core that provide geothermal energy, and (iii) solar radiation emitted from the Sun that provides direct solar energy. Solar energy further interacts with the atmosphere to generate wind energy, water bodies and the atmosphere to generate hydro-energy, and plant matter to produce biomass. Wind energy further interacts with the oceans to generate wave energy. These by-products from interactions with solar energy are considered indirect forms of solar energy.

The most abundant renewable energy resource on the planet is solar energy, which is capable of powering the world's energy demand hundreds of times over (Table 2.6.2). However, as most renewable energy resources are intermittent and unevenly dispersed, a complementary set of renewable energy resources and their conversion technologies are needed for each region to reliably supply energy. As deploying these technologies at the scale required will result in trade-offs economically, socially, environmentally, and politically, a clear understanding of the limitations of each renewable energy resource, how energy is extracted, and how our human and environmental ecosystems are impacted is needed. The next subsection therefore covers each renewable energy resource and conversion technology in greater detail such that educators may evaluate the sustainability of renewable energy technologies in their respective regions. Energy storage is another developing technology that can complement renewable energy generation, but remains outside the scope of this subchapter.

Renewable energy resources

Solar energy

Nuclear fusion reactions within the Sun drive its surface temperature to ~5800 K, which results in the emission of electromagnetic radiation in all directions (i.e. black-body radiation). At the average distance of Earth's orbit, ~1370 W/m^2 of solar power is received (i.e. solar irradiance). This amount of solar irradiance remains relatively constant and is not impacted by human activity. Solar irradiance contains a mix of visible light, infrared (i.e. heat), and ultraviolet radiation (Figure 2.6.1), with the highest intensity emitted as visible light.

While ~1370 W/m^2 of solar irradiance is received at the top of the atmosphere, not all of it reaches sea level. Under ideal conditions with clear skies and noon Sun, around a third of solar irradiance is lost before reaching sea level, leaving ~1000 W/m^2 of solar

Table 2.6.2 Renewable energy potential and utilisation in EJ

Renewable resource	*Technical potential [EJ/year]*	*Annual flows [EJ/year]*
Bioenergy	160–270	2,200
Geothermal	810–1,545	1,500
Hydro	50–60	200
Solar	62,000–280,000	3,9000,000
Wind	1,250–2,250	110,000
Ocean	3,240–10,500	1,000,000

Source: (Edenhofer et al., 2011).

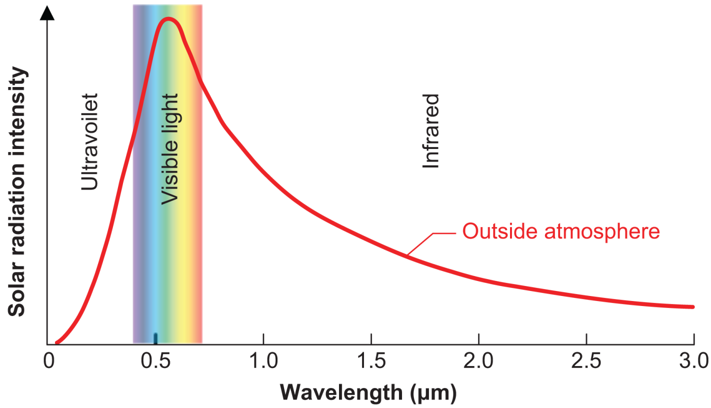

Figure 2.6.1 Electromagnetic spectrum of solar radiation.

Source: Adapted from Fondriest (n.d.).

power. A location's solar energy resources further depend on the time of day, latitude, and cloud cover. Over the course of the day, the solar irradiance gradually increases from zero at sunrise, peaks at noon, then gradually decreases back to zero at sunset. As sunrise/sunset times and sun position are affected by latitude, locations closer to the poles receive a lower amount of solar radiation. Equatorial locations are exposed to higher cloud cover due to the trade winds (see the section on "Wind energy"), which leaves locations at latitudes 20–30° north and south receiving the highest amount of annual solar irradiation (Figure 2.6.2).

Solar conversion technologies

Solar photovoltaics (PV)

Solar PV panels have become one of the lowest-cost electricity generation technologies and the largest source of new generation capacity (IEA, 2021c; REN21, 2021). Their modular construction and scalable deployment are well suited for mass manufacturing. Economies of scale have reduced costs by approximately 90% over the last decade (BNEF, 2021a; IRENA, 2021). Future cost reductions continue to be expected but at a reduced rate (BNEF, 2021b).

A solar PV cell takes advantage of the photovoltaic effect (Figure 2.6.3) to allow photons of light of a specific wavelength to generate a continuous flow of electrons (direct current electricity) that increases with solar intensity. Single solar PV cells are arranged into a two-dimensional array to construct a solar PV panel. The amount of electricity produced by a solar PV panel depends on the amount of solar irradiance, the angle it collides with the panel, ambient temperature, and the type of panel used.

The power generated by solar PV panels changes continuously as solar irradiance, sun angle, and temperature vary over the course of the day. To maximise the available power generation, solar PV panels can track the Sun both vertically and horizontally as it travels through the sky. However, if panels are in a fixed position, maximum generation generally

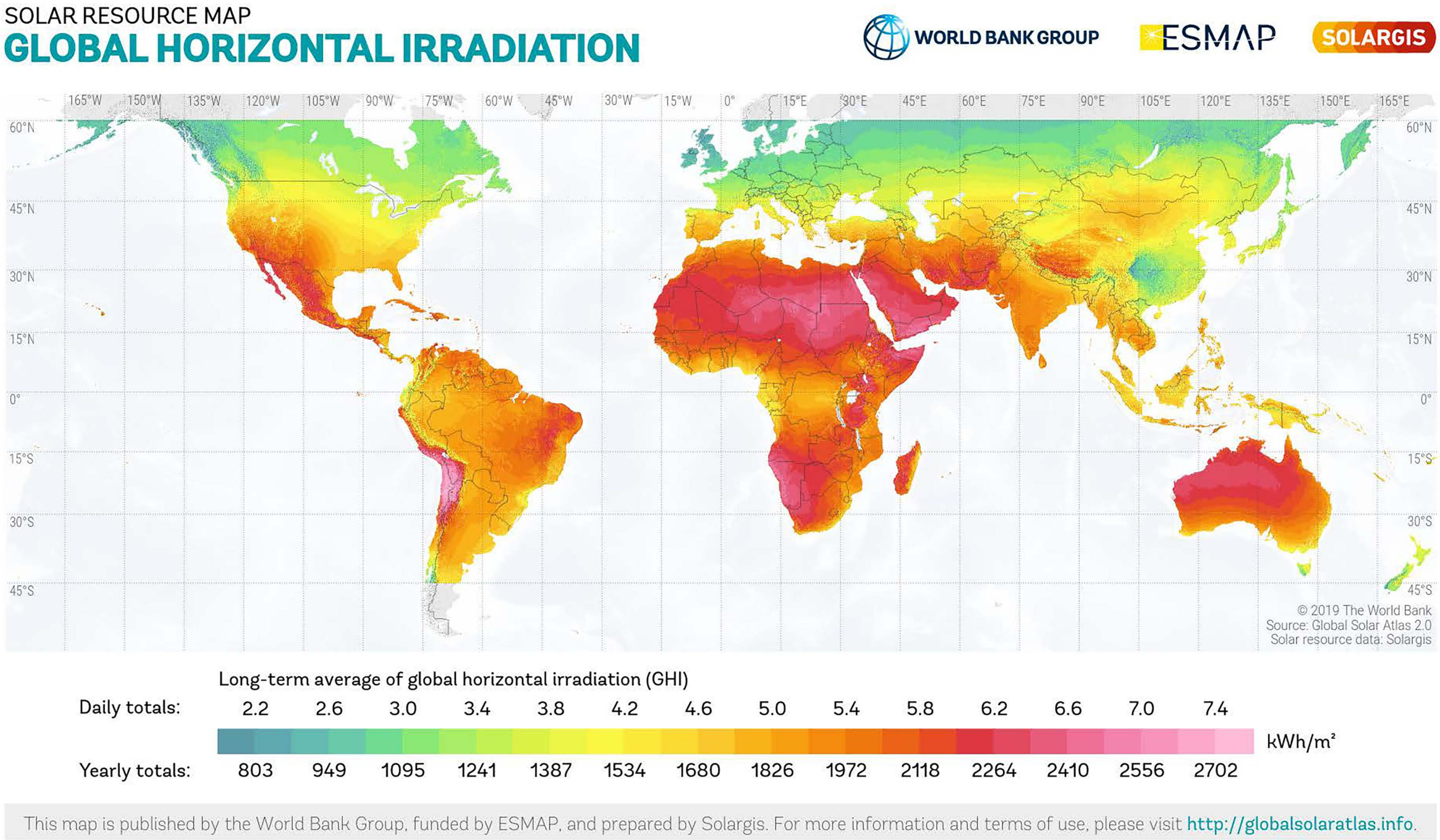

Figure 2.6.2 Map of global horizontal solar irradiation.

Source: (Global Solar Atlas, n.d.).

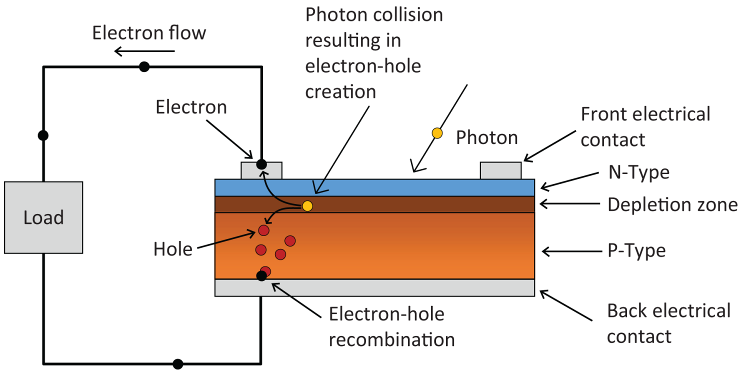

Figure 2.6.3 Electricity generation from a solar PV cell.

Source: Adapted from Bambhaniya (2020).

occurs with panels facing the equator and tilted at an angle approximately equal to the latitude (Jacobson & Jadhav, 2018).

The output of solar PV cells has continued to improve over time (Figure 2.6.4). However, as silicon PV cells are approaching the theoretical upper limit (Ehrler et al., 2020), alternative strategies are being pursued, such as stacking different solar PV cell technologies to capture more than one wavelength of light (i.e. multijunction) or using optical concentrators to increase solar irradiance on a cell at the expense of more heat. Improved cost-effectiveness may also be achieved by reducing the amount of crystalline silicon used (i.e. thin films) or using materials with potentially lower processing costs (i.e. organic, perovskite).

As solar PV panels utilise land, their continued expansion may compete with land already used for food and biodiversity. Given the amount of solar PV capacity needed in a decarbonised electricity system, van de Ven et al. (2021) quantified how it could lead to net terrestrial carbon losses in the European Union, India, Japan, and South Korea. Alternatively, they could be deployed on existing rooftops (Gernaat et al., 2020) or in combination with agriculture (Amaducci et al., 2018).

Concentrating solar power (CSP) plants

Rather than extracting energy using the photovoltaic effect, solar radiation can also be reflected and concentrated onto a thermal receiver to capture its energy as heat. As CSP plants capture thermal energy, additional processes are required to convert thermal into electrical energy. This is typically accomplished via a heat transfer fluid that transfers thermal energy from the receiver to another location to generate steam and turn (via a steam turbine) the rotor of an electric generator. Alternatively, the receiver can be connected directly to a heat engine to power an electric generator. There are four CSP plant configurations (Figure 2.6.5) based on the collector type (linear or circular) and mirror shape (curved or flat).

Circular collectors (i.e. central receiver, parabolic dish) are able to concentrate solar radiation onto their receiver and achieve high operating temperatures at the expense of greater complexity in design and operation. With a **parabolic dish**, the entire structure has to precisely track the Sun across the sky, while **central receivers** require thousands of flat mirrors to be individually positioned to ensure sunlight is reflected onto the receiver. By

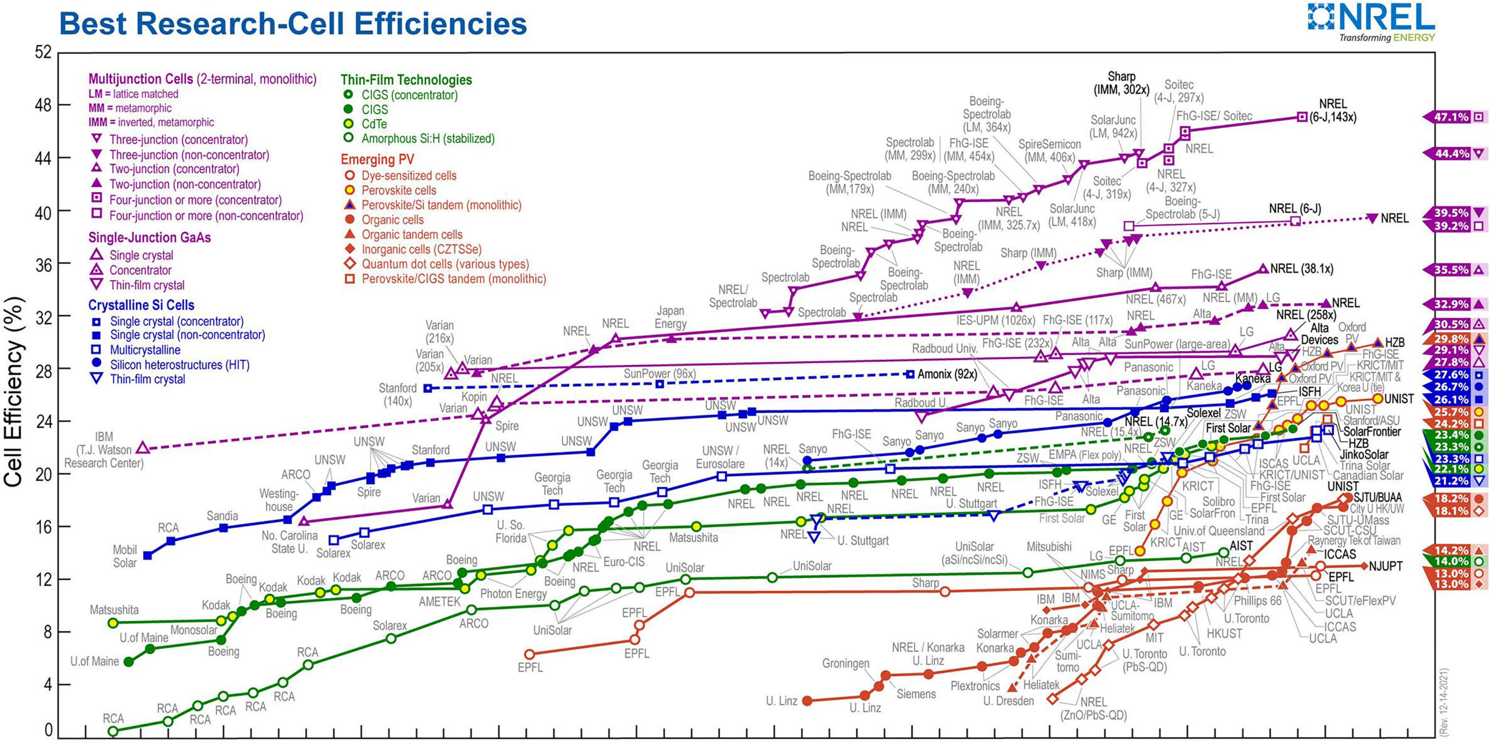

Figure 2.6.4 Best research on solar PV cell efficiencies.

Source: (NREL, n.d.).

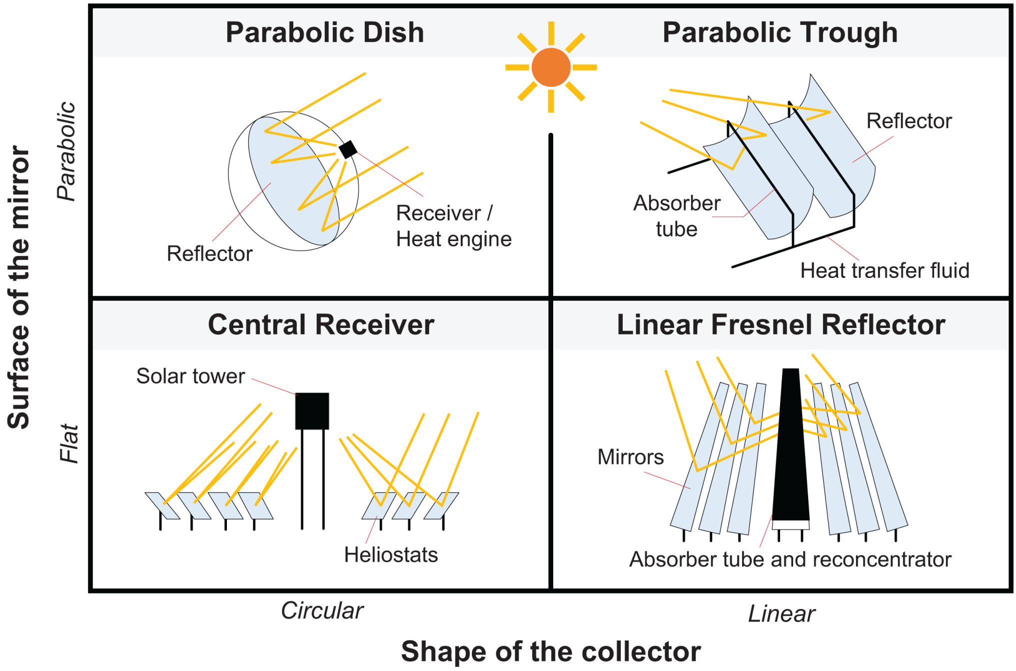

Figure 2.6.5 Different configurations of concentrating solar thermal power plants.
Source: Adapted from van Sark & Corona (2020).

contrast, *linear collectors* (i.e. parabolic trough, linear Fresnel reflector) concentrate less solar radiation, resulting in lower operating temperatures, but are comparatively easier to construct. With **parabolic troughs**, they are relatively modular rows of troughs rotating east to west to track the Sun, while **linear Fresnel reflectors** reposition their long mirrors to maintain the Sun's reflection onto the receiver.

The most common CSP plants are currently parabolic troughs followed by central receivers (REN21, 2021). While solar PV plants may have a cost advantage when producing electricity (IEA, 2021e), CSP plants have an advantage when it comes to storing energy, as thermal energy is more easily stored. (By using molten salt as a heat transfer fluid, thermal energy from the receiver can be stored in large, insulated tanks.) When electricity generation is required, thermal energy from hot molten salt is extracted to produce steam and electricity, and the cooled heat transfer fluid (molten salt) is returned to a separate cold storage tank where it may be heated again by the thermal receiver. This allows CSP plants to continue producing electricity well after sunset, which may offer higher revenue opportunities. Another opportunity for CSP plants is to forego electricity generation and supply high-temperature and zero-carbon heat for industrial applications that have limited decarbonisation alternatives.

With more moving parts, materials, and design constraints, CSP plants have a more complex design than solar PV plants. They also require significant land area that can lead to clearing and competition for land use and have a larger visual impact than solar PV. Duvenhage et al. (2019) highlighted the critical importance of water resources for CSP plants.

Ho (2016) reviewed the impact of central receiver plants on avian mortality, and while it was found to be low, reflective surfaces did lead to collisions and the concentrated solar flux led to singeing of birds. Mitigation measures included the use of deterrents and minimising solar flux while mirrors were in standby position.

Wind energy

The uneven heating of the Earth's surface by the Sun's solar radiation leads to variations in temperature and air pressure across the latitudes. Combined with the Earth's rotation, global and local wind patterns are produced as the air is heated and cooled. Wind can be considered a mass of gas travelling across the ground, circulating up into the troposphere as it is heated, and returning to the ground as it cools.

There are three main types of wind: planetary, seasonal, and local. **Planetary winds** result from a combination of the Earth's surface structure, Coriolis effect, and differences in gravity (Figure 2.6.6). It leads to distinct circulation cells that drive the direction of prevailing winds between latitude ranges, namely the trade winds (between 30°N and 30°S), prevailing westerlies (between 30–60°N and 30–60°S), and polar easterlies (around the North and South Poles). The trade winds are also responsible for gathering moisture from 30° north and south and redirecting it towards the equator, which drives increased humidity and cloud cover around the equator and leads to semi-arid deserts around 30°N and 30°S. Earth's tilt further adjusts these latitudinal boundaries over the year, leading to **seasonal winds** within these latitudinal boundaries (e.g. monsoon winds) which change their prevailing wind direction (Gadgil, 2018). **Local winds** are generally diurnal and driven by the landscape thermally interacting with the air, e.g. in coastal regions, the land and water heat and cool at different rates across the day-night cycle, driving land and sea breezes, and in mountainous regions, valleys, and mountainsides heat and cool at different rates, driving valley and mountain breezes (Britannica, 2015).

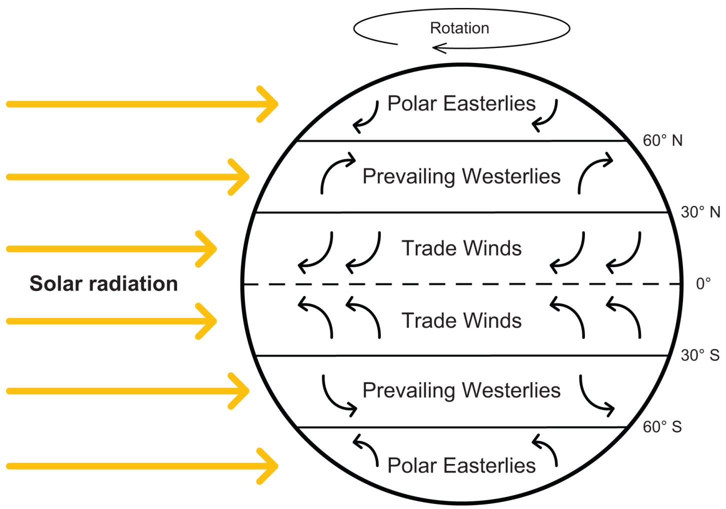

Figure 2.6.6 Formation of trade winds due to the Coriolis effect across different latitudes.
Source: Author.

The speed of wind, v, also varies by height (Figure 2.6.7), which is known as wind shear. As wind moves across the ground, the relative roughness of the terrain, α, lowers its speed. As such, urban environments reduce wind speed more than open terrain. Hence, locations with more obstacles require greater height to access the true wind speed. Furthermore, as wind may approach from different directions with different obstacles based on the time of day, the amount of wind shear may also change over time (Borsche et al., 2016).

Understanding the factors that influence wind speed, v, is critical, as there is a cubic relationship with wind power, P_{wind} (Equation 1), whereas there is only a linear relationship with the cross-sectional area, A, with a generally constant air density, ρ.

$$P_{wind} = \frac{1}{2}\rho A v^3 \tag{1}$$

This means that a location with double the wind speed will have eight times the power, greatly increasing the energy available to any conversion technology. Taking these factors into consideration globally, the difference between wind speed (Figure 2.6.8a) and density of wind power (Figure 2.6.8b) underscores the growing trend towards offshore wind resources that have higher average wind speeds.

Given that wind is a chaotic process, it cannot be completely predicted. However, statistical methods are typically used to establish broad patterns and characterisations of this renewable energy resource from region to region in order to plan their integration into energy systems.

Wind conversion technologies

Wind turbines

Wind turbines are designed to extract kinetic energy from the wind. As a mass of moving air, wind acts upon a surface to produce rotational forces that operate an electric generator. There are a wide range of possible wind turbine configurations (Figure 2.6.9), but the most

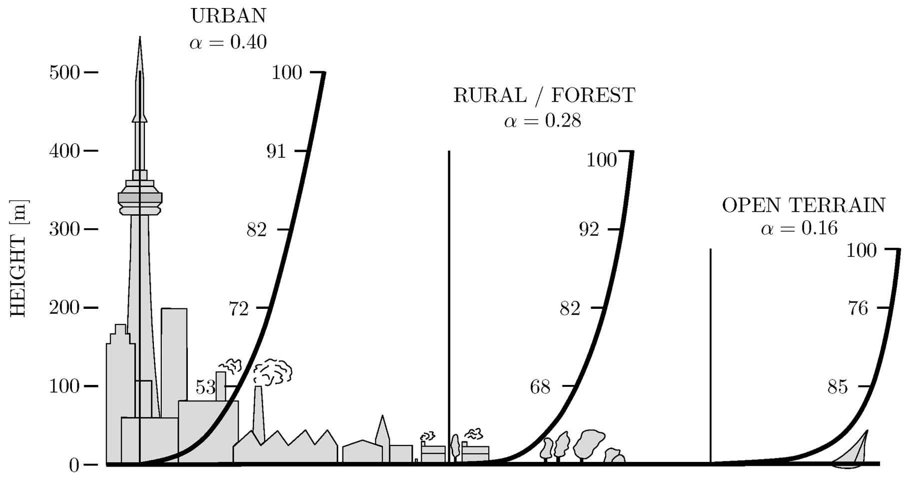

Figure 2.6.7 Wind shear, the effect of ground terrain on vertical wind speeds.

Source: (Recoskie et al., 2017).

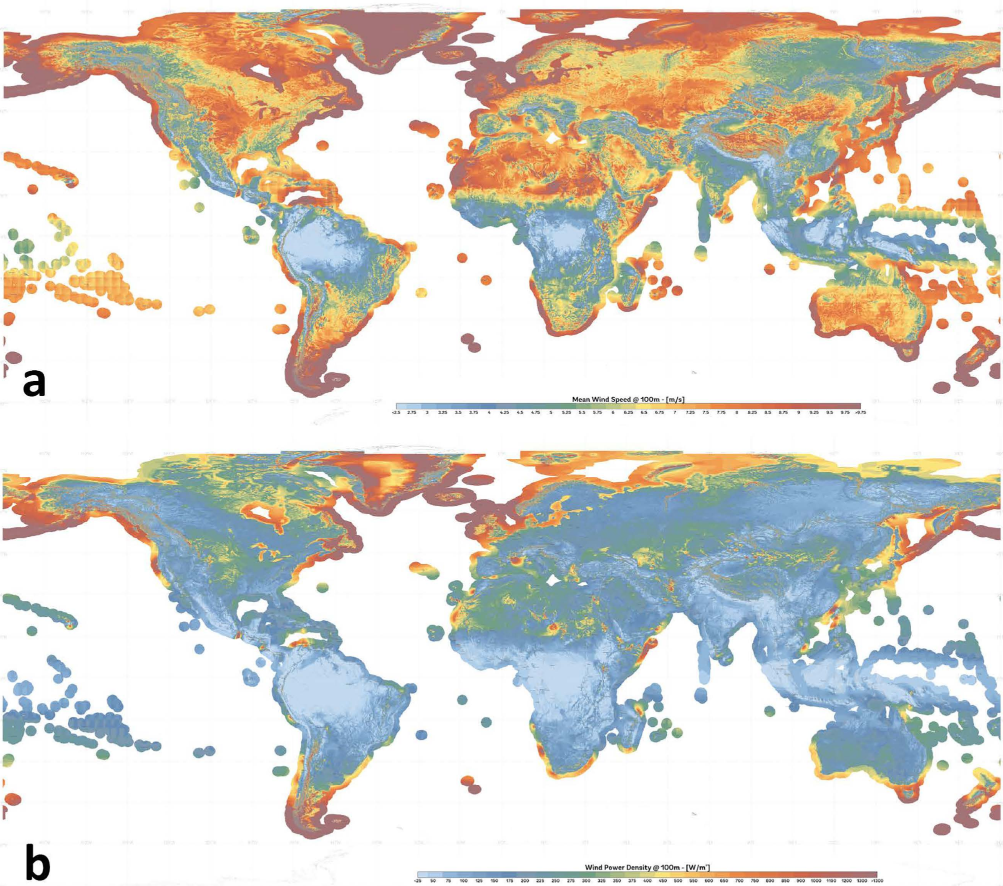

Figure 2.6.8 Wind resource map. (a) Map of wind speed. (b) Map of wind power density.
Source: (Global Wind Atlas, n.d.).

common rely on three turbine blades and aerodynamic lift to generate rotation around a horizontal axis. In this configuration, the amount of wind power (Equation 1) is determined by the circular sweep area, A, which has square relationship with the length, r, of the turbine blades (i.e. $A = \pi r^2$). This means that doubling the blade length, r, accesses four times more wind power. Furthermore, as the turbine height is also generally increased, it may access higher and more stable wind speeds (Figure 2.6.7). These physical properties provide larger three-bladed wind turbines with energy and cost advantages over smaller wind turbines, driving the industry towards ever larger wind turbines.

There are a range of different wind turbine configurations (Figure 2.6.9). Horizontal axis wind turbines have to continuously turn to face the direction of the wind, while vertical axis wind turbines can rotate regardless of the direction of the wind. Darrieus turbines rely on aerodynamic lift, while Savonius rely on aerodynamic drag. Up-draft towers (Schlaich et al., 2005) use solar energy to heat air within an enclosed space that moves through a tower. The heated air passes through a turbine and runs an electric generator. These vertical

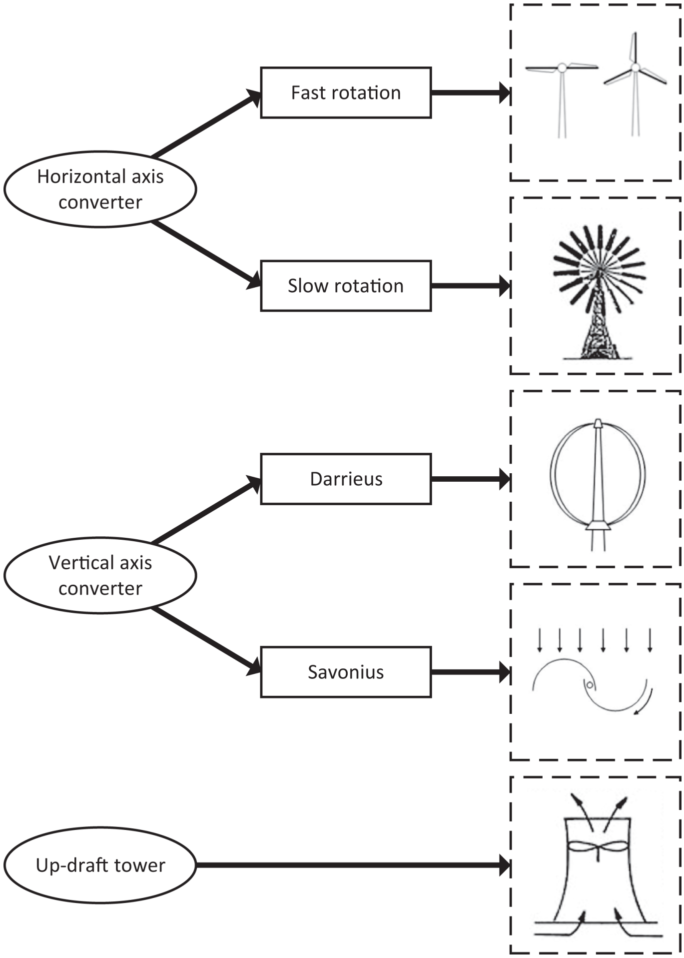

Figure 2.6.9 Different wind turbine configurations.
Source: Adapted from Wagner (2017) and Kalogirou (2014).

and up-draft configurations are capable of generating electricity from the wind; however, they lack the dimensional advantages compared to three-bladed horizontal axis wind turbines when scaling up their energy output.

However, as the size of onshore wind turbines increase, there is a corresponding impact on land use and visual and noise pollution to surrounding communities. Rotating blades cause flickering shadows that extend far beyond the site of installation (Knopper et al., 2014). Obtaining social licence has therefore become a significant requirement for their continued deployment. Furthermore, rotating blades may pose an additional risk to avian mortality, requiring mitigation measures (May et al., 2015).

Offshore wind turbines offer an alternative located farther away from communities and wildlife and access to faster and more consistent wind speeds (Bilgili et al., 2011). However, it introduces additional technical challenges and costs driven by underwater depth and the corrosive and unpredictable marine environment. As these additional costs may be overcome with even larger wind turbines, offshore wind turbines have become the largest in the world (IRENA, 2019).

Hydro-energy

As water bodies are heated across the Earth's surface, the evaporated water travels through the atmosphere and eventually returns to the surface as rainfall. Only 20% falls back on land (Figure 2.6.10) and the rest over the ocean. If this water is deposited at high altitudes, it creates an opportunity to extract the potential energy as water is returned to sea level.

Hydro-energy resources are therefore linked to the amount of rain and snow fall in a region, the amount of water from rain or ice melt that can be captured, and the vertical distance it has to travel. As rain and snow fall is influenced by changes in short- and long-term weather patterns, hydro-energy resources are susceptible to changes in the climate.

Hydro conversion technologies

Hydroelectric dams

Hydroelectric dams are currently the largest source of renewable energy generation globally (IEA, 2021d). It is a mature technology designed to operate for 50–100 years. An upstream

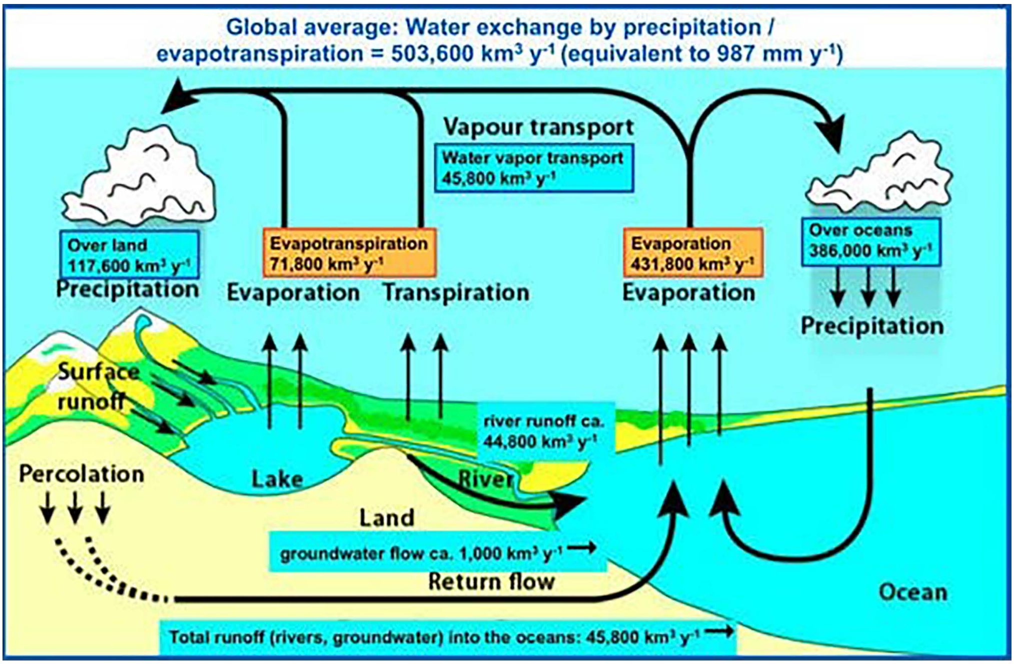

Figure 2.6.10 The hydro cycle.

Source: (Levizzani & Cattani, 2019).

dam is used to create a large reservoir of water connected via under- or over-ground pipes to a location at a lower altitude (Figure 2.6.11a). As the water flows downhill, it passes through one or more turbines that rotate generators at a powerhouse to produce electricity.

As a mature technology, there are fewer opportunities to reduce costs, especially since most costs relate to construction and materials. As new locations have become more challenging to construct, overall costs have been slowly rising (IRENA, 2021). Hydroelectric dams, however, are well-suited to complement the intermittency of other renewable energy technologies (e.g. wind and solar) as it can start quickly and its energy output can be tightly controlled.

It is, however, not suitable for all regions, as a significant amount of water is required for the upper reservoir with a sufficiently large altitude difference to a nearby downstream location. The inundation of the natural landscape leads to habitat loss and potential relocation of entire communities. Inundated vegetation also decomposes and releases methane, a potent GHG. An entire river system is also affected, as previously free-flowing water is impeded, affecting fish migration and erosion and sedimentation upstream and downstream of the dam. As the flow of freshwater is controlled, the dam has to also consider downstream water use, which has geopolitical consequences for water flowing into other nations and territories (Chen & Swain, 2014).

Pumped hydro-energy storage

Pumped hydro-energy storage uses a similar fundamental principle as hydroelectric dams. However, by adding a pump station and a lower reservoir to retain a certain amount of water, water can be returned to the upper reservoir and used to generate electricity at a later point in time (Figure 2.6.11b). Energy losses incurred as water is pumped and then subsequently used to generate electricity requires the market value of electricity when generating to be substantially higher than the cost of electricity while pumping (i.e. a sufficient price spread). This makes pumped hydro-energy storage facilities especially suited to provide power during times of high electricity demand, when prices are also high for short periods of time. As pumped hydro facilities only require an upper and lower reservoir, freshwater is not necessary, which expands the range of viable locations (Stocks et al., 2021) from using seawater (Rehman et al., 2015) to disused mine pits (Pujades et al., 2017).

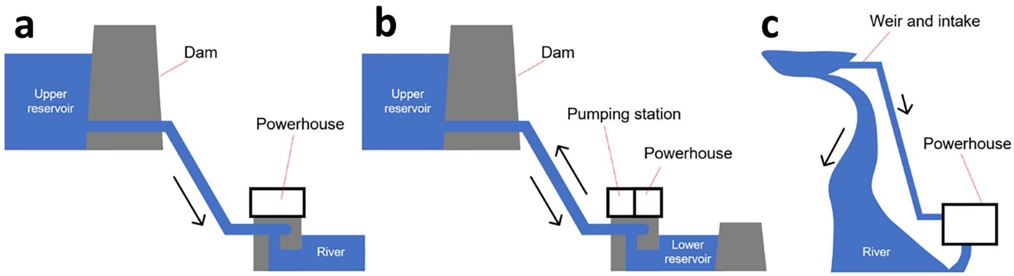

Figure 2.6.11 Hydro-energy power plant configurations. (a) Hydroelectric dam. (b) Pumped hydro-energy storage. (b) Run-of-the-river.

Source: Author.

Run-of-the-river

Run-of-the-river systems do not require large dams, but instead rely on high rates of water flow (Figure 2.6.11c) over a relatively low height difference. As it is primarily driven by the available water flow with limited reservoir storage, its electricity generation is more intermittent compared to a hydroelectric dam. However, its smaller reservoir capacity minimises inundation upstream and subsequent erosion and sedimentation. Though low vertical heights reduce the electrical power output, it increases the locations available for deployment and may be cost-effective if there are consistent and reliable water flows.

Biomass energy

The extraction of energy from biomass is known as bioenergy. Biomass is any material produced by living organisms and includes plant and animal matter. Plant matter arises from photosynthesis that converts solar radiation, water, and carbon dioxide into energy stores (i.e. sugars, cellulose, and oils). Plant matter enters the food chain via animals and leads to further by-products (i.e. organic waste) that can also be used for energy. All biomass contains carbon originally extracted from carbon dioxide already in the air. As energy is extracted from biomass, this carbon dioxide is returned to the atmosphere.

Bioenergy facilities are heavily reliant on a constant supply of biomass to operate and are better suited in regions where significant quantities of biomass are already being produced. Also, biomass products have much lower energy and bulk density than fossil fuels (Figure 2.6.12), which can make long-distance transport cost-prohibitive. This limits the

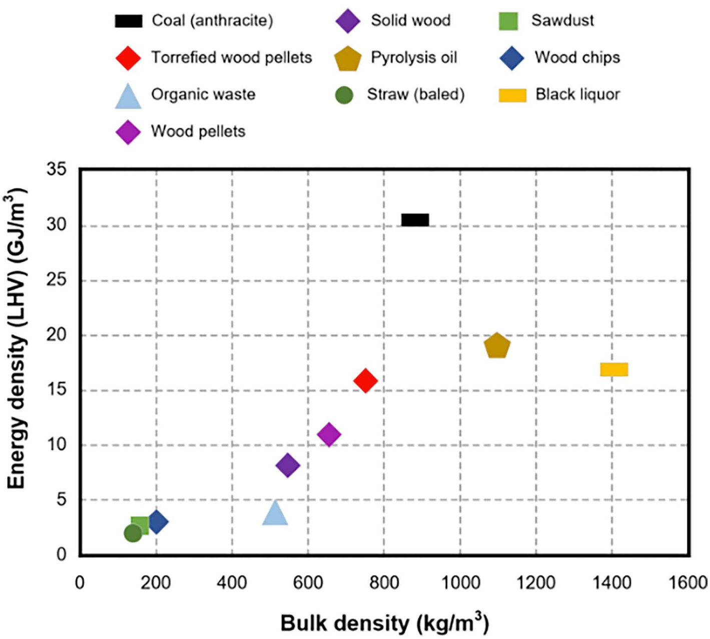

Figure 2.6.12 Comparison of biomass densities with respect to coal.

Source: Adapted from IEA (2012).

cost-effective distance between biomass and bioenergy facilities and leads to many bioenergy plants being located near their biomass resources. The growth of biomass production, however, can also drive changes in land-use that can further impact biodiversity (Immerzeel et al., 2014; Núñez-Regueiro et al., 2021).

Biomass conversion technologies

The techniques to extract bioenergy from biomass may be broadly classified as thermochemical, biochemical, and direct chemical pathways (Figure 2.6.13).

Thermochemical

The traditional approach to extract energy from biomass is **combustion**. By burning biomass (e.g. wood chips, bagasse) in a furnace, it releases thermal energy to produce steam and operate an electric generator. Another approach is **gasification**, which begins with a partial combustion of biomass to form syngas (predominantly hydrogen and carbon monoxide), which is then combusted to produce electricity. Waste-to-energy facilities utilise either gasification or combustion to consume municipal waste and produce electricity and heat (Belgiorno et al., 2003; Shareefdeen et al., 2015). **Pyrolysis** focuses on the partial combustion of biomass to form other energy products, namely bio-oil, syngas, and charcoal that can be used as an energy source or chemical feedstock for other industrial processes (Mohan et al., 2006). Bio-oil, for instance, can be further processed to create biodiesel.

While the combustion of biomass releases the carbon dioxide originally absorbed from the atmosphere, it is not always considered carbon neutral. Carbon neutrality assumes either (i) the biomass was grown specifically for bioenergy or (ii) new forests are grown to compensate for the amount of biomass being consumed. As (ii) is most commonly used, there is a heavy reliance on commitments to continually maintain these new forests over many decades without increasing the overall amount of land use. As this has not always occurred, the distinction of carbon neutrality differs by jurisdiction (Johnson, 2009; Zanchi et al., 2012).

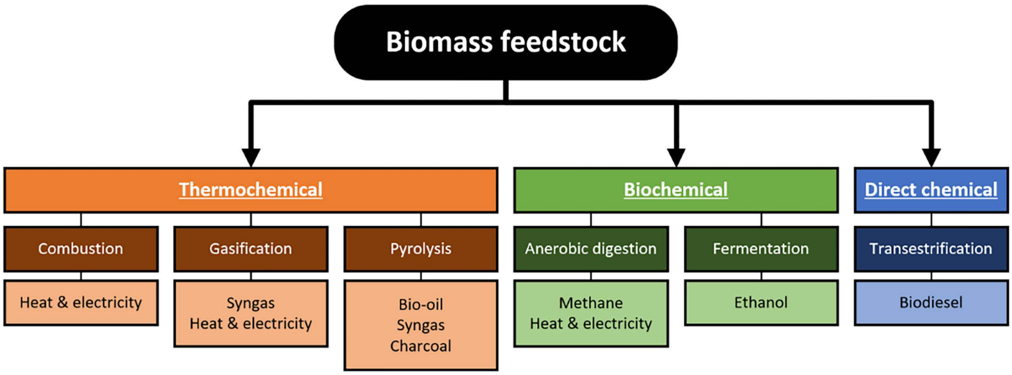

Figure 2.6.13 Biomass energy conversion pathways.

Source: Adapted from IEA (2007).

Biochemical

As methane is produced via **anaerobic digestion** from microorganisms breaking down organic matter (e.g. crop residues, food scraps, and human and animal wastes) in an oxygen-free environment, it can be collected and combusted in a gas engine to generate electricity. Another approach is yeast **fermentation** to converts biomass sugars into ethanol. Ethanol can then be blended into petroleum or used directly in neat ethanol engines (Nagarajan et al., 2002) to reduce fossil fuels in the transport sector.

As fermentation has historically used food crops (e.g. corn, cassava, sugarcane) for energy, it can negatively impact global food security (Kline et al., 2017; Tenenbaum, 2008; Popp et al., 2014) as it competes for the same agricultural land and resources. Second-generation fermentation processes (e.g. Rastogi & Shrivastava, 2017) are being developed that produce ethanol through non-food biomass, such as cellulose.

Direct chemical

Vegetable oils can be converted into biodiesel and glycerol through a **transesterification** process that combines plant oil with alcohol and a catalyst. Common biomass feedstocks for transesterification include oilseeds (e.g. soybean, sunflower, canola) and waste cooking oil (Abbaszaadeh et al., 2012). Similar to fermentation, oilseed production competes for the same agricultural land and resources as food production, which impacts global food security.

Geothermal energy

The Earth generates heat that radiates toward the surface via the decay of radioactive isotopes residing within its core. As the rate of heat transfer is affected by the underlying geology, the temperature at a given depth varies by region (Figure 2.6.14). However, on average, the geothermal gradient is approximately 25–30°C/km (Figure 2.6.14). To extract this thermal energy, a thermal transfer fluid (typically water) is circulated to a specific location underground. There are three general depth classifications for geothermal energy resources: *shallow* (0–100 m), *intermediate* (0.1–4 km), and *deep* (4–5 km).

At *shallow depths*, the ground acts as a large thermal mass that interacts with changes in surface temperatures. Since the temperature remains relatively constant (e.g. Larwa, 2019), there is an opportunity to utilise differences between surface and ground temperatures for heating and cooling applications.

At *intermediate* depths there is enough energy to heat water in aquifers into steam or pressurised hot water. The heated water or steam acts as a thermal transfer fluid as it travels to the surface, which can then be used to produce energy via geothermal power plants. However, very specific geological conditions and an abundance of natural water are required, which makes these hot sedimentary aquifers highly location dependent.

At depths classified as *deep*, there is an absence of groundwater but greater thermal energy. These hot, dry rock resources are more common than hot sedimentary aquifers, which increases the regions suitable for geothermal power. However, the lack of groundwater means that these hot rocks need to be fractured to become sufficiently permeable, such that surface water pumped into these depths can be heated and returned to the surface (Moska et al., 2021).

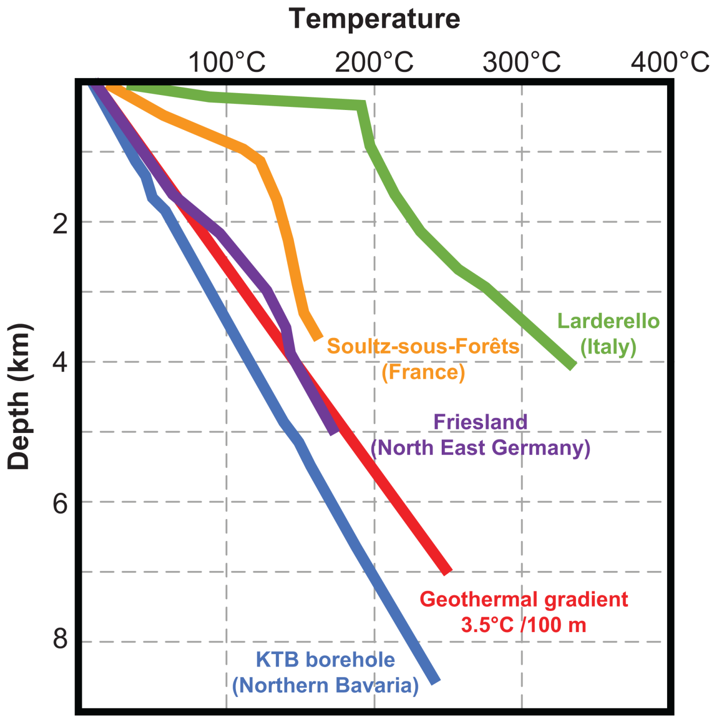

Figure 2.6.14 Temperature profile of the Earth's crust.

Source: Adapted from Bassfeld Technology Transfer (2009).

Geothermal conversion technologies

Geothermal power plants

Geothermal power plants are designed to convert the thermal energy from heated water or steam from *intermediate* or *deep* geothermal wells into electricity. There are three main types of geothermal power plants (Figure 2.6.15).

Dry steam power plants use steam directly from a geothermal well to rotate a steam turbine and electric generator. However, they generally require steam above 150°C to operate. **Flash steam** power plants are the most common and use pressurised hot water instead of steam. The pressurised hot water enters a flash tank where the atmospheric pressure is lowered, causing water to quickly vaporise into steam which then powers a steam turbine and electric generator. **Binary cycle** power plants are designed to operate with lower temperatures by using the heated water to boil a working fluid with a boiling point lower than water. This vapour then rotates a turbine that powers an electric generator.

By returning the cooled water back underground to recharge the aquifer, geothermal power plants can provide a near-continuous source of low-cost renewable electricity (IEA, 2021e). As its output can be tightly controlled, it is well suited to complement the intermittency of other renewable energy generators (i.e. wind and solar). However, as locating and establishing geothermal wells involve significant project risks and upfront costs, geothermal power plants have only had limited deployment to date (REN21, 2021).

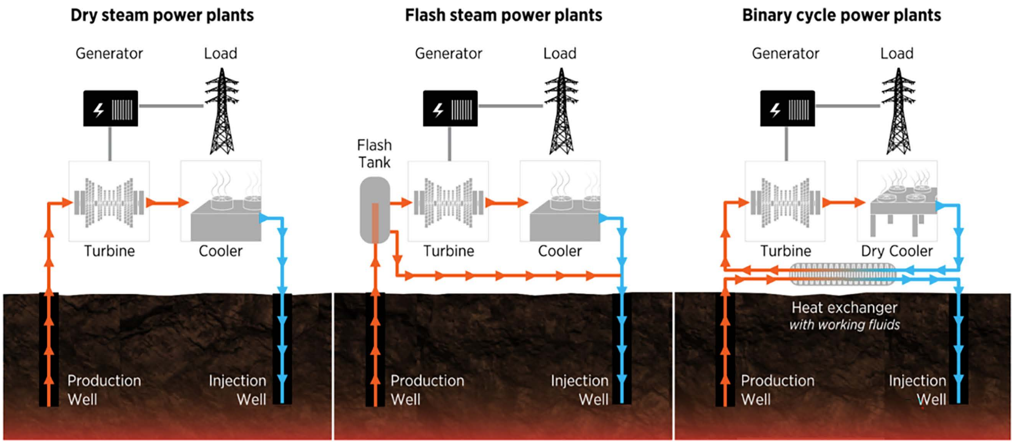

Figure 2.6.15 Geothermal power plant configurations.
Source: (U.S. DOE, 2019).

Geothermal steam also contains other gases and liquids, and their release can have environmental and social implications (Kristmannsdóttir & Ármannsson, 2003). These gaseous compounds include GHGs (carbon dioxide and methane) and also hydrogen sulphide that has an unpleasant smell and is toxic in moderate concentrations. Liquids may also include a range of metals and salts that can harm the surrounding environment if disposed of incorrectly. However, compared to other renewable energy technologies, the overall environmental impact remains relatively low. For those regions with readily accessible geothermal resources, geothermal power plants can offer a promising low-cost pathway.

Tidal energy

Two significant gravitational forces act upon Earth, namely the Moon and the Sun. Firstly, the oceans facing the Moon bulge out near the equator due to higher gravitational attraction, and the oceans farthest from the Moon bulge out due to lower gravitational attraction (Figure 2.6.16). As the Earth completes a rotation relative to the Moon, a location on Earth experiences two high tides and two low tides.

The Sun is another gravitational force that magnifies the tides. When it is in line with the Earth and Moon, it further increases the gravitational force acting upon the oceans (i.e. spring tide). When the Sun is perpendicular to the Earth and Moon axis, then the Sun's gravitational force does not increase the tides (i.e. neap tide). Since phases of the Moon correspond to Sun-Moon positions, spring tides occur during full and new moons, while neap tides occur during the first and third quarter phases.

With tides driven by gravitational forces, they are a predictable energy resource. However, as the amount of tidal energy continually changes over the course of each day, it provides less complementarity than hydro or biomass energy resources. Furthermore, as the change in the ocean's height (i.e. tidal range) is influenced by equatorial proximity and the coastline, tidal energy remains highly location dependent (Figure 2.6.17).

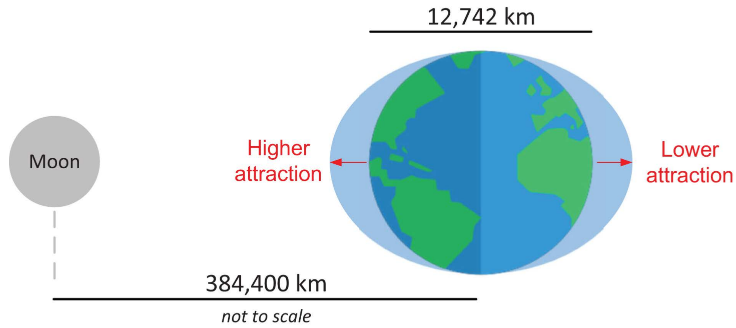

Figure 2.6.16 Effect of the Moon on the tides.
Source: Author.

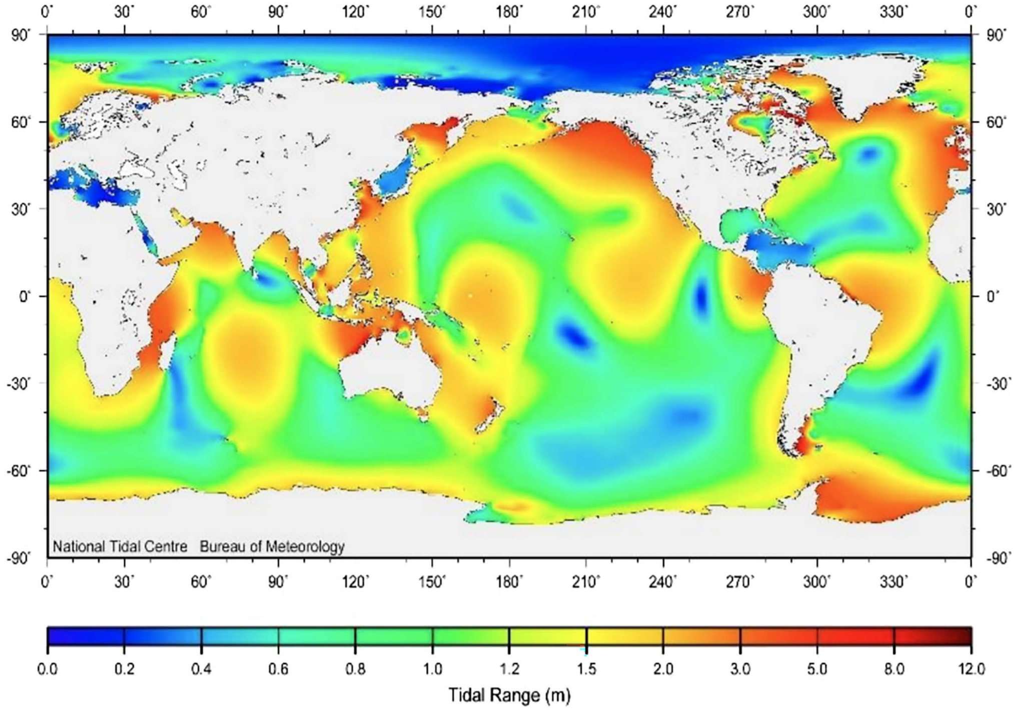

Figure 2.6.17 Map of tidal ranges.
Source: (Matthews, 2014).

Tidal conversion technologies

Tidal ranges offer two forms of energy, namely potential energy as the tide rises and falls and kinetic energy as the tide moves in and out of the shoreline. These correspond to the two types of tidal energy extraction technologies.

Tidal basins utilise reservoirs to trap a tide (Bae et al., 2010; Retiere, 1994) and extract its potential energy. As the tide recedes, seawater is released back into the ocean through gated tunnels that rotate hydro turbines, generating electricity. As the tide rises, seawater enters the reservoir through these gated tunnels to generate electricity once again. As relatively static structures, they have operational lifespans extending beyond 50 years, but only a few tidal basins have been constructed to date. As the free flow of seawater is affected, there are impacts on the surrounding environment. Retiere (1994) observed that La Rance tidal power plant initially reduced water quality and flora and fauna within the basin until the ecosystem found a new equilibrium. **Direct extraction** involves the use of underwater turbines, akin to wind turbines. Underwater turbines capture energy from the mass of moving seawater as the tide moves into and away from the shoreline. As seawater has ~800 times more mass than air, underwater turbines do not have to be as large to extract significant energy. However, given the challenges of a corrosive marine environment, more advanced materials and operating strategies are required. Their design, however, provides greater flexibility with positioning, with trials underway utilising the seabed (Simec Atlantis Energy, n.d.) to floating structures (Orbital Marine Power, n.d.).

Wave energy

As the wind blows over the ocean, waves are generated. The size of the waves depends on the distance, speed, and length of time the wind travels across the ocean surface without being obstructed. As waves travel thousands of kilometres in a constant direction, it leads to vertical changes in height across the water's surface that can be converted into energy near the shore. A range of mechanical systems are undergoing trials to extract this potential energy (Figure 2.6.18).

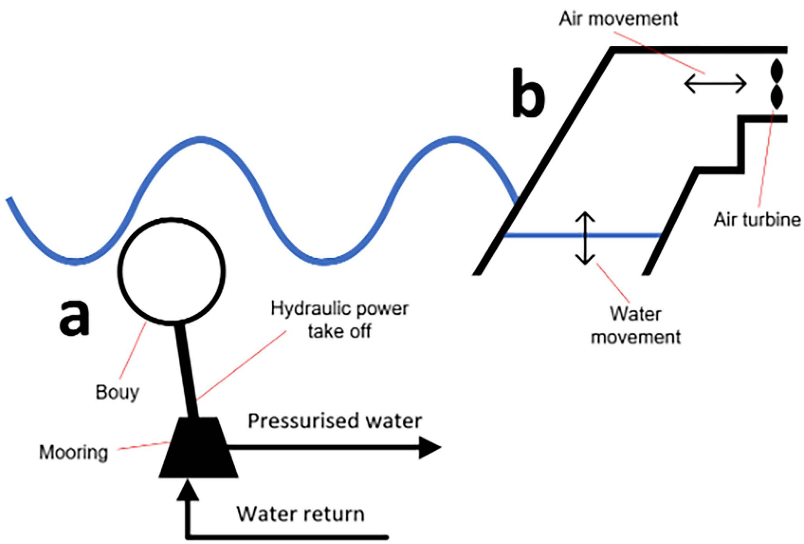

Figure 2.6.18 Types of wave conversion power plants. (a) Floating. (b) Oscillating water column.

Source: Author.

Wave conversion technologies

One wave extraction device undergoing commercialisation is a **floating** system (Figure 2.6.18a). Waves cause a buoy to move, which in turn pressurises water within a one-way piping system. By passing pressurised water through a hydro turbine, electricity is generated (Carnegie Clean Energy, n.d.; Shi et al., 2016; Beirão and dos Santos Pereira Malça, 2014). Another device is an **oscillating water column** (Figure 2.6.18b) that utilises a partially submerged chamber with a single air duct (Falcão & Henriques, 2016). As the waves interact with the chamber, the air within the chamber moves back and forth through the duct. By placing an air turbine in the duct, electricity can be generated. Other designs have been prototyped, from snake-like Pelamis wave machines (Zhang et al., 2018) to over-topping sea walls that act as small hydro dams (Buccino et al., 2015) but they were unable to reach commercial maturity.

With many remote coastal locations relying on high-operating-cost diesel generators for energy, wave energy devices may eventually provide an alternative and lower-cost source of renewable energy.

Pivoting towards renewable energy

Decarbonisation of the electricity system

With the majority of renewable energy technologies designed to generate electricity, the electricity system is the most straightforward energy sector to decarbonise. However, the supply of electricity must meet demand at all times, even as demand fluctuates in line with the changing needs of its electricity customers. Typically, only the lowest-cost generators that can meet this demand generate while all other generators do not. This creates a financial incentive for more generation capacity when there is a shortfall of supply, resulting in high revenues, and a disincentive when there is an excess of supply (lower or no revenues). Furthermore, sufficient generation capacity needs to be available at all times to avoid rolling blackouts.

Traditionally, large fossil fuel power plants were the lowest-cost generators, leading to an electricity network designed around very large generators transmitting electricity to many customers. However, as renewable energy resources are varied and widely dispersed, an electricity network incorporating renewable energy technologies also has to become more dispersed and capable of supporting a wider range of generator types. Furthermore, as deploying renewable energy technologies is capital intensive and involves long operational lifespans, the choice of which technologies to deploy today must also consider the magnitude and degree of accessibility of each renewable energy resource, the level of future electricity demand, competition from other generators, and spare transmission capacity. At present, wind turbines and solar PV technologies have become the cheapest way to generate electricity in many countries (IEA, 2021c). However, as they are intermittent energy generators, additional infrastructure is required to address the challenge of matching supply with demand. One option is to broaden the pool of renewable energy resources such that they complement one another by generating at different times (e.g. geothermal power plants to cover shortfalls from wind turbine generation). Other options include building more energy storage (Schill & Zerrahn, 2018), overbuilding renewable energy capacity (Perez et al., 2019), and creating supergrids that incorporate a wider geographical area of complementary renewable energy resources (Gellings, 2015).

The technicalities of electricity system decarbonisation require a range of renewable energy technologies, which may result in substantial land use that impact surrounding communities and the environment. This means energy decarbonisation is not just about feasible technical and economic solutions but also about determining acceptable socio-environmental trade-offs, such as: How far should onshore and offshore wind turbines be from communities to mitigate noise and visual pollution? Can transmission lines between regions of "high renewable energy potential" and regions of "high electricity demand" be built through densely populated areas? What is an acceptable level of impact to flora and fauna? How much arable land should be used for solar PV or inundated for a hydroelectric dam? How much food crop should be used for fuel? Electricity system decarbonisation requires answers to these and broader socio-political questions to determine when benefits outweigh costs and which technologies should be deployed over others.

Extending the role of the electricity system

The electricity sector only constitutes 17% of global energy demand (REN21, 2021), significantly less than the transport (32%) and thermal sectors (51%). As these other sectors heavily depend on fossil fuel (e.g. petroleum for transport, natural gas for heating), a range of new technologies is needed to establish a renewable energy pathway. As the electricity sector has the most readily available pathways to renewable energy resources, it should be expanded to supply the energy for these other sectors to decarbonise.

As identified in REN21 (2020), the **transport sector** has a limited range of decarbonisation options, namely, avoiding the need to travel to reduce demand and associated emissions, shifting towards less carbon-intensive and more efficient modes of transport (e.g. bus and rail), substituting fossil fuels for biofuels or e-fuels, and using electric powertrains via batteries or hydrogen fuel cells. From a whole-of-system perspective, each choice has further implications. Biofuels require significant quantities of fuel crops, which may displace food production and land use. When compared to direct electrification, hydrogen fuel cells and e-fuels incur large conversion losses, which would require significant additional renewable energy generation capacity (Ueckerdt et al., 2021). By avoiding conversion losses from intermediate forms of energy, direct electrification provides the most energy-efficient option. However, a limited quantity of these intermediate forms of energy (e-fuel or hydrogen) may still be required for certain transport applications that require much higher energy and/or volumetric densities to operate effectively (e.g. aviation).

In the **thermal sector**, fossil fuels are used across a range of heating applications from heating buildings to high-temperature industrial processes. Advancements in electricity-to-heat technologies may enable a significant portion of thermal demand to be electrified (Madeddu et al., 2020). Electric heat pumps have much higher energy efficiencies than natural gas or electric convection heaters and can provide temperatures under 100°C for space heating/cooling within residential and commercial environments. Advanced heat pumps can supply temperatures between 100°C and 200°C for a wider range of commercial and industrial applications while requiring less energy. As hydrogen can be produced from low-carbon energy sources and generate temperatures up to 2000°C, it could replace natural gas in industrial heating applications (Parra et al., 2019). Aside from the electricity-to-heat systems, thermal energy can also be obtained from other renewable energy technologies, namely geothermal (Lund & Boyd, 2016), solar thermal (Kumar et al., 2019), and biomass (Lenz et al., 2020).

The electrification of the transport and thermal sectors will require a substantial increase in the size of the electricity sector (Rogelj et al., 2018) that also increases the interconnections between these sectors. This creates interdependencies that can be used to complement how renewable energy is managed within the electricity system. To match electricity supply with demand at all times, the energy demand from the transport and thermal sectors can be used to respond to changes in supply (e.g. daytime electric vehicle charging to coincide with solar PV generation), which further increases renewable energy penetration and reduces additional infrastructure requirements. Furthermore, the interconnections between the electricity, transport, and thermal sectors broadens the range of options for storing and using energy (e.g. producing hydrogen or e-fuel enables renewable energy generation to be stored for seasonal changes in energy demand). It also allows renewable energy to be exported to other countries that do not have enough local renewable energy resources, such as Germany (BMWi, 2020).

The challenge of moving beyond fossil fuels

Fossil fuel demand is driven by technologies that society uses to satisfy its energy needs. At present, the electricity and thermal sectors heavily rely on coal and natural gas, and the transport sector on oil. The increased deployment of renewable energy technologies directly impacts the demand for fossil fuels and global production capacity. The level of impact, however, depends on which pathways are taken towards decarbonisation and the scale of future energy demand. If energy demand increases faster than the decarbonisation of the energy system, then the overall use of fossil fuels may increase. Therefore, political commitments such as COP21 (2015) provide an important long-term signal to discourage future dependence and subsequent investments in fossil fuel technologies, while also encouraging further renewable energy technology investment and integration.

A pivot away from fossil fuels towards sustainable and renewable sources of energy requires a broad reconfiguration of the global energy system that cannot be limited to a handful of countries. It is important that renewable energy adoption and decarbonisation pathways are made as technologically feasible, cost-effective, and socially acceptable as possible, while simultaneously taking steps to reduce society's demand for energy. Only with these technologies in place can the global demand for fossil fuels begin to decrease. With electricity being the most cost-effective sector to produce renewable energy, global coal consumption has been falling since 2014 (BP, 2021). However, as natural gas power plants can provide flexibility to manage the intermittency of wind and solar generation, they have been more resilient. Battery energy storage technologies (which are location independent) are becoming increasingly cost-competitive and may reduce the need for more natural gas power plants. In the transport sector, electric vehicles are providing a pathway to reduce future oil demand, but much greater adoption is still required (REN21, 2020). The thermal sector is the most challenging as it requires further advancements in heat pump technology and significant cost reductions in hydrogen production for industry to transition away from well-understood fossil fuel–driven industrial and chemical processes. Continued research into nuclear fusion, which fuses hydrogen into helium to produce heat (Gibney, 2022) and electricity (via a steam turbine and generator), may bring low-cost fusion power into reality; however, until then renewable energy technologies remain the most feasible and cost-effective option (IEA, 2021b).

Conclusion

Societies depend on energy systems to function, but historical reliance on fossil fuel technologies has led to significant GHG emissions and climate change (IPCC, 2021). For the global electricity, transport, and thermal energy sectors to decarbonise, significant growth in renewable energy generation technologies and energy storage will be required, along with a tighter integration between all energy sectors. Continued cost reductions of wind turbine and solar PV technologies have made renewable energy generation cost-competitive with fossil fuel energy generation.

However, as the endowment of renewable energy resources in each region varies, a different mix of renewable energy technologies is required for every region. Therefore, retooling the global energy system will require careful consideration from decision makers to establish trade-offs between the technical, social, economic, and environmental consequences that are acceptable by wider society. As challenging as that may be, inaction will allow global GHG emissions to grow unabated, consuming our remaining carbon budget and leading to significant increases in global temperatures (IPCC, 2021).

Fortunately, our planet has sufficient renewable energy resources to supply global energy demand many times over, but the challenge remains: How can we hasten the transition to an energy system that emits much lower GHG and leave the legacy of cheap fossil fuels as a distant memory? An important part of this challenge can be addressed through renewable energy thinking and technology development in sustainability education development.

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2.7

LESSONS FROM ASSESSING SUSTAINABILITY IN THE MINING AND RESOURCES SECTOR

Michael Tost

Key concepts for sustainability education

- With the transfer from "weak" to "strong" sustainability comes the view that natural capital is limited and cannot be transferred into other forms of capital.
- Mineral raw materials are a form of natural capital that in general is not renewable and also has no ecosystem functions. Hence, can we use this form of natural capital sustainably?
- The non-renewability of mineral raw materials should not be the focus of sustainability education, at least for the foreseeable future, but rather the impact of their extraction on renewable resources/the planetary boundaries as well as society, as also described in other chapters of this Handbook.
- Despite the transformation to an inclusive, circular and renewable economy, mining will still be needed – but it will need to look very different compared to today. Educators need to prepare their students to ask for this transformation and make it happen in a rather short period of time.

Introduction

For centuries, if not millennia, mining has been a source of great economic wealth. But on the other side of the coin, it has also caused social and environmental concerns. For example, the mining of silver and other metals in the German "Erzgebirge" made the region rich and made the "Silbertaler" (from which the word dollar originates) an important coin in medieval Europe. On the other hand, the production of the metals needed so much wood that in 1713 Hans Carl von Carlowitz, at the time the most senior mining official in Saxony, described in his book *Sylvicultura Oeconomica* (Von Carlowitz 1713) that only as much wood should be taken from the forests, as would regrow in the same period. Today, this is considered to be the birth of sustainability – and it was caused by mining's impact on the environment.

The "great acceleration" of economic growth after World War II (Steffen, Broadgate et al. 2015) meant that demand for mineral resources was growing exponentially (e.g.

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(Reichl and Schatz 2022)). This increase in production meant that mines became greater in number, were built in more countries around the world and grew larger. With this, the social and environmental consequences became more in number and more severe, leading to ever more conflicts – e.g. to name just two related to the largest mining companies in the world, BHP and Rio Tinto, Ok Tedi in 1984 and Bougainville Copper in 1989 – and putting ever more pressure on the industry to improve its social and environmental performance.

Based on these concerns, the CEOs of the largest mining companies came together in 1998 at the World Economic Forum in Davos, decided that a new approach to tackle these problems was needed and started the Global Mining Initiative (GMI). The Mining, Minerals and Sustainable Development (MMSD) review was launched to define what sustainable development should mean for the industry and how it could achieve it.

The report *Breaking New Ground* (IIED 2002) describes the key challenges faced by the mining industry, but also what its sustainable development principles should be (see the following box).

Economic sphere

- Maximize human well-being.
- Ensure efficient use of all resources, natural and otherwise, by maximizing rents.
- Seek to identify and internalise environmental and social costs.
- Maintain and enhance the conditions for viable enterprise.

Social sphere

- Ensure a fair distribution of the costs and benefits of development for all those alive today.
- Respect and reinforce the fundamental rights of human beings, including civil and political liberties, cultural autonomy, social and economic freedoms, and personal security.
- Seek to sustain improvements over time; ensure that depletion of natural resources will not deprive future generations through replacement with other forms of capital.

Environmental sphere

- Promote responsible stewardship of natural resources and the environment, including remediation of past damage.
- Minimise waste and environmental damage along the whole of the supply chain.
- Exercise prudence where impacts are unknown or uncertain.
- Operate within ecological limits and protect critical natural capital.

Governance sphere

- Support representative democracy, including participatory decision-making.
- Encourage free enterprise within a system of clear and fair rules and incentives.
- Avoid excessive concentration of power through appropriate checks and balances.
- Ensure transparency through providing all stakeholders with access to relevant and accurate information.

- Ensure accountability for decisions and actions, which are based on comprehensive and reliable analysis.
- Encourage cooperation in order to build trust and shared goals and values.
- Ensure that decisions are made at the appropriate level, adhering to the principle of subsidiarity where possible.

Since then, mining has progressed in many ways including its approach towards health and safety and towards community relations (Buxton 2012); (Franks 2015). However, our understanding of sustainability has also shifted – from the Rio declaration (WCED 1987) and the emergence of the three pillar model ("weak sustainability"), towards a stronger recognition of the environmental sustainability aspect, expressed through environmental limits ("strong sustainability"). In recent years, this "strong sustainability" position, or at least the parts of it related to natural capital as stated by Neumayer (2003), is becoming increasingly important on the societal agenda, given pressures such as climate change and biodiversity loss.

In their book *Pursuing Sustainability*, Matson, Clark, and Andersson (2016) describe that there is a commonality between the majority of these uses:

> A realization that our ability to prosper now and in the future requires increased attention not just to economic and social progress, but also conserving Earth's life support systems: the fundamental environmental processes and natural resources on which our hopes for prosperity depend.
>
> *(p. 2)*

They also move away from a needs-based approach focused on economic development towards one where the ultimate goal of sustainability is more generic - inclusive human development or flourishing (oftentimes coined as broader societal welfare or social well-being). Figure 2.7.1 shows the so-called MCA framework (named after the three authors) as one example of a framework for sustainability, describing the constituents (material needs being just one of them) and determinants of well-being.

The MCA framework describes five sorts of asset stocks or capital – human, natural, manufactured, knowledge and social – as the determinants of inclusive well-being; from these stocks and their dividends or flows (including ecosystem services, an important flow from natural capital), people now and in the future subsist and improve their lives. These determinants also make sustainability "measurable": sustainability, or sustainable development is achieved, when the overall stock of capital is grown, or at least sustained for future generations.

However, this also introduces another key aspect to the sustainability debate: the differentiation of weak versus strong sustainability. Under weak sustainability, each capital can substitute another ("substitutability paradigm"). Under strong sustainability, the build-up of capital is not completely interchangeable, but is limited by natural capital. This means environmental limits have to be considered in order to ensure environmental sustainability ("non-substitutability paradigm").

Whilst science might not (yet) have an answer as to which of these two paradigms is correct, Neumayer (2003) argued that "a combination of distinctive features of natural

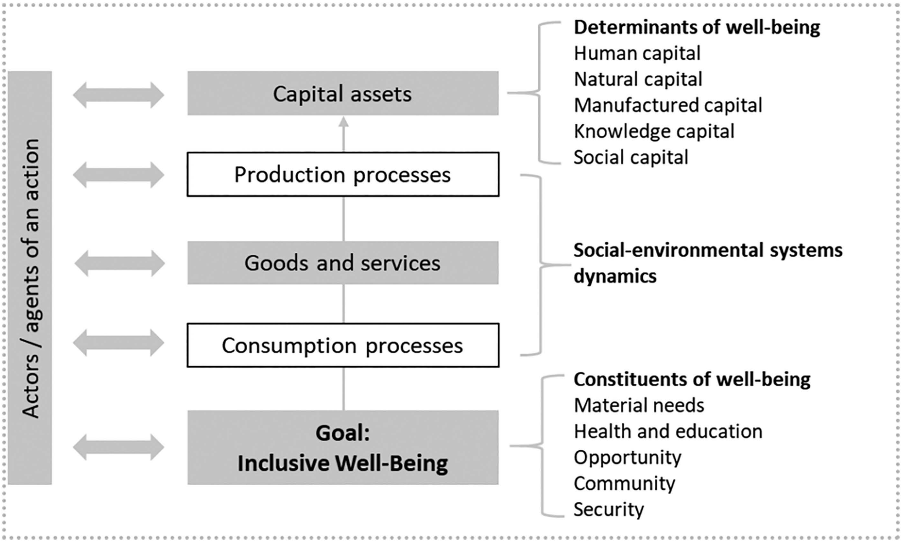

Figure 2.7.1 MCA framework for sustainability (adopted from Matson, Clark, and Andersson (2016)).

capital with the prevalence of risk, uncertainty and ignorance make a persuasive case for the preservation of certain forms of natural capital that provide basic life support functions" (p. 4).

In 2009, a group of earth system scientists, led by Will Steffen and Johan Rockström, published a concept called the planetary boundaries (Figure 2.7.2; Rockström et al. 2009). This framework "defines a safe operating space for humanity based on the intrinsic biophysical processes that regulate the stability of the Earth System" as a precondition for sustainability and thus introduces concrete environmental limits for the preservation of certain forms of natural capital. Worth noting is also that according to the authors, some of these boundaries, e.g. concerning biochemical flows, have already been breached.

It is in this context of strong sustainability, planetary boundaries and that humans are on the brink of breaching at least some of these boundaries that this chapter looks at mineral raw materials and their connection to sustainability. It is by no means conclusive, but tries to give an overview and dive into some key aspects. The focus of this chapter is on the "mining" process and not on the "products" (see later).

The issue of non-renewability

The Club of Rome published *The Limits to Growth* report in 1972, which states that "the earth's interlocking resources – the global system of nature in which we all live – probably cannot support present rates of economic and population growth much beyond the year 2100, if that long, even with advanced technology" (Meadows et al. 1972). Whilst much of the report concerned ecosystem functions and limits, it – together with the "oil shocks" following a few years later – certainly brought the issue of resource scarcity (e.g. "peak oil") and the non-renewability of minerals to the attention of the public.

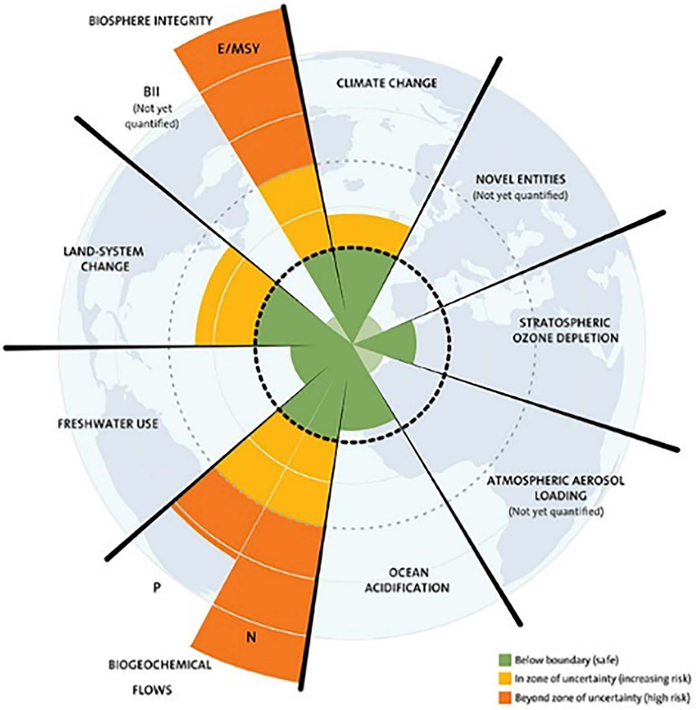

Figure 2.7.2 The planetary boundaries framework. (Licenced under CC BY 4.0. Credit: J. Lokrantz/Azote based on Steffen, Richardson et al. 2015.)

As shown in more detail later, the extraction of raw materials, including minerals, has grown significantly in recent years and is projected to continue to do so (IRP 2019). So how real is the issue of resource scarcity?

As part of the MMSD review (IIED 2002) project, this aspect of non-renewability was also looked at in more detail. The project looked at long-term availability for key minerals both from a physical/geological and economic perspective.

Geologically, minerals are not distributed equally within the Earth's crust, but they sit in so-called geological occurrences, which are concentrations of certain minerals. Exploration tries to find these occurrences and with increasing geological assurance and economic feasibility – following standards such as the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (the so-called JORC Code) – the occurrences become resources and reserves. MMSD looked at both resource and reserve estimates available at the time (these numbers are not static, but highly dynamic).

They also looked at additional economic factors that influence the availability of mineral resources such as secondary production and recycling – considering the fact that many mineral commodities are not destroyed after they are used, substitution potential, new sources beyond the Earth's crust (e.g. space mining) and the role of new technology (e.g. 3D seismics, autonomous equipment) to shift the borders of economic feasibility.

The MMSD concluded that the world was unlikely to face shortages of commercially important minerals at a global level in the next half-century. For projections beyond 50 years, the situation was considered less certain (IIED 2002). Other reviews in recent years came to similar conclusions. For example, Mohr and colleagues (Mohr, Mudd, and Giurco 2012) looked at the availability of lithium for battery production and concluded that even for their minimum estimate there was enough lithium to cover 80% of the demand in 2080.

However, scarcity and economic viability should not be the only factors to be considered when making the decision whether or not to mine. Factors such as product stewardship (e.g. Should steel be used to make tanks? Should we mine at all for luxury products such as diamonds?), intergenerational justice (extract the mineral today vs. in the future) and, above all – and same as for the mining process – the impacts on sustainability of the mineral products *and* their usage along the entire value chain should be considered (which goes beyond the scope of this chapter).

Looking into the future, the sustainability and energy transitions already underway mean that humans will have to move from a fossil fuel–based economy towards an inclusive, circular and renewable economy. Ideally, such an economy would recycle its mineral raw materials and therefore not need mining anymore. But is this feasible? At least not for the foreseeable future. There are qualitative constraints (e.g. different alloy components in steel impact the quality of recycled steel) which will require us to consider "design products for recycling" more than is currently the case. More importantly, the transition to such an inclusive, circular and renewable economy will be fully based on and enabled by minerals and metals. Hence, their growth in demand will continue (IRP 2019). For example, aluminium, steel and aggregates are crucial for wind farms, as are niobium, boron, and rare earth elements (neodymium, dysprosium, praseodymium) for wind turbine generators when a permanent magnet generator system is used. Solar photovoltaic (PV) technologies use boron, germanium, silicon, gallium and indium (EC 2020). Lithium, graphite and manganese are just a few examples of the materials needed for energy storage in batteries, and metals such as copper, nickel and molybdenum are used for all of these technologies.

But what does this increased demand for minerals and metals mean for the mining industry?

Why does mining matter?

The impact of mining has been an issue for a long time. For most of this time, however, these impacts have been mainly local such as deforestation (e.g., as already described in Saxony/Germany), water pollution (e.g., Rio Tinto/Spain) and soil contamination (e.g., in Bleiberg/Austria). Today, largely due to the "great acceleration" of economic growth after World War II (Steffen, Broadgate et al. 2015) and ever-increasing globalisation of trade, global mining is increasing significantly (e.g. (IRP 2017) and environmental pressures such as land and water use, as well as related environmental and social impacts, have become an issue of worldwide relevance. There is an expectation that this trend will continue in alignment with society's increasing demand for raw materials. Yet the question remains: how big is this issue?

The "great acceleration" has led to tremendous growth in the demand for mineral resources. More generally, it has led to tremendous global growth in gross domestic product (GDP) and population. Global population grew 5-fold to almost 8 billion (UN 2022), materials consumption grew 10-fold and global economic output as measured by GDP grew more than 20-fold, as shown in Figure 2.7.3.

Looking into raw materials in more detail, in the last 50 years their extraction more than tripled to over 90 billion tonnes in 2016, with non-metallic minerals (i.e. construction

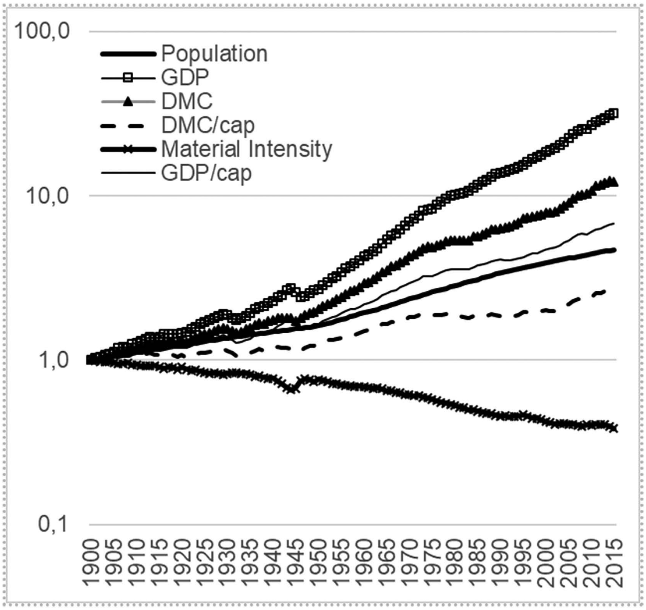

Figure 2.7.3 Development of materials use (DMC), population and GDP, based on data from (Krausmann et al. 2018).

materials such as sand and gravel) showing the largest increase, growing more than five-fold (Figure 2.7.4). The International Resource Panel (IRP) predicts that this growth will continue to 2060; depending on how strongly the world will move towards sustainability, it will be two- to three-fold.

As a consequence, at least some of the environmental and social impacts as described in the GMI now also matter on a global scale. In his book *Mountain Movers*, Daniel Franks (2015) provides a detailed overview of the current status of sustainability in the mining industry, based on the GMI and including a chapter on environment. It provides a good overview of current initiatives (e.g. related to environment, the cyanide code) and trends, i.e. stating that making progress on CO_2 and water reductions will be a challenge with declining ore grades and that the industry, through the International Council on Mining and Metals (ICMM) and a partnership with the International Union for Conservation of Nature (IUCN), has made good progress on biodiversity with the potential to lead to positive impacts. The book concludes that whilst progress has been made, it is slow, has not been reaching throughout the whole mining industry and needs a renewed effort, possibly linked to the United Nations Sustainable Development Goals (SDGs).

Numbers concerning the global environmental impacts of mining are hard to find. The author of this chapter did some calculations regarding CO_2 emissions, water and land usage from mining four key metals (bauxite/aluminium, iron ore, copper and gold) (Tost et al. 2018). He and his colleagues came to the following conclusions.

Global CO_2 emissions from fossil fuels and industry for 2016 are estimated at about 36 Gt (Global Carbon Atlas 2018), which means that the mining of bauxite, copper, gold and iron ore contributes approximately between 0.4% and 0.7% to these CO_2 emissions. Considering only fossil fuel combustion, the International Energy Agency (IEA) estimates

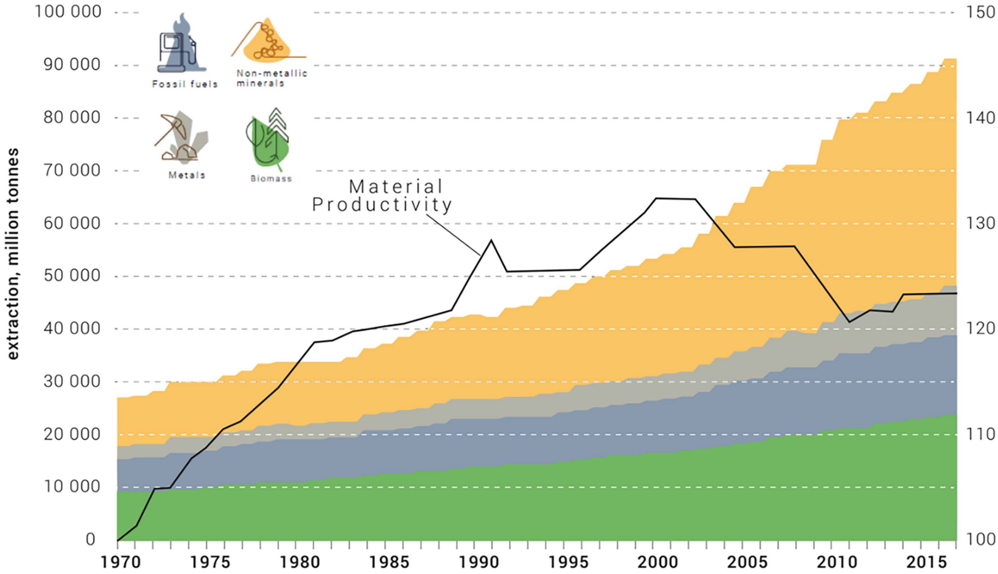

Figure 2.7.4 Raw material extraction from 1970 to 2016 (IRP 2019, p. 43).

CO_2 emissions at 32 Gt (IEA 2017), of which 36% can be attributed to industry (p. 12). Using this as a baseline, mining of these four metals contributes between 1.3% and 2% of all industrial emissions. The picture changes completely in consideration of the downstream, highly energy-intensive processes for iron ore/steel and bauxite/aluminium, where emissions for 2016 were about 3.1 Gt (World Steel Association 2017, 4) and 1 Gt (World Aluminium 2017).

The sum of the global water withdrawals is estimated with an average of about 4850 mm^3. To put these numbers into a global context, the Food and Agriculture Organization (FAO) of the United Nations estimates the global water withdrawal for 2010 as almost 4000 Gm^3, with industrial withdrawals accounting for about 19% (FAO 2014). Assuming the same growth rate as in the years 1900–2010 of about 31 Gm^3 per year for the years 2010–2016, bauxite, copper, gold and iron ore mining is in a range of 0.09% and 0.15% of global water withdrawals and 0.46% and 0.78% of industrial withdrawals. Same as for CO_2 emissions, this changes significantly if downstream water withdrawals for steelmaking (estimated at 45.8 Gm^3 based on (World Steel Association 2015, 4) and aluminium production (estimated at 1.3 Gm^3 based on (World Aluminium, 2017, appendix A) are considered.

Land use for mining these four metals is not considered significant at the global scale. A total of 318 km^2 were newly disturbed by mining of bauxite, copper, gold and iron ore in 2016. Murguia also calculated the cumulative net area disturbed for these four commodities in 2011 as 11,485 km^2 (Murguia 2015).

However, what matters is that whilst the quantity of land used might be small on a global scale, the impact can be significant at the local level – and mining very often happens in areas where it has significant qualitative land impacts. For example, Luckeneder and colleagues (2021) describe that 79% of global metal ore extraction in 2019 originated from five of the six most species-rich biomes, with mining volumes doubling since 2000 in tropical moist forest ecosystems. They also find that half of global metal ore extraction took place at 20 km or less from protected territories. Further, 90% of all considered extraction sites correspond to below-average relative water availability, with particularly copper and gold mining occurring in areas with significant water scarcity.

An issue that is already impacting mining's land use (amongst many other things such as energy use and CO_2 emissions, transport and water usage) are declining ore grades (Calvo et al. 2016). Declining ore grades also mean that the numbers for mining waste materials, i.e. waste rock and tailings, will remain high and indeed continue to grow. A recent study by Golev and colleagues (2022) estimates that 30–60 billion tonnes of mine waste are generated per year. This makes it the largest waste stream globally, way larger than all urban waste. On the other hand, the demand for aggregates (ranging from sand to crushed rocks) is estimated to be in the same order of magnitude, which could mean an opportunity for a circular economy – replacing primary aggregates with waste rock – if obstacles such as technical, qualitative and economic competitiveness and local availability can be overcome.

Besides requiring land, there are also other significant concerns playing out at the local or regional level related to overburden, waste rock and tailings: the possibility of acid rock drainage (ARD) from materials containing sulphide minerals or the safety of tailings storage facilities. The latter topic in particular made global headlines many times in recent years through dam failures with catastrophic consequences such as in Konontar (Hungary) in 2010, Mount Polley (Canada) in 2014 and especially Vale's (Brazil) two collapses at Fundao (the mine is jointly owned with BHP) in 2015 and Brumadinho in 2019, killing more than 250 people living downstream of the facility.

Recently – influenced by the mentioned disasters and sustainability-related policies such as the SDGs or Europe's Green Deal – there are considerations on how to use these wastes economically instead of depositing them. For example, Golev and colleagues (2022) describe the potential to use tailings instead of sand in the construction industry.

Economically, mining still plays a significant role. Whilst it might not build empires anymore as it used to do in the past (e.g. Spain and gold and silver from Latin America), it still has a significant impact on many countries. Table 2.7.1 shows that the contribution of mining's production value is not only relevant for developing countries such as Mongolia or Zambia but also for Australia or Chile. However, many other countries, such as Japan, the United States or the countries of the European Union (EU) might not rely as much on mining's direct production contribution to the economy, but they certainly rely on mineral raw materials as inputs to their advanced manufacturing economies, so much so that the United States and the EU some years ago established lists of so-called critical raw materials for which their economies are heavily dependent on imports. In fact, the EU's list, which is reviewed every three years, has been growing ever since its inception in 2011 and in its current version includes 30 substances, ranging from antimony to vanadium (EC 2022). It is currently going through another review, and given recent shocks to the economy such as the COVID-19 pandemic or Russia's invasion of Ukraine, one can expect this list to grow again.

The economic contribution from mining can, however, come at a cost: the United Nations Environmental Programme (UNEP) states that natural resources (which include timber) have played a role in over 40% of all intrastate conflicts (UNEP 2009). In 2015, the ICMM published a report on local mining-related conflicts (ICMM 2015) and found that the absolute number has gone up between 2002 and 2013, although this coincides also with significant growth in new mining projects. Social acceptance or social licence to operate (SLO) has therefore become a significant consideration for mining projects and operations (Thomson and Boutilier 2011; Lesser et al. 2020).

Table 2.7.1 Production value from mining as % of GDP for selected countries

Country	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*	*20U*	*2015*	*2016*	*2017*	*2018*
Australia	2.49	2.33	2.19	2.60	3.U	3.67	4.5	8.67	10.09	9.09	14.71	19.81	15.83	12.17	10.39	8.54	10.18	12.20	9.97
Botswana	16.12	16.66	12.31	16.71	12.92	18.24	18.3	15.62	14.77	8.6	11.88	16.28	14.11	3.92	2.92	32.29	31.81	0.28	13.39
Brazil	0.40	0.41	0.38	0.43	0.66	0.80	0.90	0.99	1.53	1.10	*2.2A*	2.91	2.15	1.99	1.08	1.98	2.04	2.02	2.21
Canada	0.92	0.80	0.75	0.92	1.02	1.U	1.42	2.10	2.40	1.70	2.32	3.22	2.71	2.79	2.49	2.74	2.56	2.20	1.80
Chile	5.25	*L.hL*	i.15	5.87	7.56	9.37	12.15	12.26	12.09	9.61	11.68	12.92	11.32	12.	11.53	15.45	13.41	16. A3	13.73
China	0.29	0.25	0.25	0.32	0.36	*QA7*	0.58	2.68	2.71	2.66	3.56	d.83	3.27	1.97	0.87	5.30	5.60	“0	1.32
Germany	0.06	0.05	0.05	O.Oi	0.05	0.09	0.07	0.58	0.56	0.60	0.67	0.95	0.70	CU1	*0.21*	0.39	0.6	0.63	*0.A9*
Guinea	8.i2	8.20	7.85	6.51	5.83	7.17	7.86	6.83	7.67	9.18	11.81	U.36	13.81	11.03	9.57	20.90	19.01	30_5i	U.30
Indonesia	0.37	0.35	0.34	0.44	0.39	0.50	0.61	1.79	1.49	1.73	2.51	3.07	2.34	1.92	1.02	4.73	5.09	7.2	5.68
Japan	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.01	0.Q2	0.03	0.03	0.02	0.01	0.02	0.01	0.01	0.01
Mongolia	3.57	3.42	3.17	3.72	5.12	6.13	8.73	12.15	11.17	10.50	21.38	26.34	19.47	13.26	11.85	43.64	53.61	86.A6	37.61
Peru	2.52	2.57	2.66	3.55	4.12	5.11	7.09	7.29	7.16	6.27	7.37	8.62	7.46	6.88	6.13	12.37	1412	15.83	13.0A
Russian Federation	1.12	1.03	0.87	0.96	1.09	1.15	1.17	2.21	2.08	*^.9A*	2.59	3.11	2.8	2.57	2.36	7.12	7.12	0.00	0.00
South Africa	3.02	2.79	2.58	3.33	3.95	3.55	*L57*	7.87	8.3	7.9	9.57	12.80	9.93	*9AS*	6.89	U.75	16.52	17.27	10.26
Sweden	0.30	0.28	0.25	0.31	(U2	0.51	*GM*	0.62	0.76	0.54	1.21	1.51	1.23	0.91	*G.7A*	0.56	0.61	0.76	0.68
United States	0.12	0.11	0.10	0.10	0.12	0.15	0.17	0.71	0.73	0.70	0.79	1.25	0.85	0.58	*0.A7*	0.9	0.8	0.66	0.5
Zambia	2.56	2.23	2.11	3.20	3.91	4.77	8.15	8.98	9.00	*7.U*	11.33	13.35	10.34	11.38	9.00	23. U	21.10	26.17	*20.6A*

Source: Data from (ICMM 2022).

Given the economic importance and conflict potential of mining, governance of the sector has always been a significant topic. In addition to legislation and regulation at the regional and national level – which allow for significant differences between countries – a vast number of policies, standards and frameworks, etc., at the international (e.g. Extractive Industry Transparency Initiative [EITI], principles on business and human rights, SDGs, Global Reporting Initiative [GRI]), industry (e.g. Initiative for Responsible Mining Assurance [IRMA], ICMM principles and performance expectations, Towards Sustainable Mining [TSM]), corporate (e.g. Anglo American Social Way) and civil society levels (e.g. publish what you pay) have been developed and have been adopted by the industry at various levels in recent years.

It is important for educators to make their students aware of such standards and that, as consumers, they should demand products to be at least in accordance with them, but also as future policy makers or industry leaders to drive the development and implementation of such standards even further, i.e. towards sustainability.

Sustainable mining

But what does sustainability as described earlier, i.e. one of strong sustainability and planetary boundaries actually mean for the mining industry? The EU project Sustainable Management of Extractive Industries (SUMEX 2020) tries to give an answer to this question. It is worth mentioning that their view on this topic is from a European, i.e. advanced economy, perspective, which means that certain aspects (e.g. related to mining's contribution to poverty reduction or infrastructure development) but also the distribution of benefits between mining countries and manufacturing or consuming countries might feature or be assessed differently in other parts of the world.

SUMEX follows Neumayer (2003) and takes a hybrid position between weak and strong sustainability: Given that the project's mandate is sustainable management in extractive industries (the ability of a society to convert natural capital for the purpose of enhancing wellbeing), SUMEX considers the extraction of raw materials to be substitutable (e.g. to turn natural capital like a copper orebody into manufactured capital like an electric motor) but considers natural capital affecting the planetary boundaries (i.e. the environmental impacts from mining) to be non-substitutable.

SUMEX sees legal compliance with all applicable legislation (local, regional, national and international) as the baseline and as a minimum requirement for companies in the extractive sector. But even in the EU, with member states with advanced economies, more or less well-developed democratic systems and strong governance of the extractive sector (i.e. through mining and environmental legislation), legal compliance by no means equals sustainable management of the sector. In fact, governance systems are very diverse across Europe (EC 2016); (EC 2021), and hence SUMEX suggests one common standard to describe what responsible extraction should mean in the EU: to use the IRMA standard (IRMA 2018) to describe the criteria that a responsible extractive operation should fulfil today. In addition, SUMEX suggests for the industry to transition (which is mostly aligned with the European Green Deal from responsible extraction towards a future state of sustainable management, as expressed through the sustainability aspects described later, over a time period up to 2050, via the milestone of contributing towards achieving the SDGs in 2030. Some of the goal descriptions contained in the aspects might be relevant earlier than in 2050 and therefor action should not be pushed backwards.

These aspects describe key components of what sustainable management of the extractive industry should consider. They represent a set of topics (e.g. valuing social and natural capital, planning beyond the mine life) and goals (e.g. no bribes, zero greenhouse gas emissions) which have to be underlined with processes in order to get to such a state. The sustainability aspects consider the European Green Deal and its aspiration to transform the European economy to an inclusive, circular and carbon-neutral economy in 2050. As already stated, they are a mixture of topics that should be considered part of responsible mineral extraction in the present (e.g. emergency preparedness and risk management, diversity and anti-discrimination) and future aspirations (e.g. defining the role of extractives in a green economy, carbon neutrality) which the sector needs to move towards going forward. Figure 2.7.5 gives an overview of the sustainability aspects in a temporal context.

Environmental sustainability

As discussed in previous sections, our planet has biophysical boundaries, which are expressed in the concept of the planetary boundaries (Rockström et al. 2009). These boundaries describe limits which humans and their economic activities should not trespass on. The extraction of minerals has many impacts on the environment of which we evaluated the main ones in the context of planetary boundaries and for which the sector will need to find ways on how to significantly reduce its impact, often towards zero or even a positive impact.

Mineral extraction and processing often require large amounts of water. Integrated, watershed-based stewardship means comprehensive and jointly planned management of all water systems, company internal and external ones, where all waters are used as valued resources and water efficiency and avoidance of freshwater use are key. Thus, a flexible, resilient water infrastructure that can respond to various scenarios can be achieved. Equally, the extraction of minerals and processing is energy intensive. Companies need to continuously optimise and innovate their processes to improve energy efficiency. With the aim of carbon neutrality, energy consumption needs to be predominantly based on renewable energy. Other harmful air emissions also need to be reduced to zero.

The use of land for mineral extraction and its impact on biodiversity and ecosystem services is another important aspect. Land use stakeholders, including the extractive industry, need to work together to find collaborative ways on how to use the land both spatially and temporally, before, during and, considering especially the finite nature of mineral extraction (see earlier), after the extraction phase. Of particular concern in the context of land use are impacts on biodiversity and ecosystem services, where the sector will need to find ways on how to turn these from being negative towards net positive. This should also include the consideration of potential indirect impacts caused by related industry activities (e.g. additional economic activities due to better transport infrastructure or renewable energy provision). Lastly, and also due to the transformation to a circular economy, advanced waste management systems will be required. These comprise secondary resources from traditional waste by-products (e.g. waste rock and tailings), the continuous reduction of waste generated and the treatment and/or storage of waste without the need for landfilling and any impacts on the surrounding environment.

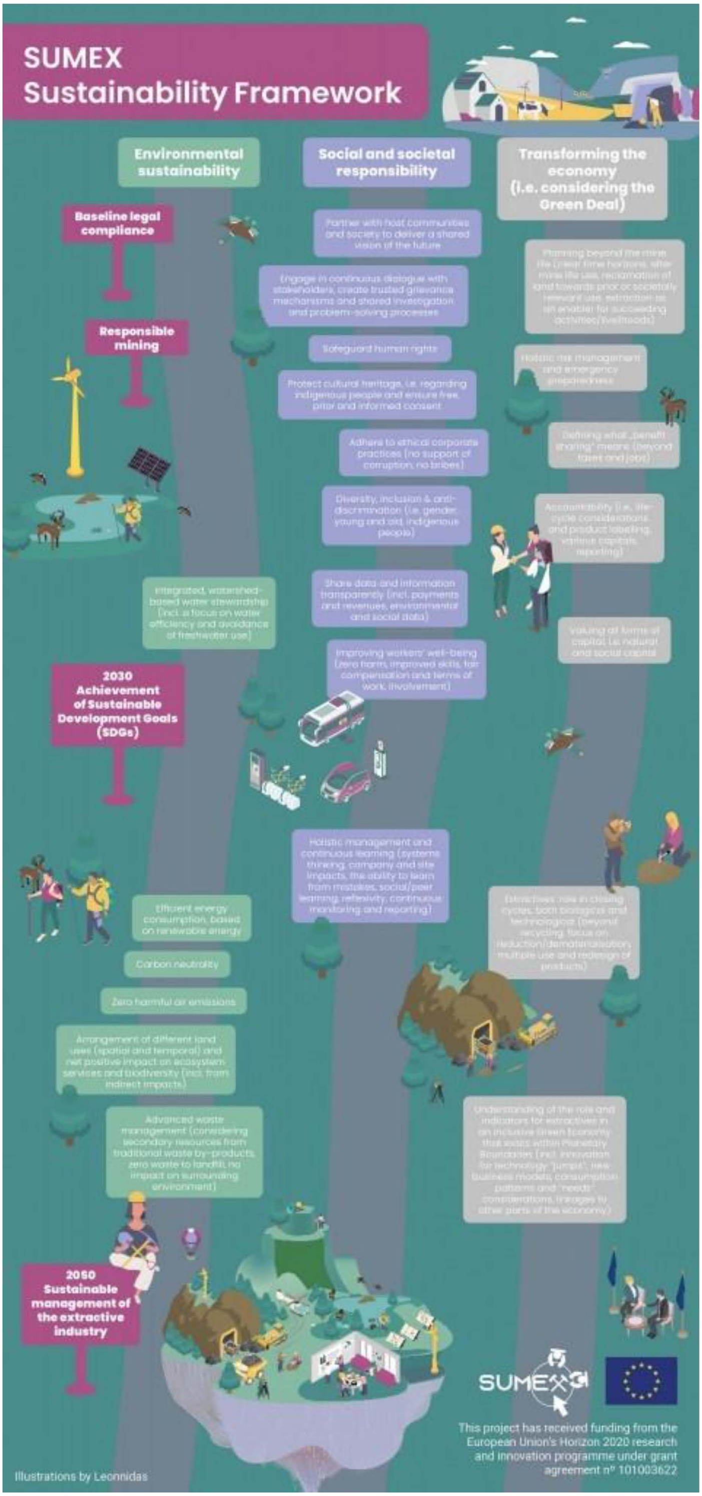

Figure 2.7.5 SUMEX sustainability framework (SUMEX 2021).

Social and societal responsibility

Different views (locally and globally) can potentially influence the progress of an extractive project. The lack of social acceptance or SLO can even lead to the project being hindered or failing. Engaging with stakeholders, ranging from the community affected by the extractive operation to broader society, helps to achieve active collaboration between the company and society in order to define and deliver a shared vision of the future (Adloff and Neckel 2019). Part of this is the continuous engagement with stakeholders to give them the opportunity to actively participate in the process, deliver procedural and deliberative justice and take an active role in decision-making. Trusted grievance mechanisms and shared investigation and problem-solving processes enable all parties involved to raise critical questions, concerns and complaints without hesitation. It also ensures that the issues raised are addressed in the best possible way. Data and information are shared with stakeholders in a transparent and timely fashion, where required at a site, and not the company level. This includes payments and revenues, as well as data from environmental, health and safety.

Extractive companies adhere to ethical corporate practices, including, for example, that corruption and bribery must neither be supported nor tolerated. Human rights (e.g. free and prior informed consent and participation) and cultural heritage have to be respected and safeguarded. This, in particular, includes also special consideration of indigenous people like the Sami in Sweden and Finland. Also, diversity and inclusion are supported on the one hand and discrimination is eliminated on the other. This refers to factors such as gender, age, skin colour and origin of the people involved in the extraction project, as well as indigenous people and different cultural or religious groups.

The workers' well-being in a company is fundamental. To ensure and improve the objective and subjective well-being of workers, ongoing efforts are made. The basis is a zero-harm culture, health and safety, as well as fair compensation. Continuous improvement of skills and the involvement of workers in the company processes are to be analysed.

As already stated in the MMSD process 20 years ago, the extractive sector needs a culture of continuous learning and engagement with societal actors in order to see the bigger picture of how a site, a company, the sector or its products are embedded in an ever-changing society and environment. It also requires reflexivity and deliberation of a form of learning in the sense of a jointly developed vision and values that guide a theory of action for certain practises.

Transforming the economy

The European Green Deal intends to transform the EU's economy towards a green, circular and inclusive one ("leaving no person behind"). Extractives play, and will continue to do so, an essential role in achieving the goals of the European Green Deal, as they are a basic requirement for the transition. However, the extractive sector needs to understand its role in this transition (e.g. which raw materials will be required and which will not be), how to measure this role with indicators and what types of improved and innovative technologies and new/modified business models will be required. It also needs to deal with changing consumption patterns (usage instead of ownership) and considerations of "needs" (e.g. what is the role of mineral raw materials for producing luxury items like jewellery in such an economy). A key part of such a green economy will be closed cycles with highly increased material efficiencies, reduced dependency on imports of minerals overall and from irresponsible sourcing practices and a demand that can be partly covered by secondary sources. Different loops such as sharing, prolonging, remanufacturing and recycling (see the circular economy system diagram of the Ellen Macarthur Foundation[1]) will be crucial. Therefore, circularity will significantly impact the extractive sector well beyond recycling, with a focus on reduction/dematerialisation, multiple use and redesign of products. Waste products can be reused as a secondary product for other industrial processes (e.g. full value extraction), which means also closer linkages to other parts of the economy/avoiding enclaves. The sector will need to examine life cycle considerations regarding its products and product labelling and will be accountable for them.

Natural capital that needs to be considered by the extractive sector includes, for instance, biodiversity and ecosystem services. Social capital refers to relationships and networks between individuals and groups, as well as the resulting ability to secure or maintain resources, knowledge or information. Knowledge of their value, which is not only monetary but also includes ethical, moral or cultural ("values") dimensions, facilitates their inclusion in accounting and reporting systems and decision-making processes and enables natural and social capital to be reflected accordingly. For natural capital in particular, this knowledge is important for conducting an appropriate appraisal of services and benefits to ensure either its restoration or its continuation and sustainable use. As the extractive industry has the potential to generate huge benefits, it is important to define what benefit sharing in the context of a shared vision of the future means, considering all dimensions of value and beyond paying taxes and creating jobs. The question is how these benefits can and should be shared between stakeholders, i.e. since the current "social contract – jobs vs. environmental impacts" will change with ongoing automatisation in the near future.

All of this is also relevant for planning beyond the life of the mine right from the start when planning for the operation begins to ensure that the extractive company has budgeted the financial resources for the phase after mineral extraction has been completed and considered the full variety of social and environmental aspects. This includes the closure of an operation, required socio-economic transitions to enable succeeding activities/livelihoods and the subsequent land use. The same goes for risk management, where the extractive sector needs to exert a holistic approach towards risks and opportunities in the context of this transformation, but also needs to do better concerning emergency preparedness in order to prevent events with catastrophic consequences going forward.

In addition to describing sustainability aspects, the SUMEX sustainability framework also includes evaluation or decision-making criteria in order to assess a policy's, project's or operation's sustainability. SUMEX describes three very different schemes: i) leverage points to assess the transformative scale of actions such as changes to policies in a sustainability context (Meadows 1999), ii) an updated version of the MMSD's The Seven Questions to Sustainability (MMSD 2002a) for assessing projects or operations and iii) the institutional resource regime (Gerber et al. 2009) to specifically assess the issue of mining and land use, a top priority in Europe.

The SUMEX sustainability framework should therefore be seen by students reading this Handbook as an example of the extended responsibilities under the sustainability umbrella that resource companies will have to consider going forward.

Conclusions

The transfer from a "weak" to a "strong" sustainability view – where planetary boundaries represent limits to the use of natural capital – has a significant impact on the extraction of mineral raw materials, meaning that mining has to significantly transform its processes in the coming decades in order to limit its impact on the biophysical processes that regulate the Earth's system. Therefore, whilst the non-renewability of mineral raw materials features prominently in sustainability discussions, it should not be considered as *the* priority for now.

The SUMEX sustainability approach sets out a roadmap for this transformation process. It goes beyond current responsible extraction and regulatory requirements to meet the holistic and inclusive concept of sustainable extraction up to 2050. This roadmap is guided by i) the current scientific debate on sustainability and ii) the current political debate in Europe, i.e. in relation to the European Green Deal and the transition to an inclusive, green and circular economy, which could be a guidance globally. The sustainability aspects describe the issues and overarching goals that the sector should primarily consider in the context of the required change.

It remains to be seen whether the approach suggested in SUMEX will have an impact on policy makers and the extractive industry, especially the large number of small and medium-sized enterprises, to initiate the necessary transformative measures. The recent announcement of the ICMM regarding the commitment of member companies to be CO_2 neutral by 2050 (ICMM 2021) at least indicates that industry leaders are aware of the transformation needed in this respect.

Certainly, education has a strong role to play in this transformation. Educators and especially their students should be taught about future oriented sustainability frameworks such as the one developed by SUMEX and which might be considered by today's mainstream as raising the bar too high (i.e. SUMEX goes beyond the requirements of the SDGs). Only then will they be able to become active agents of change and to hold relevant players accountable in the sustainability transformation awaiting our society. This transformation is, of course, not unique to the mining industry but is relevant to all sectors of the economy and therefore should be included in all sustainability education.

Note

1 https://ellenmacarthurfoundation.org/circular-economy-diagram

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2.8

SUSTAINABILITY CHALLENGES IN WATER MANAGEMENT

Adam Loch and David Adamson

Key concepts for sustainability education

- Water is a unique and finite resource that all users (humans, agriculture, and the environment) need to survive. However, supply is both diminishing and highly uncertain in the future due to climate change, driving intense competition between users. This situation demands we urgently teach and adopt sustainable water management for the benefit of all.
- Successful sustainable water management depends on careful measurement, good quality information, high levels of caution, and flexible arrangements that are challenging to design and implement. However, most of us are also unwilling to give our water up.
- Innovative sharing and reallocation of water resources offer a modern basis for teaching sustainable outcomes condensed to supply and demand concepts. Yet these concepts also face problems, which we discuss here for structuring effective teaching.
- Sustainable water management is a shared problem requiring shared adjustment, which has proven challenging to achieve in the past. However, the current pressures on inequitable supply, increasingly variable supply, and uncertainty are increasing the urgency for reform.

Introduction

The sustainable use of water resources is a particularly wicked problem for the world. Freshwater, the water we need for drinking, economic activity, and meeting freshwater environmental requirements, accounts for less than 2% of total water resources. This makes freshwater (water) scarce, increases the demand for access, and can create conflict between alternative users, especially between those that have access to water and those that do not. In the near future, water stressors around the world will be high to extremely high in many countries (Figure 2.8.1), highlighting a need for users and managers of water resources alike to arrive at sustainable solutions as a priority.

While individual countries will experience different water stresses, ultimately all will have to deal with a common set of problems and solutions. This is because water has unique

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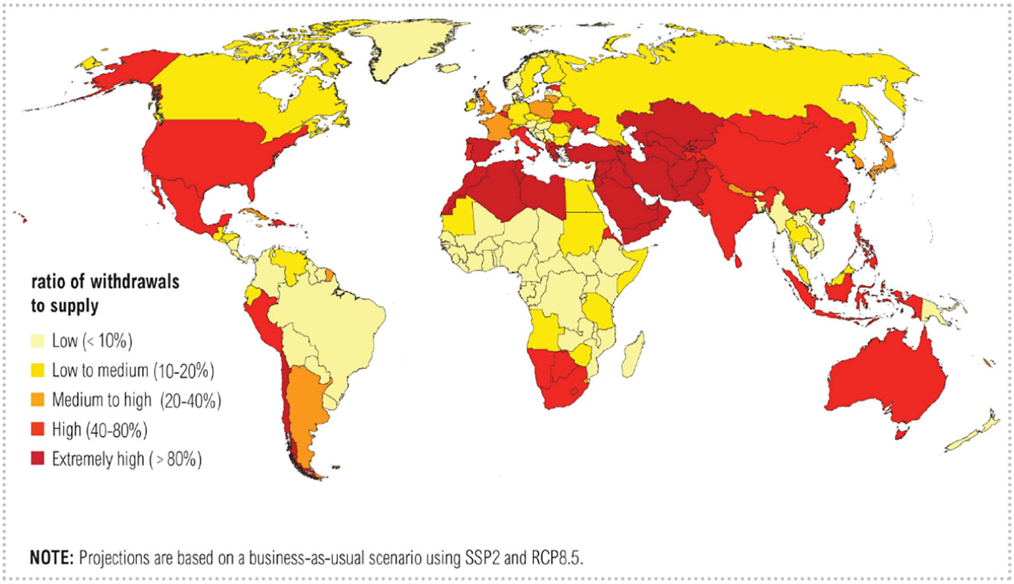

Figure 2.8.1 World water stress by 2040 (Maddocks et al. 2015).

So how do we assess our water resources, identify feasible management systems for water use, choose between competing demands for water resources, and shift our thinking and structures to sustainable use pathways? The aim of this chapter is to introduce the basics with respect to sustainable water management, typical solutions suggested for improvements, and some ideas about the problems that arise when we look at *water.*

properties such as being highly mobile, highly variable in availability (i.e. droughts and floods), in very high demand, and legally/politically complex within and between nations that affect all users equally. As a result, the global development of water supply infrastructure and demand patterns have followed broadly similar stages throughout the world such that today many contexts struggle to achieve sustainable use challenges.

Water's unique characteristics

Water is not a standard good. It is essential to life, commerce, ecosystems, and social or cultural activities. Therefore, water is highly sought by all users but is inequitably shared, with irrigation accounting for around 70% of water use globally. Water is also very heavy and bulky to capture, store, and deliver, making it an expensive good to manage. That said, water is also quite mobile such that the use of water by one user (e.g. in a lake for recreational purposes) does not necessarily exclude other uses (e.g. hydropower generation). This creates complexities and nuances when managing water. Further, water supply is highly variable and when systems periodically experience drought or flood events there can be catastrophic consequences. This highlights a need to build infrastructure to curb such catastrophic consequences (e.g. dams and weirs), but these choices subsequently create new problems such as disrupted river habitat and fish movement, reduced downstream flows, inundation of land, and changed river morphology which lowers sustainability. Finally, the importance of water to large-scale food production, trade, employment, and regional economies drives legal and political issues that complicate the management of water further, especially when irrigated land displaces wetlands. These complexities often serve to confuse users, analysts, and observers alike.

Water's unique characteristics in turn drive many countries to develop laws, infrastructure, management systems, and reallocation mechanisms – that is, a means to move water between users – in broadly similar ways. Early periods of low water use and need are often followed by a sharp growth in demand which often exceeds the actual supply. This creates shortages and tension among users that may be addressed technologically or via reallocation mechanisms. But ultimately, the limits to water supply are reached and a reduction in total use must be achieved to create a sustainable future where users can adapt to absolute scarcity (Figure 2.8.2). The question is, how do we get there?

As shown at the bottom of Figure 2.8.2, groups of solutions are also typically experienced in the water context. Building more storages, extending supply delivery networks, and pumping water farther afield can provide access to more users (i.e. Stage 1 – Supply-side solutions). Then, as the limits to further new infrastructure arise, investments in less leaky delivery pipes, water-saving technology (e.g. low-flush toilets), and other engineering improvements may stretch the resource further (Stage 2 – Demand-side using technical

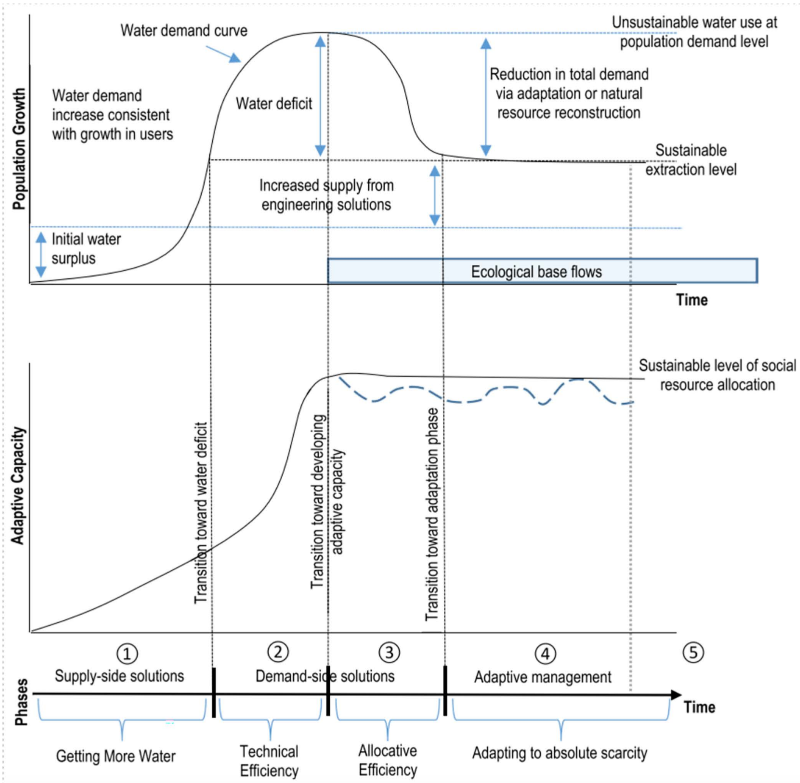

Figure 2.8.2 Links between increasing water scarcity and achieving sustainable use over time (Loch et al. 2020).

Assessing the total resource

efficiency). Efficient uses of water may motivate increased consumption of other inputs (e.g. fertilizers), making their sustainable status increasingly tenuous.

However, as we reach the limits to use and technology, we may have to introduce increased pricing, charges, or other cost incentives to change the demand for water and ensure users value the resource (Stage 3 – Demand-side using allocative efficiency). Finally, if we have exceeded the sustainable level of use – possibly because we did not factor in a need for environmental base flows as a minimum system health driver – we may have to reduce total use (potentially quite dramatically) so that we are aligned again with system limits (Stage 4 – Adapting to absolute scarcity). After that, we will need management arrangements capable of maintaining that sustainable use in light of the unique characteristics of water already discussed (e.g. high variability of supply and demand). Typically, this resembles some form of adaptive management (Stage 5 – Sustainable use).

Ideally, we would recognize this common water resource development pathway ahead of exceeding sustainable limits to avoid Stage 3/4 outcomes. However, many contexts have already reached such outcomes or are close to them. In that light, what must we think about to achieve sustainable water management?

Water resources need to be managed conjunctively; that is, we need to understand all of the water resources that are available. We need to understand the alternative surface water and groundwater reserves available and the limitations associated with their use to prevent the overallocation of resources to consumptive uses. Therefore, a first step is to measure the total system and its limits – ideally with a healthy margin of error as a precaution to address uncertainty to deal with the inherent variability/uncertainty in future supply. This process serves to identify i) a realistic range of total supply under variability; ii) where water is available, how quickly water infiltrates into aquifers, and how it may be captured, stored, and moved elsewhere; iii) the point at which the resource will be exhausted; and, critically, iv) a capacity to monitor progress toward that point over time. Given a high degree of uncertainty that may be associated with system limits dependent on available data, and the likelihood of legal or political complexities as mentioned earlier, a high level of caution is also advised to ensure future flexibility as system limits grow closer. For example, in the case of groundwater, if we fail to understand the rate of infiltration into the aquifer and over-extract water resources, the aquifer can be degraded so that future infiltration is not possible. In that case, we turn a renewable resource into a non-renewable resource (Loáiciga 2003).

Once system limits are near to being achieved or at the point where resources have been completely allocated, it will be necessary to 'close' the water resource context (e.g. basin or catchment) to further uses (Gomez et al. 2018). This is akin to reaching the Stage 2 'plateau'; although in an ideal world this would be situated at the *sustainable use* level and not at one above system limits, creating a situation where water is over-allocated across all users and thus avoiding Stage 4 reductions at a future point as well as the costs that go with over-allocation reduction requirements.

Factoring in environmental base flows

As shown in Figure 2.8.2, the identification and inclusion of environmental base flows – the minimum volume of water in river systems needed to maintain ecological processes and refugia for critical species – typically occurs late in the development process. Clearly, this is far from ideal, complicates the sustainability outcome, and may in turn create social/cultural/economic and environmental harms. To counter this, following the total system resource assessment a critical second step should be to identify, quantify, and then prioritize minimum environmental base flow requirements across relevant river sites, if not all sub-systems. This would serve to extend the environmental base flow bar in Figure 2.8.2 back into Stages 1 and 2.

As a foundation volume of water needed to protect and ensure ecological functions, base flows also need the highest priority because they underpin the rest of the system. If those base functions fail, the entire system fails. Thus, base flows are often referred to as planned or regulated water, as they may be enshrined in law and provided in all states of nature. Achieving this level of protection for base flows is a critical requirement for sustainable water management. Some base flows may also be used to augment – or themselves be augmented by – conveyance water volumes, which are used to deliver consumptive resources (e.g. irrigation rights) to users. Given the high levels of losses of around 25% in most circumstances (Young 2005) that can be associated with system delivery, base and conveyance flows may constitute around 5–10% of prioritized total water resources.

Water rights, system characteristics, and information

After environmental base flows are established and set, all other users can be considered. But care is needed here as you must fully define the environmental context/conditions demanded by society both now and into the future. This then allows environmental use to be prioritized based on their respective levels of anticipated total demand and importance. For example, urban or household users – which may include livestock water – could be the next priority group due to their low, but critical, consumptive level (i.e. ~1–2% of total) needs for reliable drinking water. By contrast, irrigated agricultural users (60–70% of total) may be provided access to large-scale supply but have their use swiftly and heavily curtailed during periods of shortage (e.g. drought). Agricultural irrigation uses also tend to experience large losses between extraction from a delivery channel/river; that is, only around 50% of extracted water is used productively to achieve yield or other productive crop objectives (Young 2005). This necessitates agricultural irrigation sector access to large quantities of water, but also highlights the inefficiencies during low-supply periods that lessen the sector's priority ranking.

Therefore, within the group of higher prioritized rights should be another set of environmental rights, known as held or real water (i.e. ~10–15% of total). It is these rights that provide a set of actual water supplies for river basin management, which may be used to 'irrigate the environment' (Adamson 2019) and drive national benefits from ecological health. Again, as a basis for sustainable water management these rights may sit above agricultural uses, such that they can be relied upon to help smooth sustainable outcomes in response to variability and uncertainty (see Stage 4 in Figure 2.8.2).

What if total water use already exceeds maximums?

If, as shown in Figure 2.8.2, the total level of water use exceeds a sustainable level denoted by the system resource assessment mentioned earlier, then a range of supply-side and demand-side solutions may be suggested to reduce total usage. Supply-side solutions (e.g. dams) are quite common if an area is at earlier stages of development (i.e. Stage 1). But feasible options become harder to develop and justify over time as suitable sites diminish, and the financial and opportunity costs of new infrastructure works increase as society progresses through the development stages (i.e. Stages 3–4). As discussed, water infrastructure also has a high impact on its location, impeding fish movement and other species habitat, inundating large areas of land, creating siltation build-up over time, and disturbing natural flows downstream. Water infrastructure also has a limited life; it may be 100–150 years, but is still limited overall. As such, supply-side solutions are increasingly viewed as challenging to justify and argue in the sustainable water management space.

By contrast, demand-side solutions are now more commonly viewed as the answer to wicked water management problems in the literature. Demand-side solutions are aimed at reducing the claim for water by different users to obtain a sustainable level of consumption. In economics we identify two broad solution groups: technical and allocative efficiency. Technical efficiency involves making the most of available resources to extract as much productivity or output from a drop of water as possible. Thus, taking the agricultural loss example earlier, if we can reduce delivery losses to ~20% – and in-field application losses to ~40% – then we may be able to increase our water use elsewhere by 15%, provided those 'savings' are actual. Herein lies the problem though. Often in water management, assessments of efficiency losses are complex and difficult, making it hard to determine what is being 'lost' elsewhere in the system, and at what rate (e.g. seepage to groundwater, which may not be measurable). Further, if we 'save' water in order to try and reduce total consumption but then allow those 'savings' to be consumed elsewhere – a common requirement for investments in technical efficiency programs – then we will not move the system toward a sustainable objective (C. Dionisio Pérez-Blanco et al. 2021) via reductions in total use. Adamson and Loch (2021) contend that, knowing water savings are complex and rarely possible, farmers are often reluctant to invest in technical efficiencies themselves, only committing to such programs with government support (e.g. subsidies). Other reviews of public-supported investments in large-scale technical efficiency programs have found poor assumptions often used as a basis for program justification (Adamson and Loch 2014), huge spending for limited gains (Loch et al. 2014), and outcomes contrary to objectives (Pérez-Blanco et al. 2020). For these reasons, many analysts now dismiss general technical efficiency solutions for sustainable water management.

By contrast, allocative efficiency mechanisms are used to reallocate water resources between users via incentives to change behaviour. These include (i) cooperative agreements between users to alter decisions via payments (e.g. payments for ecoservices as in Maziotis and Lago 2015), (ii) social contracts between parties to establish rules for sharing water and reallocating scarce resources when needed (Nekhvyadovich et al. 2022), (iii) pricing and charges for water use to raise an appreciation of the value of water and its sustained use (Pérez-Blanco et al. 2016), and (iv) at the extreme end of such mechanisms water trading between users which can improve economic resilience and adaptability (Quiggin 2012).

Allocative efficiency mechanisms should increase motives to reduce water use at the margin and reduce water use over time as costs – including the opportunity costs of the next best alternative uses (Young 2005) – that are passed on to users. Selecting between allocative efficiency measures should be based on Stage 4–5 water development requirements; that is, those mechanisms that will facilitate a movement toward, and then the maintenance of, adaptive arrangements to preserve sustainable use. As one example, while expensive, complex to establish, and imperfect with respect to externalities (e.g. environmental damage may not be priced into a market trade – although it can be if structured correctly), water markets may provide an effective adaptation mechanism in more advanced economies.

Allocative efficiency can also be used to create 'common property' (Ciriacy-Wantrup and Bishop 1975). Here overallocation is dealt with by transferring rights from private users to an 'environmental manager' who utilizes those rights for the environment. In the case of water, by resorting to environmental flows negative externalities are reduced either by directly watering the environment and/or from increased water diluting pollution (including salinity issues) and/or preventing issues from developing (e.g. blue-green algae) (Adamson 2015).

Water markets and trade

There are always calls for water to be provided as a basic human right and, given the low total system requirements for human consumption outside of agriculture, this may be possible to achieve. However, the unique characteristics of water discussed earlier (e.g. bulky and costly to store/deliver) will require large-scale investment to provide such public benefits. After those investments are made, the question of who will bear the costs of that decision, and repay them over time, should be considered for sustainable system outcomes or else the system will fall into disrepair. Again, given the limited timeframes of water supply systems (e.g. 100–150 years), how replacement costs will be met in future should also be taken into current charges so that future generations are not disadvantaged.

One way to promote thinking about the benefits and costs of water resources is through accurate valuation – premised on any number of key objectives or strategic aims (e.g. sustainable outcomes). In economics, that which is valued tends to get managed, and where a system is approaching its upper limits of use effective management becomes highly important. Identifying progress toward system limits and designing/implementing management arrangements ahead of that to assist users adapt to inevitable change is an important phase to get right. Most systems will fail to achieve sustainable outcomes if they seek to impose reforms after limits have been breached, users have gotten used to supply/use conditions, and investments have been made to support that water use. This is where legal and political complexities will work against sustainable objectives, and may even make things worse.

For example, in Australia a period of drought between 2017 and 2020 motivated some water users – particularly irrigators – to blame high market prices on water hoarding and market speculation by external investors (e.g. investment funds from Canada), rather than viewing those high prices as a result of supply shortages. Their complaints triggered several costly public inquiries into those hoarding/speculation claims (Treasury 2019). Due to the complexities of modelling water market speculation (Loch et al. 2021), the inquiry generally found little evidence in support of either claim where data and analysis were challenging (ACCC 2021). Further, once system supply returned to more favourable conditions (i.e. 2021–2022), prices decreased dramatically and the suspected hoarders miraculously disappeared – along with irrigator complaints. The political complexities of water thus drove these costly inquiries, and there was ultimately little to no public benefit from that expense.

However, a similar investigation into the hoarding/speculation claims found many water market failures with respect to price signalling, data integrity, and information asymmetry via a range of analysis techniques (Loch et al. 2021). These studies show that water markets are far from a panacea and must be consistently reviewed and updated within a regulated environment – but preferably not self-regulated as recommended by the Australian Competition and Consumer Commission (ACCC 2021). Self-regulation introduces a lack of accountability and allows slippages of standards, which in the case of water will lead to poor water values, trade inefficiencies, and reserved (if any) sustainability drivers.

In the absence of water markets, surplus water can have no value and it can remain within the river system, providing a dilution effect. However, water markets provide the capacity to access previously unutilized water resources and trade it to those who need it. Water trade can then exasperate the negative externalities generated from using water. Beyond market transactions there are numerous ways to value water, and these are widely used (see Young 2005 for an excellent coverage of these techniques). However, an efficient water market is very hard to beat, as it provides the capacity to properly reallocate water resources between users. Again, those outside the market (e.g. environmental, cultural, or recreational users) may find it difficult to compete, and as such the 'true' price signal may be confounded. However, if all water uses can be included in a market, then water's true value can be easily, and quickly, determined at any given point in time or for different supply conditions (e.g. drought).

The main power of the market is in reallocation at the margin. If all opportunity costs of water can be considered and evaluated (which is tricky at best), the real value of water can be determined. Then, based on that value, water should flow to its highest-value alternative uses via market transfers. For example, if we value ecological use most highly in a drought to protect key species sites and functions, then we should see public authorities paying high market prices to secure that water. Alternatively, if we desire more water to be held aside for ecological support in the future, we may enter the market to buy rights off other users (e.g. irrigators) in the national interest. This will lower the total cost of achieving environmental gains in the long run (Horne et al. 2018; Loch et al. 2011, 2016).

Further, water markets are very good at reallocating rights between users in response to changed supply/demand conditions, where we will typically not have the political will or fortitude to reallocate scarce resources via regulatory reforms (e.g. legislation and compensation). As low political will is a common, and increasing, characteristic of governments globally, markets ironically provide at least some realistic means by which social preferences for sustainable water use may be achieved.

Finally, there are some other issues that are important to consider in the search for sustainable water management.

Groundwater substitutes and their risk

Unfortunately, many water analyses fail to consider the conjunctive nature of water resources. This then fails to understand how the alternative reliably of all resources (surface and groundwater reserves) can be utilized, and the risks associated with their utilization. In a great many contexts, groundwater may be the major source of water and, if so, it may already be heavily exploited. For example, despite massive land subsidence and irreversible damage to the aquifer, California is still grappling with groundwater management. Up until very recently there were no restrictions on groundwater use, and this comes with great private gains and significant social costs (Adamson and Loch 2021).

However, where surface water resources still dominate, increases in scarcity and pressure to find viable substitutes may motivate water managers to access and use more groundwater. An argument for this substitution may be made that groundwater is more sustainable as a resource given its relatively cheap access costs, lower evaporation exposure, next to no engineering infrastructure requirements, and larger volumes. Indeed, these were key arguments in Australia's Murray-Darling Basin (MDB) when the government agreed to release 927 gigalitres (GL = 1 billion litres) of groundwater rights to agricultural users as part of the new Basin Plan aimed at improving water resource sustainability (MDBA 2012). Groundwater was viewed as more reliable in its supply than variable surface water, prone to drought and intermittent availability. In turn, this perception of increased reliability may help transform agricultural irrigation producers – particularly in the northern MDB where dams and storages are limited – toward perennial plantings (Adamson et al. 2021).

It is anticipated that increased access to a perceived highly reliable groundwater resource will rapidly increase the value of those rights. However, there are associated risks attached to this groundwater use. Consistent with the key principle earlier, we should be able to know the resource limits and when those limits are being approached. In groundwater this is highly challenging given its nature; that is, underground and out of sight. Further, as climate change impacts grow, so too will the demand for groundwater testing political and legal barriers to maintaining already shaky resource limits. But when groundwater use is linked to higher-valued perennials, which require water in *all* states of nature (Adamson et al. 2017) as discussed later, the tendency to grow that resource use rather than sustain it in the face of high uncertainty (e.g. developing greenfield irrigation sites to take advantage of growing export markets) will diminish any potential that groundwater resources have for sustaining current water uses and their benefits. Therefore, a high level of precaution should be applied to groundwater and its access right provision/allocation.

The importance of minimum water requirements

With regard to perennial crops, the critical relevance of the distribution of these production systems within a water resource management area cannot be understated when sustainability is an issue. In short, perennials dramatically increase the risks associated with water as an input to production and can undermine sustainable objectives where the basics are not well appreciated. Water must be viewed as having two important functions: maintaining a capital base (e.g. tree stock) and generating agricultural outputs (e.g. fruit yield). In general, any sustained or uncertain variability of water supply can be particularly damaging to the capital protection values of water, where future uncertainty can be challenging to quantify and capture in models (see later).

For example, if perennial production systems comprise the majority of the water demanded, there may not be sufficient flexibility in that system to cope with future shortages. That is, perennial crops require a minimum amount of water (g) in all states of nature (i.e. droughts, floods, and normal years) just to keep trees/vines alive, after which more water (h) is needed to deliver crop yields that can be sold to cover costs (Loch et al. 2020). If water managers are oblivious to minimum (g) water requirements, then tipping points (i.e. system failure across all users) become highly probable, and these tipping points can be rapidly reached during supply shortages. This makes the sustainability of a system vulnerable to shocks, as well as the need for costly public interventions/supports in response. Further, because perennial crops often attract higher returns motivating transformations within a production area, economic and other justifications (e.g. perceived illegitimacy of other users such as environmental flows) may drive increased water theft to maintain perennial crop capital and the likelihood of profits (Loch et al. 2020). Once again, increased theft will do little to support sustainable water objectives and exacerbate tipping points in the system.

The problems of risk and uncertainty

As we have shown, it is necessary to look to the future to describe, assess, and ultimately determine how systems will be able to achieve sustainable use outcomes. Naturally, whenever we look forward, we encounter considerable *risk* (i.e. future events which we are aware of and might be able to assign a probability of occurrence to) and *uncertainty* (i.e. events of which we have absolutely no knowledge, and thus cannot be assigned a probability) (Knight 1921). Typically, we may select a course of action (e.g. build a dam) and then test the robustness of that choice to a range of plausible futures. But those futures are likely to alter our choice sets and final decisions as we continually learn about our choices and reflect on the outcome of those alternatives. It will therefore be useful to apply models that can take such learning and adaptation into account – for example, state contingent analysis techniques (Chambers and Quiggin 2000) – which can explore rare events and how decision-makers may reallocate resources (e.g. water inputs) as a consequence (see for instance drought adaptation responses in Adamson et al. 2017).

Such analysis coupled with sensitivity testing may be used to determine when existing knowledge, technology, or management responses may fail (i.e. tipping points are reached), providing lessons for on-going management adaptation at both private and public levels. Future research paths and questions will be informed by increased awareness of the full set of contingencies that may or may not be applicable under future climate change. However, in practice, the success of those choices will still be constrained by decision-maker bounds to awareness and any deeply uncertain events that may arise.

Australia as an example for the world

Many of the examples drawn upon here are from an Australian perspective. This is deliberate as Australia is one of the driest continents on Earth and has been forced to act earlier than some other countries to reform water management – sometimes not as well as might be hoped. That said, Australia is also expected to face severe water shortages in the future under climate change. Recent Intergovernmental Panel on Climate Change (IPCC 2018) estimates suggest that, by 2050, Australia will experience drought conditions in 75% of years – frankly, a terrifying prospect. In the MDB, for example, Australia's premiere agricultural production region, this will have dire consequences for water availability (Figure 2.8.3).

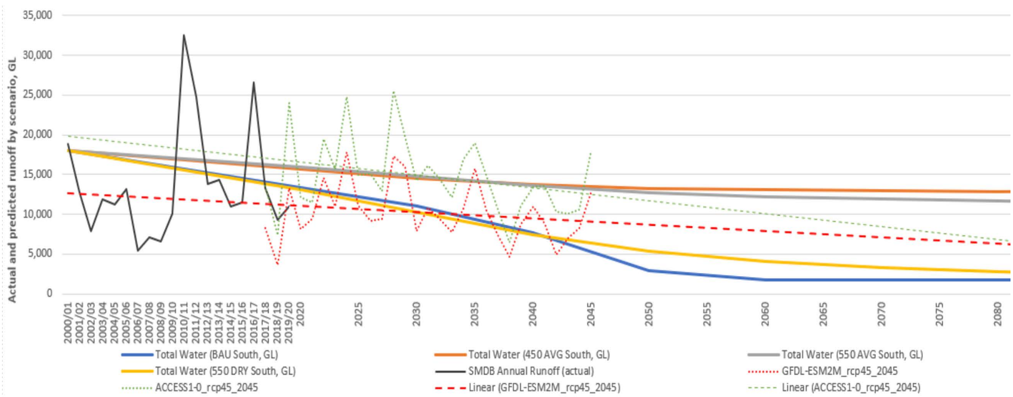

Figure 2.8.3 Garnaut climate change scenarios, actual runoff (2000–2020) and study climate model runoff predictions (2021–2080) for southern MDB based on last 20 years of climate history and CSIRO/BoM RCP45 scenarios.

Source: Author's own interpolation

In essence, Figure 2.8.3 depicts an update to the 2008 Garnaut Climate Change Review which assessed a number of possible pathways for water availability in the MDB with and without effective emission reductions (e.g. business as usual [BAU] in the southern MDB, or BAU South). Looking at actual runoff in the southern MDB (solid black line) and the trends for two Commonwealth Scientific and Industrial Research Organisation (CSIRO) climate model projections out to 2080 (red and green dashed lines), we can see a very clear expected decline in water availability by 2050 to around 10,000 GL (gigalitres, or a billion litres) on average. Note runoff is not inflows to storages, which will be a lower proportion, and total current water rights in the MDB exceed 19,000 GL – or roughly twice expected runoff. This clearly shows a need to arrive at sustainable solutions to water problems relatively soon in Australia, with lessons for other possibly more water-abundant (for now) contexts to then learn from.

The insurer of last resort problems

Finally, in view of future climate changes, it is necessary to consider who will be impacted by any failure to create sustainable water systems and who then should or will pay to address those failures and their impacts on users. In recent years we have seen a great many impacts on communities, farmers, businesses, and individuals as a result of extreme events (e.g. fire, drought, and flooding). These have significant economic, social, and cultural costs for society (Quiggin 2018) and typically require considerable private and public investments to achieve recovery (Moss 2002). These interventions logically also have a tipping point; that is, where the burden on public funds becomes so great and common that there is simply no capacity to continue. As climate change impacts increase (IPCC 2022) and – where we have failed to invest in flexible systems beforehand – the cost to change systems based on historical events is expected to increase due to urgency, multiple stakeholders competing for limited funds, and a need to address many concerns at once. This also is unsustainable. As such, we must investigate, design, assess, and select flexible production systems and water uses that are able to adapt to future uncertain conditions and provide the best basis for future sustainability (Adamson and Loch 2021).

Conclusion

In this chapter we have sought to provide a very basic set of issues to consider with respect to identifying and teaching the core concepts for sustainable management of water resources. The reality for water management is in many ways far more complex, but the issues raised herein give at least some understanding of, and structure to, what must be thought about when aiming to teach sustainable water use. Crops can only last around two to three weeks without irrigation, a human can survive about three days without drinking water, and most industries would cease almost immediately if their access to water was removed. These are the stakes involved in sustainable water management, why it is so important for us all, and what must be included in teaching about the concepts. The recent COVID-19 pandemic has shown us how fragile our food and consumable supply system is, but in a situation in which the underlying access to resources did not disappear. If we take water away from any single area the consequences will be immediate, challenging to address, and potentially costly in human lives. There will be little time or patience to try and get it right then.

As such, when teaching this subject we need to be aware of the risks we face and the complex nature of water sustainability issues to ensure the problem is taken seriously and addressed by those who can make a difference – we as teachers, students who will manage these issues in the future, policy makers/resource managers as instigators of change, and all of us as water users.

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SECTION 3

Sustainability transition outcomes and the language of 'sustainability'

"Look deep into nature, and then you will understand everything better"
(Albert Einstein)

The issues presented in Section 3 are vital concepts and contexts in sustainability education. They are invariably interlinked and together present some of the most critical sustainability and resource issues that the 21st century will face, including the scale of environmental impacts that are associated with our increasing production and consumption decisions, as well as the need to consider new paradigms in our future economic business models and governance frameworks.

This section focuses on a broad array of perspectives and topics that frame the sustainability transition and therefore the 'sustainability education transition.' It introduces several ways of thinking that assist the transition from modern linear economics, which sees the world as a 'resource pool,' to one that sees the world as an ecological system on which we depend for clean air, water, resources and nature based amenity. These topics help us to more clearly understand how to sustainably and equitably manage our resources and the physical 'limits to growth' we face on planet Earth (Meadows et al., 1972, Steffen et al. 2015).

These topics are interconnected as we transition into a more complex Earth system of climate change adaptation, significant population growth, limits to resource availability and the complexity of this new system, and its inherent uncertainty and unpredictability.

Macedo (see Chapter 3.2 in this volume) discusses the 'language of sustainability' and recommends that ecological footprint, eco-design, and biomimicry are important terms in sustainability education. Ecological footprint is an ecological accounting term that reviews the impact of human activities on Earth by measuring the specific area of biologically productive land and the amount of water needed to produce the goods and services required and to assimilate the wastes generated by our production and consumption activities.

Eco-design is an approach in designing products that reduces the associated environmental impacts of a product across its whole life cycle. Eco-design focuses on minimising the consumption of energy and natural resources and reducing the waste and emissions associated with the production and use of a product. Biomimicry looks to nature to inspire new innovations that mimic natural systems.

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Threshold concepts are another important approach in helping students understand difficult concepts. That is, once a student has grasped a 'sustainability' threshold concept, the learning is irreversible, and the understanding of the concept transforms the learner. Marinelli and Male (see Chapter 3.3 in this volume) suggest several important sustainability concepts that are considered 'threshold concepts' in their ability to reframe a student's understanding of sustainability. These concepts include systems thinking, multiple ways of knowing, triple bottom line, life cycle thinking, and design thinking.

An increasing focus in sustainability education has been the need for transdisciplinary and multidisciplinary thinking, often using problem-based and group-based learning techniques. Pereverza and Ho (see Chapter 3.4 in this volume) note that transdisciplinarity in sustainability curricula is essential to provide a more complete understanding of the sustainability challenges we will face together with the complexities inherent in managing sustainability problems.

Environmental impact assessment (EIA) is a critical way of thinking in terms of measuring the environmental impacts associated with our production and consumption behaviours. Biswas and John (see Chapter 3.5 in this volume) review the increasingly important role of EIA in modern sustainability reporting and help frame the wide variety of variables that need to be considered in determining our production and consumption impacts on the environment.

Futures thinking and regenerative sustainability look at the importance of maintaining our natural systems by utilising regenerative technologies and practices to restore the environmental system to ensure long-term productivity. Thomas (see Chapter 3.6 in this volume) discusses regenerative sustainability as an extension of broad sustainability management and restorative management principles, using holistic thinking to allow economic, environmental, and social systems to better address planetary stewardship.

Macedo's chapter (see Chapter 3.7 in this volume) on moving beyond growth thinking discusses the 'limits to growth' modelling done for the Club of Rome in 1972 (Meadows et al., 1972) and sets the scene in examining the sustainability challenges the world will face. This chapter importantly highlights the ongoing impact of our exponential population and industrial growth on the Earth's finite resources. The need to adopt new patterns and dynamics of human production and consumption are discussed, as is the importance of sustainability education in extending student understanding of the fallacy of unlimited growth.

Korevaar (see Chapter 3.8 in this volume) examines how the new production paradigm of Industry 4.0 will improve the sustainability performance of our industrial production. Korevaar notes that since the first Industrial Revolution, which was powered by cheap coal-fired energy in the 1760s, the world has externalised the environmental costs of our industrial production, which has resulted in significant levels of environmental destruction and climate change. Industry 4.0 will see the increasing automation and dematerialisation of industry and manufacturing, with an increased focus on sustainability performance and circular economy thinking. The vision for Industry 5.0 is to then focus on the desires of the community, stakeholders, and employees in the rapid transformation and decarbonisation of industrial production.

Reference

Meadows, D., Meadows, D., Branders, J. and Behren, W. (1972) *The Limits to Growth: A Report from the Club of Rome's Project on the Predicament of Mankind*. https://www.donellameadows.org/wp-content/userfiles/Limits-to-Growth-digital-scan-version.pdf

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3.1
EDUCATION FOR THE SUSTAINABILITY TRANSITION

Michele John

Key concepts for sustainability education

- Sustainability education should be a transformative learning process that provides both teachers and students with the sustainability knowledge, values, methods of thinking and future focus required to balance our economic and social demands within the natural boundaries and health of our global ecosystems.
- Sustainability education development is needed to develop students, as our future workforce and future leaders, with the skills, sustainability mindset and values needed to meet the challenges of the sustainability transition.
- Global education institutions are slowly beginning to recognise the need to focus more on sustainability education development and leadership.
- There are many challenges in the sustainability education transition including the complex multidisciplinary definition of sustainability, a poor understanding of sustainability content and curricula by educators, tightly controlled discipline-focused curricula and a lack of institutional focus on sustainability education development.
- 'Sustainability' is an evolving definition of concepts, ideals and values with 'regenerative sustainability' a newly emerging definition with increased responsibilities for sustainability stewardship and management.

Introduction

Whilst the European Union (EU) and its education focus on the UN Sustainable Development Goals (SDGs) has provided historic leadership in systemic sustainability education development, globally, sustainability education is typically led by relatively small numbers of future-focused education 'champions' whose personal value systems and wisdom have led the development of sustainability-focused pedagogy and curricula, often without specific governmental or tertiary administration direction.

This *Handbook* has been developed for teachers, students, policy makers and community leaders interested in the challenges of the sustainability education transition to support their understanding of modern sustainability thinking, context and values and aid in the

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development of an education system that will help secure a sustainable future – for us and the ecosystems and biodiversity we share this planet with.

In Section 1 we introduce the precepts of a noble (sustainability) education. In Section 2 we present many of the major sustainability challenges of the 21st Century. Here in Section 3 we introduce a number of important concepts and ideas that frame the interdisciplinary challenge that is sustainability education.

Challenges for educators in sustainability

> "We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect".
>
> *(Aldo Leopold. Cited in the Foreword 'A Sand County Almanac'. Oxford University press. 1949)*

Educators are faced with a broad number of challenges in teaching and developing sustainability education.

Firstly, as noted by Antonio Guterres, secretary general of the UN in the Transformative Education Summit held in 2022, "Teachers are often poorly trained, undervalued, and underpaid, and are held back by outdated roles, methods, and tools of instruction" (UN 2022). Training and enabling our educators in sustainability education is perhaps one of the most significant challenges in the sustainability education transition.

Secondly, modern curricula typically focus on narrow discipline-led teaching outcomes. This is particularly challenging in a world facing increasingly complex sustainability problems with multidisciplinary causes and impacts.

Thirdly, sustainability education needs to be framed within the ethics, values and principles underwriting modern sustainability thinking and decision making. This is a challenge for many educators in both understanding these values and principles and committing them to inclusion in their curricula.

Fourthly, the term 'sustainability' is often poorly understood and even more poorly recognised in education curricula. For the purposes of this Handbook, the concept of sustainability goes beyond the commonly used Brundtland definition for sustainable development: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Report 1987). This Handbook acknowledges the emerging definition of 'regenerative sustainability' as a new paradigm for sustainable development thinking. This evolving definition of sustainability is now discussed.

The history and evolving definition of sustainability

> *"Don't limit a child to your own learning, for he was born in another time".*
>
> *(Rabindranath Tagore, 1861-1941)*

Initially, sustainability principles were recognised as three separate and competing elements – economic, social and environmental – and typically valued in that order. The 'Three circles sustainability diagram' (Figure 3.1.1) highlighted the early definition of sustainability that was developed from John Elkington's 'triple bottom line' (TBL) thinking in his book *Enter the Triple Bottom Line*, which represented sustainability as three independent priorities: economic, social and environmental (Elkington 1994 and 2004). Elkington developed this sustainability framework to help assess a company's social, environment and economic impact.

The definition of sustainability then progressed to the (intersecting circles sustainability model) (Figure 3.1.2) (O'Riordan 1997) which represented sustainability as a small area of intersection (grey area in Figure 3.1.2) between economic, social and environmental priorities.

The 'intersecting circles' model was recognised as marginalising the role of sustainability and inferred that the sustainability interface with modern production and consumption was not systemic across all elements within economic, social and environmental decision making.

Next came the 'nested circles' or 'nested dependencies' sustainability model (Figure 3.1.3) which highlighted the importance of economic and social demands having to operate within the physical and environmental system boundaries of the Earth. This reflected the importance of our environment in providing the resources and ecosystems services on which the economy and society depend.

An understanding of 'weak' and 'strong' definitions of sustainability then began to develop. A 'strong' definition of sustainability, unlike the weak definition, recognised the interdependence and interconnectedness of the environment, society and the economy (Figure 3.1.4).

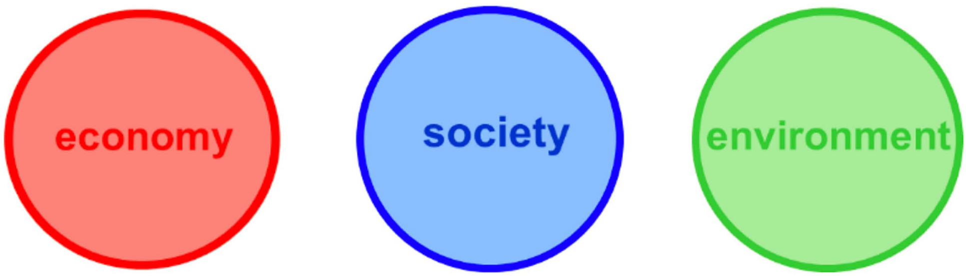

Figure 3.1.1 Three circles sustainability model (Elkington 1994 and 2004).

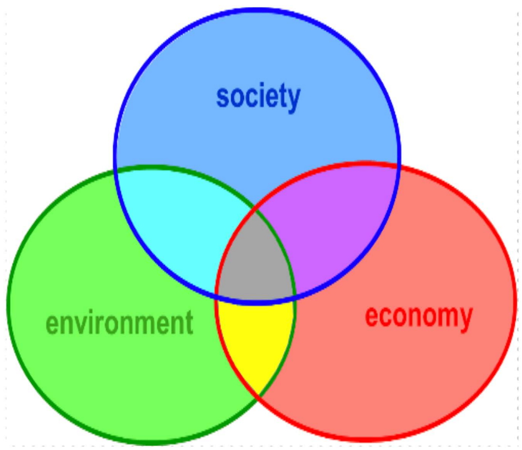

Figure 3.1.2 Intersecting circles sustainability model (O'Riordan 1997).

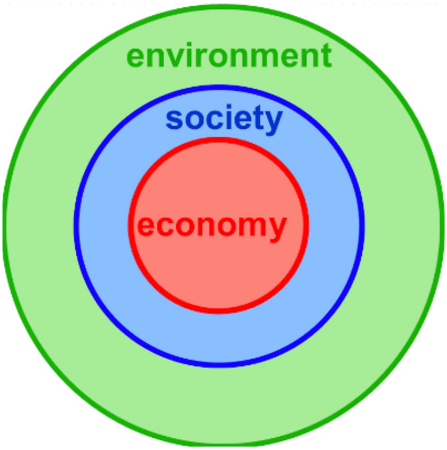

Figure 3.1.3 Nested circles sustainability diagram (Engineers Australia 2017).

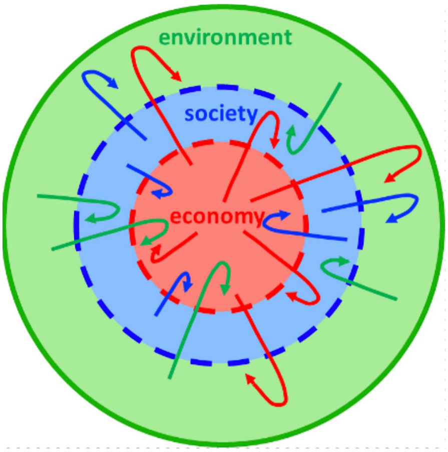

Figure 3.1.4 Interconnected dependencies sustainability diagram (Rice 2023).

Engineers Australia (2017) include reference to this interdependence and interconnectedness in their definition of sustainability, which contends "that a healthy economy is underpinned by a healthy environment and respect for all life on earth".

Given the increasing realisation that our production and consumption systems are degrading much of our environment, and in many cases resulting in irreversible permanent damage to many global ecosystems, a new definition of sustainability has began to emerge.

To mark the 25th anniversary of his TBL assessment framework, John Elkington (2018) proposed a strategic recall to do some fine-tuning to the original framework. Since the TBL definition was published in 1994, it has become a business and management lexicon for 'sustainability performance assessment'.

Elkington noted that the original TBL framework wasn't designed to be just an accounting tool for sustainability assessment but was intended to provoke deeper thinking about capitalism and its future. Many adopters saw the TBL concept as a balancing act that involved trade-offs between the three sustainability pillars.

Elkington (2018) noted that "Clearly, the Triple Bottom Line has failed to bury the single bottom line paradigm". He further commented:

> I hope that in another 25 years we can look back and point to this as the moment we started working toward a triple helix for value creation, a genetic code for tomorrow's capitalism, spurring the regeneration of our economies, societies, and biosphere.
>
> *(Elkington 2018)*

This regeneration of 'our economies, societies and biosphere' is inherent in the newly developing 'regenerative sustainability' definition of sustainability, which hopes to develop net positive outcomes from the interdependent interactions between economic, social and environmental systems.

Regenerative sustainability (RS) is now being considered as the next sustainability paradigm, focused on the development of thriving and productive systems, where whole-system health and wellbeing increase continually for individuals and the whole Earth system (Gibbons 2020). Regenerative sustainability utilises holistic approaches and living-system principles and technologies like ecological design and planning, regenerative development, regenerative design, regenerative community development and regenerative landscape development (Gibbons 2020).

Importantly, regenerative sustainability has a significant focus on addressing historical legacies of negative environmental, ecological and socio-economic impact with a focus on planetary repair and long-term stewardship including climate change mitigation and adaptation and biodiversity restoration (see Chapter 3.6 in this volume).

It utilises Indigenous and local, place-based knowledge systems to help facilitate sustainable ways to live, by including First Nations wisdom to help regenerate biodiversity and support human wellbeing (see Chapter 7.6 in this volume).

RS thinking moves beyond the limitations of previous sustainability paradigms, which largely focus on eco-efficiency and 'doing less harm', to focus on new restorative paradigms that require transformative action (see Chapters 3.6 and 7.6 in this volume)

RS in the 21st century will take into account a world of limited resources and the need to reduce the practices of environmental degradation, which have become the hallmarks of 20th-century economic production and growth. Such action will focus on developing operational stewardship models that ensure that our economic production results in constant improved social and environmental outcomes. This regeneration of our economic, social and environmental systems will allow the 21st century to continue to thrive whilst enabling future generations to have the same opportunity.

The RS diagram (Figure 3.1.5) illustrates the potential flow of 'net positive' regenerative contributions into each sustainability pillar.

This Handbook supports the broader and more holistic definition of RS, whilst recognising that currently, the most widely referenced and utilised definition of sustainability is that embodied in the SDGs.

The SDGs came about in 2015 as part of the development of the 2030 Agenda for Sustainable Development, where a 15-year plan was set out to achieve 17 specific goals as

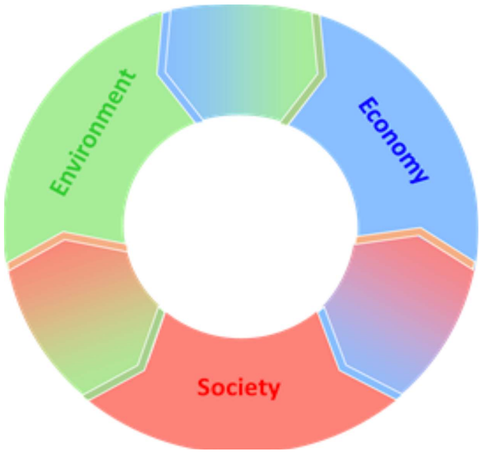

Figure 3.1.5 Regenerative sustainability diagram.

Figure 3.1.6 UN Sustainable Development Goals (UN 2015).

global targets for sustainable development. These 17 goals are noted in the widely recognised SDG diagram noted in Figure 3.1.6. These goals are commonly used as a framework for defining sustainability and sustainable development interchangeably. They are often used within this Handbook as a framework for describing and actioning sustainability.

The language of sustainability

> "We have forgotten how to be good guests, how to walk lightly on the earth as its other creatures do."
>
> *(Barbara Ward,* The Stockholm Conference: Only One Earth *(1972), 24)*

In “The Future Fit Framework: An introductory guide to teaching and learning for sustainability in higher education”, Sterling (2012 pp32) noted the 1998 UK government’s Sustainable Development Education Panel suggestions for key concepts and values for sustainable development included:

- Interdependence – of society, economy and the natural environment, from local to global scales.
- Citizenship and stewardship – rights and responsibilities, participation and co-operation.
- Needs and rights – of future generations.
- Diversity – the importance of cultural, social, economic and biological variety.
- Quality of life, equity and justice.
- Sustainable change – development and carrying capacity.
- Uncertainty and precaution in action.

Given the multidisciplinary and transdisciplinary nature of sustainability, sustainability education and sustainability management both include a variety of concepts that help define sustainability.

Sterling (2012 pp31) noted that “sustainability education suggests not a definitive list, but rather concepts and ideas that may be more or less relevant to your own situation and disciplinary area, and which you might want to use/adapt/extend as entry points to sustainability education content.”

Defining this *language of sustainability* in terms of commonly used sustainability concepts is an important role of this Handbook. Important sustainability concepts and ideals covered in the Handbook are noted in Table 3.1.1 with cross reference to the (relevant chapters) in brackets. As noted in the sustainability definitions discussed earlier in this chapter, it is important to acknowledge their multidisciplinary use and the transdisciplinary context of these concepts.

Sustainability education and the Sustainable Development Goals

> “Scientists may depict the problems that will affect the environment based on available evidence, but their solution is not the responsibility of scientists but of society as a whole”.
>
> *(Mario Molina. Cited in Physics Today, 74 (2),60, 2021)*

Sustainability education should be focused on the development of sustainability knowledge and thinking. A sustainability mindset should also include an understanding of prevailing sustainability management principles and values that guide sustainable development thinking. Sustainability education should also incorporate sustainability measurement practices and ideals, together with a broad understanding of the environmental and ecological systems that need to be protected and conserved to ensure their long-term health and availability for future generations.

Many authors have noted that sustainability education should be a transformative learning process that provides both teachers and students with the sustainability knowledge,

Table 3.1.1 Summary of common sustainability concepts and ideals covered in this Handbook

Biophilia and biomimicry (3.7)	**Business school–focused sustainability education (4.5, 6.1, 8.1, 8.4)**
Climate change (1.3, 2.1, 2.7, 3.6, 7.1, 7.3, 7.5.)	**Collaboration with stakeholders** (3.4, 3.6, 6.6, 8.5)
Connection with nature (1.6, 3.7)	**Corporate social responsibility** (6.1, 8.4)
Decarbonisation/low carbon (3.5, 3.8,4.2)	**Deforestation** (7.4, 7.5)
Design for the environment/design thinking (3.3, 4.2, 4.4)	**Eco-centric/bio-centric views/biophysical** (3.6, 6.2, 7.1, 7.2, 7.6)
Ecological footprint and carrying capacity (2.3, 3.5, 3.7, 4.2)	**Environmental 'tipping points'** (2.2, 7.4, 7.7.)
Environmental and sustainability education (ESE) (5.5, 6.2, 7.2, 9.7)	**Environmental impact assessment** (2.3, 3.5, 3.8)
Ethics (3.7, 4.4, 4.5, 8.1, 9.3)	**Futures thinking/anticipatory thinking** (3.6, 3.8, 6.2)
Gaia hypothesis (1.2, 3.6, 3.7)	**Greenhouse gas emissions (GHG)** (2.2, 2.5, 2.6, 7.5)
Indigenous nations knowledge and engagement (1.6, 3.3, 3.6, 5.6, 7.2, 7.6)	**Inter- and intra-generational equity** (2.3, 3.6, 9.2)
Interpersonal competencies and stakeholder engagement (3.8, 4.6, 6.6)	**Life cycle assessment** (3.2, 3.7, 4.2)
Limits to growth (2.2, 2.3, 3.2, 9.1)	**Planetary boundaries** (2.2, 2.7, 4.2, 5.4, 7.2)
Population growth challenges (2.3, 2.5, 3.5, 3.7, 7.1, 9.5)	**Precautionary principle** (4.3, 7.7, 8.1)
Regenerative sustainability development (2.1, 3.6, 3.7, 3.8, 7.6)	**Risk** (1.3, 7.7)
Resilience (1.2, 7.3, 7.7)	**Renewable energy** (2.5, 2.6, 6.4)
Social licence to operate (2.5, 2.7, 3.8)	**Sustainable Development Goals** (4.3, 5.3, 6.1, 6.5, 7.2, 9.4, 9.5, 9.7)
Sufficiency versus need (2.5, 3.7, 6.1, 6.4)	**Sustainability competencies** (3.6, 4.3, 5.5, 6.1, 6.4)
Sustainability education accreditation (3.3, 4.5, 9.5, 9.8)	**Sustainability governance and policy** (2.8, 7.1, 7.3, 7.4, 7.5, 8.3, 8.4, 8.5, 9.4)
Sustainability leadership (6.1, 8.3, 9.3, 9.7)	**Sustainability mindset and triple bottom line** (2.4, 3.1, 3.3, 4.5 5.4, 8.4)
Sustainability values (2.4, 4.5, 5.6, 7.4, 7.6, 9.2. 9.4)	**Systems thinking** (3.3, 3.5, 4.1, 4.6, 6.5, 6.7, 7.1)
Tragedy of the commons (2.3, 7.5, 8.1)	**Transdisciplinarity** (3.1, 5.2, 6.5, 9.1)
Transformative learning (3.3, 4.5, 6.2, 6.7, 7.6, 9.7)	**Waste management and circular economy** (2.4, 3.7, 3.8, 4.1, 4.2,)

values, methods of thinking and future focus required to balance our economic and social demands within the natural boundaries and health of our global ecosystems.

The UN Secretary-General António Guterres noted in his Vision Statement on Transforming Education at the United Nations Transforming Education Summit in September 2022 that:

> Young people are also keenly aware that humanity faces existential threats in the form of the triple planetary crisis: climate change, pollution, and biodiversity. Throughout the Summit process, they made clear that they want to know more about these issues and to become part of the solution. As countries advance their commitments to Education for Sustainable Development, I urge them to consider how curricula and pedagogy could empower learners with the awareness, values, attitudes, and skills necessary to drive the change we need.
>
> *(UN 2022)*

In this Handbook, 'sustainability education' is referred to using a variety of terminologies (sometimes discipline specific) including but not limited to – education for sustainability (EfS), education for sustainable development (ESD) and environment and sustainability education (ESE). These terms, whilst sometimes framing certain dominant perspectives like 'sustainable development' or the 'environment', in this Handbook, are often used interchangeably to refer to the broad inclusion of sustainability thinking, sustainability principles, sustainable development goals and sustainability context in education curricula, which provide students with "the knowledge, skills, attitudes and values necessary to shape a sustainable future" (UNESCO 2014).

A sustainability mindset

> "To halt the decline of an ecosystem, it is necessary to think like an ecosystem"
>
> *(Douglas P. Wheeler, EPA Journal, Sept-Oct 1990)*

The entire formal education system from preschool to tertiary level, together with non-formal and informal education, has an important role to play in developing a sustainability mindset in our students. Universities in particular should be influencing public good–focused sustainability research and governance. Universities are also an important provider of professional education, and often the final element of formal education.

Sustainability education also helps in the development of a 'sustainability mindset' that cultivates a systems thinking understanding of the impacts of our production and consumption decisions on the environment and future generations, and moves the focus away from 'me' to the global 'us'. It should also provide a constant framing of sustainability values and principles to guide decision making (see Chapters 2.4 and 9.4 in this volume).

In developing a sustainability mindset, educators need to provide an understanding of sustainability knowledge and thinking to students, as well as to explain the overriding global or institutional operating context that influences sustainability management outcomes, together with the ethics and values underwriting modern sustainability thinking and decision making.

Sustainability education should focus on global citizenship and the collective good

Sustainability education has an increasingly important role in preparing and developing our students as future leaders and global citizens, with an introduction to the interconnected economic, environmental and social complexities of our modern world. Sustainability education is intrinsically focused on the connection between individuals and their environment and the responsibility we have in managing the 'collective good' for the benefit of both.

Social inclusion and diversity are also increasingly noted in our modern discourses as we reflect on the politics of gender equity and diversity in employment and public office. In addition, the importance of cultural identity and protection and racism are often-cited examples of social challenges and are discussed in this Handbook. Many of the chapters in this Handbook also allude to the social responsibility we have as educators in preparing our students for the many economic, environmental and social tribulations we will face in the 21st century.

In terms of global citizenship, Albert Einstein in his later life philosophically reflected on the selfish nature of the human condition and the need to embrace our being part of a bigger universe:

> A human being is a spatially and temporally limited piece of the whole, what we call the "Universe." He experiences himself and his feelings as separate from the rest, an optical illusion of his consciousness. The quest for liberation from this bondage [or illusion] is the only object of true religion. Not nurturing the illusion but only overcoming it gives us the attainable measure of inner peace.
>
> *(Albert Einstein, circa 1950s quoted in Calaprice (2005))*

The role and value of personal and cultural identity, social inclusion and diversity are well noted in modern literature and thinking. However, the UN has more recently recognised the importance of 'global citizenship' in sustainability education development:

> Global citizenship is the umbrella term for social, political, environmental, and economic actions of globally minded individuals and communities on a worldwide scale. The term can refer to the belief that individuals are members of multiple, diverse, local and non-local networks rather than single actors affecting isolated societies. Promoting global citizenship in sustainable development will allow individuals to embrace their social responsibility to act for the benefit of all societies, not just their own.
>
> *(UN Academic Impact: https://www.un.org/en/academic-impact/global-citizenship)*

Conclusion

The development of a sustainability mindset together with critical sustainability concepts, values and an increased awareness of global citizenship and collective good are key requirements in the sustainability education transition. The development of sustainability education curricula and pedagogy that encapsulates this new sustainability mindset should be the responsibility of all educators, regardless of their discipline.

This sustainability mindset must provide a clear understanding of the critical importance of the Earth's ecology in sustaining us and the significant, and in some cases irreversible impact, our human activity is having on the planet.

Educational institutions have a responsibility to provide an education that prepares students for a world requiring increased resilience in management; anticipatory governance and the important value of First Nations wisdom, knowledge and culture and their connection to land.

Furthermore, regenerative sustainability paradigms are now emerging that are re-imagining the responsibilities involved in the sustainability transition and these new responsibilities also need to be inculcated into our sustainability transition education, thinking and actions.

Sustainability education development is one of the most pressing challenges of the sustainability transition. We hope that this Handbook on 'Global sustainability education and thinking in the 21st century' provides teachers, students, policy makers and community leaders with the sustainability knowledge, thinking, values and future focus required to balance our economic and social demands within the natural boundaries and health of our global ecosystems.

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3.2
BEYOND GROWTH THINKING
The promise of regenerative development

Joseli Macedo

Key concepts for sustainability education

- Limits to growth thinking originated in the 1970s and made people aware of the finite character of our planet and its natural resources.
- The reality of exponential growth has been propagated ever since, and the impact that growth has on the sustainability of our planet is now better understood.
- The fallacy of unlimited growth was debunked and the need for ever-increasing economic growth challenged.
- The need to adopt new patterns and dynamics of human production and consumption has finally become clear, and sustainability education plays a significant role.

Introduction

> "It is scarcely necessary to remark that a stationary condition of capital and population implies no stationary state of human improvement. There would be as much scope as ever for all kinds of mental culture, and moral and social progress; as much room for improving the Art of Living and much more likelihood of its being improved."
>
> *(John Stuart Mill 1848)*

The world has been warned for a while now that the growth patterns experienced in the past cannot be maintained into the future. The notion that our planet's resources are finite is finally sinking in; however, the drive for infinite economic growth continues. Achieving sustainability in a world that does not respect the finitude of our planetary systems is impossible; we can strive for sustainable development, which means we continuously improve the quality of limited growth, not the quantity of limitless growth. One strategy is to adopt the notion of regenerative development, whereby we not only respect the planet's limits and strive for quality development but also rebuild and nourish the systems that may guarantee our survival.

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Limits to growth thinking

Several scholars, thinkers, and authors, among them Lester Brown, Herman Daly, Paul Ehrlich, Garrett Hardin, and Donella Meadows, started warning the world in the 1970s that there should be limits to the unbridled growth that was being experienced in the 20th century. Computer models were created to analyse production and consumption of world resources, articles and books were written warning us about the consequences of exponential population growth, and reports were published cautioning that we were using resources beyond the planet's carrying capacity. One of these reports was commissioned by the Club of Rome upon their decision to undertake the Project on the Predicament of Mankind; the report was later published as a book (Meadows et al. 1972).

In *The Limits to Growth*, which became a classic in several disciplines, the authors concluded that the then present trends would only allow the planet to survive for another 100 years but that sustainability could be achieved if trends were altered and ecological and economic stability was reached. Fifty years in, we are still arguing and trying to figure out the best way to heed their advice. The five elements those researchers focussed on during their project were population, food production, industrialization, pollution, and consumption of non-renewable natural resources, all of which were increasing exponentially at the time. For example, between 1950 and 1986, the world population doubled from 2.5 to 5.0 billion, whilst in the same time period, gross world product and fossil fuel consumption each quadrupled (Daly et al. 1989). If the same growth rate had been maintained, the world would have reached 10 billion people in 2021 (Figure 3.2.1), so we did make a minor course correction in population trends, but we still have a long way to go in many other aspects and not much time left.

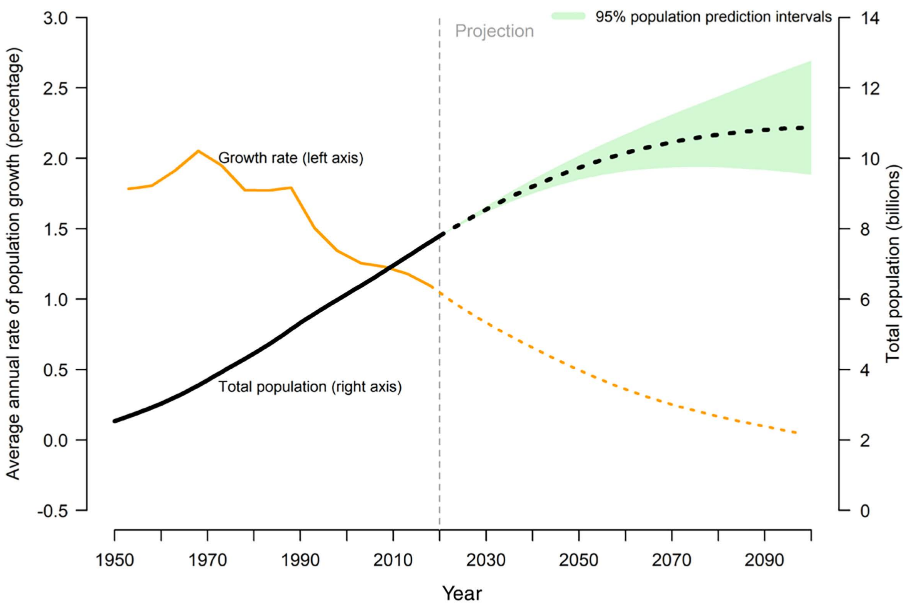

Figure 3.2.1 Population size and annual growth rate for the world (UN 2019; World population prospects. 2019).

One of the reasons for this minor course correction is the ingraining of the notion that, given limited resources, quality of life can be better for fewer people. Even in developing countries and in places that do not have population control policies such as China's one-child rule, a stabilization of population has been observed and attributed to two factors related to the economy: employment opportunities for women and their resulting affluence. This improvement manifests itself in the form of increased financial independence for individuals or increased overall family income given the additional contribution of employed family members. In addition, the perception that quality of life is improved for smaller families, with access to health care and better education opportunities, is widespread.

A case in point is that of Brazil, featured in a *National Geographic* article, part of the *7 Billion* series published by the magazine in 2011, when the world's population reached 7 billion (Gorney and Stanmeyer 2011). Brazil's fertility rates plummeted between 1960 and 2010, despite low levels of development and the influence of the Catholic Church, who frowns upon birth control and has made it impossible for Brazil to legalize abortion. In 1960, Brazil's fertility rate was 6.3; by 1980 it had fallen to 4.4 and by 2000 to 2.4 children per woman. The declining birth rate that took place in Brazil within 40 years took 120 years in England and was only achieved in China through the harsh one-child family policy. In the same period, the number of women in the workforce went from 15 million in 1980 to 34 million in 2000 (Gorney and Stanmeyer 2011). Today, Brazil, the largest country in South America, has the lowest fertility rates in the continent, comparable to Australia and the United States and only slightly higher than Canada and Europe. The current fertility rate of 1.9 children per woman is below replacement levels, and it is important to recognize that this decline was not driven by state policy but by women's decision to choose education and professional careers over childbearing and to raise small families.

Choices such as those being made by Brazilian women will have to be made in the process of transitioning from a paradigm of growth to one of equilibrium. And the choices to be made when a society realizes it cannot "maximize everything for everyone" will be based on human values: "Should there be more people or more wealth, more wilderness or more automobiles, more food for the poor or more services for the rich?. . . Yet few people in any society even realize that such choices are being made every day, much less ask themselves what their own choices would be" (Meadows et al. 1972, 181–182). Policy making and the political process that generates (or not) what is needed to make choices possible has been moving backward in the recent past. Strong action, grounded on values and ethical behaviour, will have to emerge if we are to effect the changes necessary to achieve some modicum of equilibrium in the next 50 years.

A "state of global equilibrium" would require that population and capital investment be of a constant size and be kept at a minimum and that the ratio and levels of both be decided according to society's values (Meadows et al. 1972). More importantly, a state of equilibrium could only be sustained if equitable distribution of resources, which arises from ethical decisions, were possible. Economic theorists distinguish between optimal allocation and optimal distribution; however, the issue of scale is what impacts sustainability (Daly et al. 1989; Daly 1996). An optimal scale would have to be determined relative to ecosystems and independent of optimal allocation. Market principles regulate allocation relatively well; however, "it cannot rightly determine its own scale or assure just distribution" (Daly et al. 1989, 244). Scale and distribution need to be detached from allocation and should be determined by the community at large, based on the values of each society making the difficult choices required to achieve sustainability. Most importantly, we need to achieve a sustainable scale first and later decide what the optimal scale is and whether our ethics will require us to opt for a biocentric optimum or an anthropocentric optimum (Daly 1996).

Unlimited growth fallacy

Classical economists believed that a stationary state of the economy would naturally be reached and, eventually, there would be no need for growth and hence no further progress (Daly 1996). Their thinking was based on physical and quantitative elements, which is the focus of a sustainable paradigm that recognizes the finite nature of resources, unlike the neoclassical paradigm that has ruled most of the 20th century. The latter is based on qualitative elements that demand an adjustment of the physical world so that it fits non-physical parameters, such as preferences and distribution of income. The neoclassical paradigm that has prevailed for more than a hundred years now "shifted attention away from resources and labour and onto utility, exchange, and efficiency" (Daly 1996, 4) with no limits to growth and no regard for the ecological capacity of Earth to sustain unlimited expansion.

Our addiction to growth took root in the post-war, post–green revolution era, when there was a lot of hope underlying the thinking of the times but, in hindsight, we know that even the best thinkers made erroneous predictions. The American engineer and futurist Buckminster Fuller, best known as the creator of the geodesic dome, for example, stated 55 years ago that "[h]umanity's mastery of vast, inanimate, inexhaustible energy sources and the accelerated doing more with less of sea, air, and space technology has proven Malthus to be wrong. Comprehensive physical and economic success for humanity may now be accomplished in one-fourth of a century" (Fuller 1967, 48); however, that promise has not materialized. Likewise, goal number 2 of the Sustainable Development Goals (SDGs) put forth in 2015 (UN 2015) – zero hunger – would not be necessary if the predictions to completely eradicate hunger "within a matter of a decade or two" (Bogue 1969, 828) had come true. The hopeful vision of unlimited growth calls for physical impossibilities, whilst a vision of limited growth calls for political impossibilities.

With economic growth comes increased industrialization and food production, and with affluence comes increased consumption. It is a foregone conclusion that a growing and affluent population will consume more than they would at lower levels of development; nonetheless, an increase in levels of development would also increase production of goods and services so that supply would meet demand. This simple economic growth equation, however, disregards the fact that biophysical resources may not be available for increased levels of production and consumption. And that is the fallacy of unlimited growth; a standard economic perspective that disregards social and environmental factors is unrealistic.

Even recipients of the Nobel Prize in Economics have focused on unsustainable growth. Capital accumulation, including land and human resources, population growth, and thus growth in the labour force, and technological progress were considered the major factors of economic growth in any society. Simon Kuznets, 1971 Nobel recipient, upgraded the traditional components of economic growth – capital, labour, and technology – to include a sustained rise in national output based on institutional and ideological adjustments to advancing technology (Todaro 1989). His six growth characteristics include high rates of capital output and population growth; productivity increase; economic structural transformation; and social, political, and ideological transformation, along with international economic outreach and limited spread of economic growth. Although this upgrade hints at social innovation, there is still no mention of adjustments needed to accommodate finite resources.

Furkiss (1974, 235) provides a graphical description of our situation:

> Present-day society is locked into four positive feedback loops which need to be broken: economic growth which feeds on itself, population growth which feeds on itself, technological change which feeds on itself, and a pattern of income inequality which seems to be self sustaining and which tends to spur growth in the other three areas. Ecological humanism must create an economy in which economic and population growth is halted, technology is controlled, and gross inequalities of income are done away with.

An economic development perspective, one that is not based on quantitative indices, may be better suited to this discussion. Power (1988, 127) argues that the economic base of a community "includes the quality of the natural environment, the richness of the local culture, the security and stability of the community, the quality of the public services and the public works infrastructure, and que quality of the workforce." The difference between growth and development is key in debunking the fallacy of economic growth. Todaro (1989) defines development as "the process of improving the quality of all human lives" (620) and economic growth as "the steady process by which the productive capacity of the economy is increased over time to bring about rising levels of national income" (622). Most quantitative indices used to measure economic growth – such as increases in sales volume, number of jobs and respective income, and population – do not measure development, particularly in local communities as opposed to nations, but the qualities that determine the welfare of citizens do (Power 1988). And both social and environmental qualities ought to be included. Sustainable economic development can be achieved if policies are formulated based on carrying capacity and ecological limits.

Impact of exponential growth

The impact that economic and population growth may separately have on the planet can be extrapolated based on current indices; however, it is difficult to predict the impact of factors hinging on the population-economy nexus. There are two different categories of needs to sustain both economic and population growth: physical necessities and social necessities, neither of which are sufficient in isolation (Meadows et al. 1972). Nonetheless, physical necessities, such as natural resources, food, and an environment free of toxic pollutants, are considered to be the first order of extrinsic human needs (Maslow 1943). In addition, basic physical needs can be quantified based on simple population-related indices, and their exponential growth can be easily projected based on current expectations of supply. The problem is that these simplified projections do not take into account the limits of Earth's ability to meet the total demand created by these needs, nor the interrelationships between different needs.

The interaction of needs makes projections much harder: "Population cannot grow without food, food production is increased by growth of capital, more capital requires more resources, discarded resources become pollution, pollution interferes with the growth of both population and food" (Meadows et al. 1972, 97). Not accounting for these interrelationships and feedback loops of the entire system makes predictions unreliable, and they only become foreseeable when the known limits to supplying the needs are approached. The difficulty of making such projections increases when trade-offs, which are rarely taken into account, are added to the equation. And their complexity increases when they involve not only the present population but also future generations.

We need to "keep the rich from leaning too heavily on the poor and the present generations from leaning too heavily on future generations" and keep "human beings from leaning too heavily on other creatures whose habitats must disappear as we convert more and more of the finite ecosystem into a source for raw materials, a sink for waste, or living space for humans and warehouses for our artifacts" (Daly 1996, 215). Many decisions being made today will not impact those making them; it may take a few generations before the impact of some poorly conceived policies are felt. And then it will be too late to reverse the process: "if the global society waits until [the physical constraints of the planet] are unmistakably apparent, it will have waited too long" (Meadows et al. 1972, 183).

Another obstacle to overcome is that growth in one area may increase the exponential rate in others and per capita resource use does not remain constant; for example, as a population becomes wealthier, there is a tendency that its consumption patterns will change and per capita consumption will increase. Some of these issues have been resolved by technological advances, and this has created a perception that technology can take care of everything and all the challenges can be overcome by ingenious solutions. That perception creates this illusion "precisely because science and technology have given us such power that the scale of our economy has been able to grow to the point where we now must consciously face the fundamental limits of creaturehood: finitude, entropy, and ecological dependence" (Daly 1996, 214). This perspective is particularly poignant when we consider the fact that more than half of the population on Earth lives in urban areas today and rates of urbanization are continuously increasing, having reached 90% in the case of some countries (Angel et al. 2010; UN-Habitat 2008). Each growing urban area has a growing ecological footprint that extends beyond the political boundaries of the city and, in some cases, national boundaries. Globalization has made it possible for urbanites to rely on resources that not only require several times the territory of a city to be produced but also are produced for the lowest cost in places far removed from the cities that consume them.

Scientific advances have helped us understand how urban systems work and how the process of urbanization has impacted our ecosystems (Pincetl et al. 2012); however, occasional linkages among different areas of scientific knowledge have not comprehensively addressed the complexity of urban sustainability. Although cities occupy only about 2% of the Earth's land surface, the majority of people live in urbanized areas, and cities are responsible for 80% of the global gross domestic product (GDP), thus achieving urban sustainability is akin to achieving global sustainability. Whether we study urban sustainability from an anthropocentric or an ecocentric viewpoint, multiple perspectives need to be taken into consideration. Feedback loops and the unintended consequences of beneficial patterns of urban development can only be studied and evaluated from a multidimensional framework that takes into consideration social, economic, environmental, and civic processes as part of the metabolic transformation of urban areas.

Patterns and dynamics of human production and consumption

One of the most coveted commodities in the capitalist world is land. The consumption of land may be at odds with sustainable development, and although several countries, such as

China and the Netherlands "produce" land by extending their territories into the ocean, it is not exactly a commodity that can be produced in large scale and infinitely. Human settlements have been consuming land, along with other natural resources found on it, for millennia. Development patterns and dynamics of human settlements underlie several discussions within numerous disciplines and encompass a variety of issues, among them environmental conservation, land tenure, citizens' rights, social welfare, land use legislation, and economic development, to name a few. In the last 25 years or so, several countries have instituted policies and legislation with the intention of conserving land and protecting natural resources, whilst allowing land (in most cases "private property") to fulfil its economic purpose, an idea aligned with the principle of optimal allocation/distribution/scale discussed earlier in this chapter. These conservation areas, usually set aside because of their physical characteristics and environmental sensitivity, are not preserved; permissible land uses are determined based on the feasibility of simultaneous economic development and sustainability of environmental conditions. This stipulation is founded on the premise that certain activities that spur economic development are compatible with land use restrictions concerning the protection of natural resources. A basic argument behind legislation that allows limited uses without totally curtailing the economic potential of land is that these schemes make it possible for these laws to be enforced (Macedo 2004).

Urbanization and the way land is developed and subdivided have a direct influence on ecological conditions; this leads to fragmented landscapes, altered hydrology, and disconnected homogeneous habitats (Alberti 2005; Alberti et al. 2020). Spatial patterns of human activity in urban areas have a direct influence on how land uses evolve and what ecological impacts the various uses will have in the bioregion. As non-renewable resources become scarce and the impacts of climate change more severe, urban economies will become more localized and dependent on regional ecosystems. Better coordination between resource management and urban design and planning is fundamental for advancing sustainable development (Kennedy et al. 2011). Several attempts have been made to measure urban sustainability to provide both policy makers and the general public the necessary tools to monitor urbanization impacts and to target their efforts in increasing the sustainability of cities. Indicators, impact assessment tools, and performance systems have been developed and used to define and qualify sustainable cities (Alberti 1996; Pickett et al. 2013), some with more success than others. A significant hurdle is the dearth of information on environmental aspects of cities. Some cities keep track of pollutants, water consumption, and energy flows, but there is no uniformity, which makes it difficult to develop indicators that would work in multiple places with different sizes, conditions, and climates.

One option to deal with the discrepancies of information and inconsistencies of datasets is to analyse cities within their specific ecosystems. Some researchers and scholars have linked cities to their ecological base within the framework of urban metabolism to measure the impact of urban growth on the environment (Ferrão and Fernández 2013; Kennedy et al. 2011; Pickett et al. 2013; Pincetl et al. 2012). Urban dynamics analysis should include not only urban systems in all of their complexity but also their non-urban surroundings and the interface between them, so that "clear and essential linkages between dynamic urban trends and resource flows" are uncovered (Ferrão and Fernández 2013, 158). Ferrão and Fernández (2013) offer a conceptual framework built on several layers of physical elements that constitute the physical urban space and that can be used to model the metabolism of urban systems, connecting energy and material flows to the economic activities that create the demand for them. Combining urban metabolism and life cycle assessment (LCA) into a multiscale framework has been suggested as a way to enhance our understanding of sustainability and devise strategies to achieve it in urban environments (Chester et al. 2012). LCA methods can quantify resource depletion and ecosystem damage, complementing urban metabolism analyses and the evaluation of flows in the ecosphere. Although the concept of urban metabolism provides the means to analyse cities in terms of flows and storage of energy and materials, the social dimension of sustainability, which is not included in most studies, needs to be included in any evaluation model used to assess the efficiency and the sustainability of urban systems.

The discussion has evolved from a steady-state economy and sustainable development to regenerative development. In economic terms, we have the opportunity to try and achieve a steady-state economy, which is necessary for sustainable development. In development terms, the paradigm of regenerative development may allow production to supersede consumption, particularly in urban areas, by building cities that create social and natural capital. The concept of regeneration was originally promoted by Robert Rodale's work in organic farming (Lyle 1994); the same principle of self-renewal can be applied to replace outdated linear systems with regenerative systems. Lyle (1994, 10) proposed to design regenerative systems that would provide "for continuous replacement, through [their] own functional processes, of the energy and materials used in [their] operation." A regenerative design and development approach can operationalize natural processes to addresses the population and climate challenges to current ecological, economic, and socio-cultural systems whilst recognizing and respecting natural limits. Based on natural renewal processes, regenerative systems are a long-term solution that can be adopted globally through local actions. In fact, regenerative practices have been used continuously, mainly in agriculture, by several cultures in the world. Adapting these practices to an urban world, where a regenerative economy shapes consumption patterns and material goods are produced for a steady-state economy using renewable energy sources, could take us in a potentially sustainable direction. Our ultimate goal should be to have cities that "are like a living ecosystem that repairs and restores itself providing its part in the broader bioregional and biosphere cycles of carbon, nitrogen, phosphorus, water and minerals" (Zingoni de Baro and Macedo 2020, 226) by subscribing to the core principles of regenerative design and development, notably, systems thinking, respect of place, community engagement, and co-evolution.

The concept of regenerative urban development was advanced by Girardet (2010) in his 2010 World Future Council report, in which he argues that creating sustainable cities is no longer enough. A regenerative approach to urbanization and urban living would allow cities to contribute to ecosystem services instead of simply aspiring to not creating further damage to the environment by lowering carbon emissions and becoming more resource efficient. A regenerative city is defined as a city that "1. Relies primarily on local and regional supplies. 2. Is powered, heated, cooled and driven by renewable energy. 3. Reuses resources and restores degraded ecosystems" (Girardet 2013, 4). The same concept has been used under different names, such as ecocities (Register 1987) and ecopolis (Downton 2009). Girardet (2013, 9) defines ecopolis as a city that "reintegrates itself into its surrounding environment, not only drawing on regional biologically productive land but also developing the potential for regional renewable energy supplies." Regenerative design is an alternative way of approaching the built environment, developing it to not only mitigate ecosystem degradation but also promote the value of nature with humans as part of it. This restorative relationship between cities and the ecosystems that sustain them needs to be supported by comprehensive political, financial, and technological strategies (Girardet 2010).

We could begin to regenerate the planet if, instead of seeing urbanization and city growth as a threat to the world's future, we took the necessary measures to do more than simply minimize their impact; restoring the damage and helping reconcile past impact with local and regional ecosystems could be our promise of protection for the planet. In other words, regenerative urban design and development could make cities part of the solution rather than the cause of environmental damage.

A regenerative approach goes beyond reducing the ecological footprint of cities and striving for biophilic urbanism (see Chapter 3.7 in this volume); regenerative design addresses the complexity of ecosystems and the need to restore them. Acknowledging the built environment as a social-ecological system contained in the ecosphere requires the integration of city form and physical processes with those processes utilized to make decisions (Moffatt and Kohler, 2008). To enhance the value of cities and their potential in regenerating the environment, we will need to incorporate natural ecosystems services into the urban regenerative design process across scales – local, regional, and national – and time (Zingoni de Baro and Macedo 2020). Creating ongoing regenerative capacity that can be sustained over time will require active and reflective stewardship, not only by designers but also users of urban space, and an understanding of social-ecological systems as the foundation for long-term capacity. In addition, design based on ecosystem services can generate new and more sustainable patterns of development that allow for ecological restoration, including habitat provision and climate regulation. Finally, a regenerative approach can establish and maintain symbiotic relationships among elements that co-evolve and support the health and resilience of all systems across time horizons; feedback loops should show the regenerative capacity of a system and its durable evolution over time.

If we accept the first law of thermodynamics – nothing is produced or consumed, only transformed – the discussion needs to be about human transformation rather than human production and consumption. Humans transform natural capital into man-made capital. At an optimal scale, production is for maintenance, not for growth, and "since natural capital has replaced man-made capital as the limiting factor, we should adopt policies that maximize its present productivity and increase its future supply" (Daly 1996, 79). Economic policy going forward needs to focus on a sustainable or, as Daly argues, a "steady-state economy" (Daly 1996). And if we succeed in establishing a sustainable, steady-state economy whose focus is to regenerate the environment and the social-ecological systems that support our life on the planet, we may just make it out of this planetary predicament in which we find ourselves today.

Conclusion

The debate around limits to growth flourished in the 1960s and 1970s, when an environmental consciousness developed, and fizzled in the 1980s and 1990s, when neoclassical economists and neoliberal policies prevailed. Despite all the conferences and treaties around sustainable development, change is slow. Perhaps, if the limits-to-growth debate was rekindled, the world would start moving towards optimal global equilibrium or a steady state. In a capitalist world, though, it is difficult to detach the need for economic development from the need to preserve the environment: "Economic policy for sustainable development must no longer seek solutions to economic problems in terms of the modern central organizing principle of growth, but in terms of the traditional principles of sustainability, sufficiency, equity, and efficiency" (Daly 1996, 222). Education plays an important role and may be the only avenue to change a paradigm of growth and sustainable development into one of regeneration. Through an educational system that values life, not only human, but all life, a ruling ethic of sustainability could be established:

> In this vision, along with sustainability, the associated values of sufficiency, equity, and efficiency become the central organizing principles of the economy. Growth in population or per capita resource use would be encouraged or discouraged according to their favorable or unfavorable effects on sustainability, sufficiency, equity, and efficiency.
>
> *(Daly 1996, 224)*

The challenge for this and future generations is to accept the reality of limits to growth and to devise ways to not only curtail growth and reduce its impact on the planet but also adopt a development paradigm of regeneration of the very natural systems that provide us the resources we demand. In the particular case of urban development, restorative urbanization needs to become the norm; regenerative practices need to be embedded in urban policies and building codes and environmental practices. In addition, the connections between urban areas and the hinterlands that support them will have to be reconceptualised based on the social-ecological systems within cities and their surrounding bioregions.

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3.3
THRESHOLD CONCEPTS IN SUSTAINABILITY EDUCATION

Melissa Marinelli and Sally Male

Key concepts for sustainability education

- Curricula can be focused by identifying threshold concepts and capabilities and how they are troublesome for students, and designing learning activities and assessment focusing on threshold concepts.
- Threshold concepts are transformative, critical and troublesome.
- Sustainability is a threshold concept, which relies on threshold concepts including systems thinking, multiple ways of knowing, transdisciplinarity, triple bottom line, life cycle thinking and design thinking.
- Educators should consider pre-liminal variation between students, that is, the different backgrounds students bring when they encounter threshold concepts, and how this leads to students experiencing the same threshold concepts differently.
- Sustainability is a threshold concept for many educators in many disciplines, and teaching sustainability is a threshold capability. Therefore, educators are likely to require support to teach sustainability.

Introduction

Many chapters in this Handbook have discussed the roles of educators and how to teach sustainability. In this chapter we focus on what to teach in sustainability education, particularly the need to focus on critical content. The chapter begins with an introduction to the curriculum development framework of threshold concept theory (Meyer and Land 2003) and how the framework can be used to focus curricula. We then apply the framework to sustainability education to identify some of the threshold concepts in sustainability education, namely sustainability, systems thinking, multiple ways of knowing, transdisciplinarity, triple bottom line, life cycle thinking, and design thinking. We argue the case for each identified concept being threshold in nature and therefore a recommended focus of learning activities and assessment in sustainability curricula. The purposes of this chapter are to identify some critical concepts that sustainability educators

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should focus on in their curricula and to demonstrate the value of identifying threshold concepts and capabilities, so that readers can also identify additional threshold concepts and develop curricula accordingly.

Additionally, we explore the value, limitations, and opportunities with respect to accreditation as one of the drivers for sustainability education, using the example of engineering accreditation internationally. We recommend that accreditation criteria focus on threshold concepts in sustainability education and note that, due to the threshold nature of sustainability, educators will need support to develop capability for sustainability education.

Threshold concepts

Threshold concept theory was conceived in 2003 by Meyer and Land and has been used in curriculum development and research in numerous disciplines since (see https://www.ee.ucl.ac.uk/~mflanaga/thresholds.html for a comprehensive compilation). The theory proposes that in every discipline there are 'threshold concepts' that are critical to future learning and practice in the discipline and transformative for students. These concepts form gateways in a student's learning. Being transformative, threshold concepts are usually troublesome for students (Perkins 2006).

By identifying threshold concepts and how they are troublesome, an educator can identify the most important and challenging learning in a discipline and thereby focus learning activities and assessment in curricula. Although other concepts might be important, they are not as transformative, meaning that they do not require such a major change in how the student thinks and acts, and therefore they are not as challenging. Students can learn many concepts independently and quickly. Threshold learning, in contrast, requires extra attention from students and educators. In a curriculum, educators should emphasise learning activities and assessments focusing on threshold learning.

Identifying threshold concepts

Threshold concept theory describes common features of threshold concepts (Meyer and Land 2003). These features can be helpful in identifying threshold concepts and in designing curricula and assessments that focus on the identified threshold concepts.

The compulsory feature of a threshold concept is that it is *transformative*. Becoming comfortable with a threshold concept involves a major change in how a student thinks and understands the world and leads to development of a new capability required for future learning or for practice.

Due to being so transformative, threshold concepts are usually *troublesome* for students (Meyer and Land 2003, 3). This can be for any reason. Examples of sources of trouble are being counterintuitive or requiring a perspective that is unfamiliar to the student given their background.

Threshold concept theory describes additional common features of threshold concepts. Two common features that are often useful in identifying threshold concepts are being 'integrative' and 'irreversible' (Meyer and Land 2003, 4). Being integrative refers to students frequently finding that understanding a particular threshold concept connects other concepts between which the student previously saw no connection. Threshold concepts are usually irreversible in the sense that a student rarely loses their understanding of a threshold concept once achieved.

Some threshold concepts in sustainability

We present seven threshold concepts in sustainability. These concepts are central to sustainability education and practice, and several are discussed in detail in other chapters within this Handbook. They have been identified as threshold concepts in sustainability from recent conceptual and empirical research.

Taylor (2008, 185) states:

> Each discipline is acknowledged as having distinctive ways of thinking and practicing in the subject, which transcend understanding and use of discipline knowledge, and taken together, describe the community, its way of seeing the world, and the position of its members.

While sustainability is inherently interdisciplinary, in that it extends beyond a single discipline, the threshold concepts presented encompass ways of knowing and thinking that define the field.

Many of the threshold concepts in this chapter are interrelated. Understanding of a threshold concept may depend on understanding other threshold concepts or may provide access to further threshold concepts. These relationships are presented in Figure 3.3.1.

Each concept is introduced in a concept overview. Its transformative nature, troublesome features, and other features common to threshold concepts are then presented. The descriptions of transformative features of each concept include how a student changes how they think once comfortable with the concept, as well as the new capabilities opened to the student by understanding and becoming comfortable with the concept. These new capabilities are described specifically with relevance to sustainability.

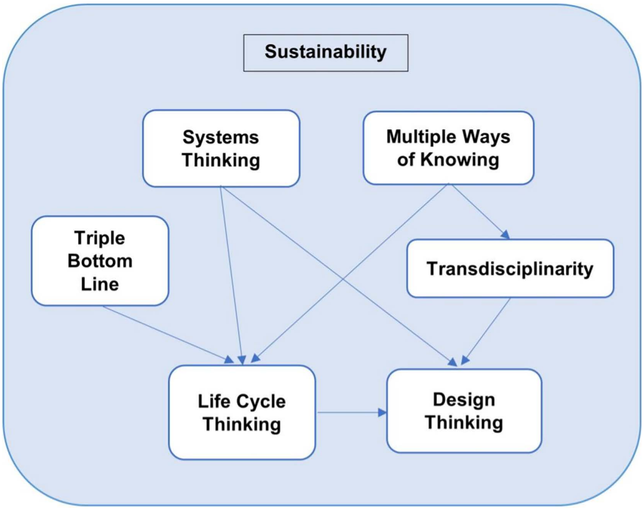

Figure 3.3.1 The threshold concepts of systems thinking, multiple ways of knowing, transdisciplinarity, triple bottom line, life cycle thinking, and design thinking sit within the threshold concept of sustainability and both inform and are informed by it. Note: The direction of the arrow indicates dependence or influence. Sustainability is considered an overarching threshold concept.

Sustainability

Concept overview

Loring (2020, 190) describes sustainability as "a fundamentally new way of exploring the world" that reflects a shift away from purely material progress.

Sustainability is broadly defined as "meeting the needs of the present without compromising the ability of the future to meet its needs" (World Commission on Environment and Development 1987). Linking to the three pillars of sustainability, this implies "that social conditions, economic opportunity, and environmental quality are essential if we are to reconcile society's development goals with international environmental limitations" (Mihelcic et al. 2003, 5315).

Sustainability as a threshold concept

Sustainability is in itself a threshold concept, in that it is both transformative and troublesome.

Sustainability isn't just a new concept that can be added to existing ways of thinking and managing; it is a new paradigm altogether (Loring 2020, 183).

Transformative: As a concept, sustainability is transformative in that it has created and has potential to continue to create permanent shifts in consciousness and outlook at individual and collective levels. The sustainability worldview challenges beliefs that we hold about human nature and our position in the world and is in contrast to the dominant existing worldview (Hess and Strobel 2013). Deep understanding of sustainability requires transformation of individual thinking and perspective. It also impacts how we relate to one another and the rest of the natural world (Barrett et al. 2017).

Troublesome: Sustainability is a complex and multidimensional concept that can be difficult for learners to comprehend. Drawing from research of sustainability worldview and threshold concepts (Hess and Strobel 2013; Lam et al. 2014; Levintova and Mueller 2015), reasons for complexity include:

- A broad and consequently vague definition of the concept;
- Pluralistic visions of sustainability based on diverse needs and desires;
- A range of approaches to studying and understanding sustainability;
- Conflict between the three aspects of sustainability and the need to consider these three pillars concurrently rather than independently;
- Tension between local, national and global priorities; and
- Conflict between the sustainability worldview and the "contemporary dominant Western worldview".

At the philosophical level, a shift in worldview demands the learner to learn to think in a fundamentally new way (Loring 2020). This may challenge learners, as it requires a shift from the dominant positivist paradigm. Undertaking this shift may be more challenging for students who are schooled in the more reductive and deterministic disciplines, such as engineering, science, and technology (Hess and Strobel 2013).

At a conceptual level, understanding the individual elements of sustainability is achievable for students, but the understanding and internalising of sustainability as a balanced concept is difficult. In studying students' comprehension and application of sustainability, Levintova and Mueller (2015) observed that students struggled with the multidimensional nature of the concept and favoured environmental aspects of sustainability over economic and social dimensions.

Systems thinking

Concept overview

To make sense of the complexity of the world, we need to look at it in terms of wholes and relationships rather than splitting it down into its parts and looking at each in isolation (Ramage and Shipp 2009, 1; from Sandri 2013).

Systems thinking sets out to view phenomena in a holistic way, as an integrated whole, comprised of elements, and the linkages and interactions between them.

Merali and Allen (2011, 32) list the features of systems thinking:

- The existence of a distinct entity that can be identified and explicitly defined as 'the system' or 'the whole';
- The composition of 'the whole' from interconnected parts; and
- The existence of distinctive properties that can be ascribed to 'the whole' but not to any of the individual parts that constitute 'the whole' (i.e., 'the whole' is more than the sum of its parts).

This contrasts with the reductive and deterministic way that most of us have been taught to understand life (Hess and Strobel 2013). Systems thinking requires a shift from considering simple, linear relationships to inter-relationships, multiple perspectives, and influences.

Systems thinking and whole-system approaches are at the heart of sustainability practice and learning (Sandri 2013) (see Chapters 3.3, 3.5, 4.1, 4.6, 6.5, 6.7, and 7.1, in this volume). Sustainability problems are systems problems – complex, difficult, even 'wicked' (Phelan et al. 2015). Taking effective action towards sustainability requires learning to adopt a systems mindset. Concurrent consideration of the big-picture and element connectivity has the potential to reveal multiple avenues for effecting change.

Systems thinking as a threshold concept

Systems thinking can be considered a threshold concept for sustainability education due to its transformative, troublesome, and integrative nature.

Transformative: Systems thinking expands sustainability understanding by transforming awareness and perspectives. Sandri (2013) and Loring (2020) highlight several changes in thinking that result from the shift from reductionist to systemic paradigms:

- From small picture to big picture;
- From simple cause and effect to complex interconnectedness with multiple influences and perspectives; and
- From external to internal: as a learner becomes aware of their role as an active element within the system, rather than a passive observer.

These shifts in perspective may uncover unexpected connections and unanticipated consequences (Loring 2020). Life cycle thinking, discussed further in this chapter, is an example of a practice for which systems thinking is critical.

Troublesome: While paradigmatic shift is transformative, adopting a systems mindset has been described as resistive and "deeply unsettling" (Meadows 2008, 3). Loring (2020) and Barrett et al. (2017) highlight that systems thinking challenges our current (dominant) approaches to addressing complex problems, and our relationship to the natural world.

Further, it is often difficult to identify the most valuable system boundary. Larger systems include more of the relevant elements for analyses but add complexity to an extent that may make it infeasible to complete analyses.

Integrative: Effective sustainability learning and the ability to respond to issues and effect change require awareness and understanding of systems approaches. Systems thinking underpins core sustainability competencies, including:

> interdisciplinary skills, critical thinking, working with multiple stakeholders, foresighted thinking, dealing with complexity and uncertainty, social justice and equity, care for the environment and the physical world.
>
> *(Sandri 2013, 812)*

Learners may find it difficult to understand and practice sustainability without a grasp of complex interactions and interdependencies (Phelan et al. 2015). Systems thinking can be considered a foundational threshold concept in sustainability, providing access to other threshold concepts including life cycle thinking and design thinking (see Figure 3.3.1).

Multiple ways of knowing

Concept overview

Multiple ways of knowing is a philosophy of knowledge that posits that there are many ways to understand and engage with the world. There are multiple valid ways of knowing that extend beyond the positivist philosophy of knowledge underpinning Western science and acknowledging a single, intellectualised way of knowing (Hess and Strobel 2013).

In relation to sustainability, Barrett et al. (2017) and Loring (2020) identify ways of knowing to include:

- Academic discipline knowledge;
- Indigenous and other local ways of knowing, which draw on experience gained first-hand while working and living with the land;
- Knowledge obtained or revealed through communication with more-than-human agents; and
- Intuitive, transrational, and embodied ways of knowing.

The multiple ways of knowing philosophy recognises the validity and value of ways of knowing and knowledge that are held by Indigenous peoples, other local experts, and more-than-human agents (Loring 2020).

Extending from multiple ways of knowing is the concept of plurality – that there are a range of different ways of conceptualising or understanding a concept. Sustainability is a flexible, pluralistic concept adapted and influenced by myriad contexts (Lima and Partidario 2020).

Acknowledging different frameworks for knowing is a key learning outcome of sustainability education (Phelan et al. 2015, 19):

> Knowing about the varied ways in which environment and sustainability is understood, and how this varied knowledge is generated and used and its limitations, is critical to transdisciplinary approaches. Awareness of their differences and their value is critical for synthesising new insights into environment and sustainability issues.

Multiple ways of knowing are operationalised through transdisciplinary approaches (transdisciplinarity is also a threshold concept in sustainability and is discussed further in this chapter).

Multiple ways of knowing as a threshold concept

Multiple ways of knowing is considered a threshold concept due to its transformative, troublesome, irreversible, and integrative nature.

Transformative: Acknowledging, accepting, and using multiple ways of knowing requires a shift from the positivist philosophy of knowledge to a transdisciplinary perspective. For learners, this results in a broadened and more inclusive perspective. They may encounter conflicts or contradictions in knowledge that result from diverse ways of sense making, but as Loring (2020, 188) explains, a transdisciplinary perspective allows learners to reframe these as "aspects of reality which neither knowledge system can fully account".

Troublesome: Becoming aware of and accepting the existence and validity of multiple ways of knowing can be difficult for learners because:

> the positivist philosophy of knowledge that is so extensively taught in Western society teaches us that the scientific method is not just a powerful way of knowing but also the legitimate way of knowing.
>
> *(Loring 2020, 188)*

In practice, the validity and credibility of diverse ways of knowing such as local and traditional knowledges, intuition, transrationality, or embodiment may be questioned by those not engaged with the concept (Barrett et al. 2017).

Acknowledging multiple ways of knowing also requires learners to become aware of their own worldview:

> An awareness of one's own worldview, and the worldviews of others, is critical to understanding diverse concepts and approaches associated with environment and sustainability.
>
> *(Phelan et al. 2015, 20)*

Becoming aware of one's own worldview can be confronting, as it requires unearthing and acknowledging values, attitudes, and identities. Learners may encounter tensions between their own position and diverse epistemologies (Barrett et al. 2017). For sustainability education, this may require learners to accept that their own understanding of and beliefs about sustainability may be different from others' understanding and may not be paramount in every situation.

Irreversible: Exposure to diverse ways of knowing makes it difficult to return to a rational scientific worldview (Barrett et al. 2017).

Integrative: Understanding of multiple ways of knowing is required for adopting a transdisciplinary perspective (see Figure 3.3.1).

Transdisciplinarity

Concept overview

Linked to systems thinking and the inherently complex nature of sustainability issues is the need for responses grounded in a transdisciplinary approach (Annan-Diab and Molinari 2017; Feng 2012).

Disciplinarity refers to "a bounded way of understanding the world through shared language, tools, institutions, rules and epistemological commitments" (Feng 2012, 32). Disciplinarity commonly relates to academic disciplines, holding their "own concepts, definitions, and methodological protocols for the study of its precisely defined domain of competence" (Lawrence 2010, 126).

Adopting a transdisciplinary approach involves the integration or synthesis of knowledge and experiences from diverse groups, including but not limited to academic disciplines, with a view to generating new and expanded insights, enriched understanding, and novel approaches to issues or problems (Lam et al. 2014; Lawrence 2010). Adopting this approach requires acceptance of the validity of multiple ways of knowing.

In relation to sustainability education, Phelan et al. (2015, 11) explain:

> Transdisciplinarity encourages a shift in perspective that includes and extends beyond single traditional disciplines: this approach recognises that effective responses to 'wicked' sustainability challenges (challenges which are difficult to clearly define, constantly evolving, and have no clear resolution) lie beyond individual disciplines. The field thus encompasses and synthesises the contributions of many disciplines and seeks to draw academic knowledge into dialogue with other forms of knowledge.

A transdisciplinary approach is needed to address and find solutions to the multidimensional, complex issues that characterise sustainability (Lam et al. 2014). Drawing on the knowledge of different disciplines enables new and relevant insights that cannot be achieved through the limited perspective of a single discipline approach.

The inclusion of 'other forms of knowledge' extending beyond academic knowledge, distinguishes transdisciplinarity from interdisciplinarity (Lawrence 2010). As both approaches require integration and synthesis of diverse knowledge and experiences, the benefits and challenges of interdisciplinarity established in research are also relevant to this threshold concept.

For detailed consideration of this topic, refer to Section 2, Thomas, in this volume.

Transdisciplinarity as a threshold concept

Transdisciplinarity is a transformative, troublesome, and integrative concept for learners.

Transformative: Studies of interdisciplinary approaches have found that transdisciplinarity helps learners make sense of the complex issues of sustainability education.

Exposure to the multiple perspectives and approaches to sustainability that range across and beyond disciplines equips learners to recognise strengths and limitations of various perspectives. It prompts learners to explore, reflect on, and develop their own perspectives (Feng 2012).

Exposure to knowledges and perspectives outside academic disciplines, such as Indigenous knowledges, is particularly powerful. It can lead to increased awareness, curiosity, and new senses of responsibility, and drive action (Kilada et al. 2021). In a similar way to systems thinking, transdisciplinarity is transformative as it can shift a learner from passive observer to active participant (Barrett et al. 2017).

Troublesome: Transdisciplinary approaches to sustainability require a shift away from conventional discipline learning. This may be challenging for some learners, as it requires them to cross disciplinary boundaries. This demands a certain mindset of learners characterised by openness, curiosity, and adaptability; a reflective capacity; and valuing of multiple ways of knowing (Utrecht University 2022).

Some learners experience discomfort, tensions, or forms of cognitive dissonance (Feng 2012). Integration of knowledge beyond a single bounded discipline can reveal apparent conflicts between various areas of knowledge or between self and others. This may be a particular issue when embedding sustainability into existing 'traditional discipline' curricula (for example: engineering) or for students with a background in a single discipline area who transition to further studies in sustainability.

As with multiple ways of knowing, the access to and application of diverse knowledge beyond academic knowledge can be challenging. Learners may struggle with lack of knowledge or lack of experience with holders of diverse knowledge (for example: with Indigenous elders (Kilada et al. 2021; Thomsen et al. 2021)). Learners may realise that their knowledge, perspectives, and approaches are limited or inappropriate. However, continued exposure can support learners to move through discomfort.

Integrative: Shift to a transdisciplinary perspective builds on accepting the validity of multiple ways of knowing and is required for life cycle thinking and design thinking (see Figure 3.3.1).

Triple bottom line

Concept overview

The triple bottom line originated as an organisational-level sustainability concept that considers a company's social, environmental, and economic impact (Elkington 2018). It offers a shift from the traditional, purely economic view of business purpose – to increase profit regardless of impact – to an expanded view of purpose encompassing the dimensions of profit, people, and planet. The triple bottom line concept is significant as it has introduced sustainability to the boardroom, providing a touchstone for sustainable business strategies and practices, and a way of approaching decisions from multiple dimensions.

The nested hierarchy model (Sidiropoulos 2014) extends Elkington's triple bottom line concept to consider interdependence and hierarchical position of the three dimensions. The nested hierarchy model depicts economic systems (profit) as dependent on human society (people) encompassed by the environment (planet). This offers a further paradigmatic shift, resulting in the understanding of the connection between humans and their systems with the planet (Icawat 2018).

Triple bottom line as a threshold concept

Triple bottom line is considered a threshold concept due to its transformative, troublesome, and integrative nature.

Transformative: The Triple Bottom Line (TBL) wasn't designed to be just an accounting tool – it was intended to provoke deeper thinking about capitalism and its future (Elkington 2018).

Understanding the triple bottom line is transformative, as it provokes a shift away from reductionist thinking. At its core, understanding the concept promotes disruptive change (Elkington 2018). It transforms learners' understanding of business purpose and definitions of success from a one-dimensional economic view to a broader, multidimensional view grounded in sustainable practice. Understanding of the nested hierarchy concept represents a further shift in thinking, towards a holistic, interdependent and hierarchical understanding of sustainability.

Troublesome: As a concept, triple bottom line can be difficult for students to comprehend, as it requires integration of all three elements of sustainability. As a way of thinking, it requires a shift from one-dimensional to multidimensional thinking. This may be challenging for learners coming from technically focused disciplines who have not been previously exposed to social or human contexts and perspectives (Rosano 2018).

Triple bottom line has been critiqued for failing to cause the intended disruption to the single bottom line paradigm (Elkington 2018), indicating that integration and application of this concept is also troublesome in practice.

Integrative: Understanding of the triple bottom line provides access to life cycle thinking and builds on systems thinking (see Figure 3.3.1).

Life cycle thinking

Concept overview

Life cycle thinking recognises the economic, environmental, and social consequences of a product or process throughout its life. Linked to the triple bottom line concept and systems thinking, life cycle thinking considers the multiple phases of the life of a product, asset, or system, from material extraction through to end of life, and the inputs and output, gains, and losses associated with each phase. It is a detailed systems approach to exploring the impact of products and materials on the planet and people. Life cycle thinking requires a collaborative attitude, with involvement of stakeholders from all stages (Mazzi 2020).

Each life cycle stage of a product or process offers opportunities to minimise resource consumption and broader adverse impacts and to improve performance and efficiency. When the life cycle is considered holistically (as opposed to a series of separate stages), the shift of impacts from one life cycle stage to another is avoided (Acaroglu 2018).

Life cycle thinking is operationalised through tools such as life cycle assessment, life cycle costing, and social life cycle analysis, which enable systematic analysis of a product's environmental, economic, and social impacts over life.

For a detailed consideration of life cycle thinking, refer to Chapter 3.5 in this volume.

Life cycle thinking as a threshold concept

Life cycle thinking and its application through structured processes can be considered a threshold concept due to its transformative, troublesome, and integrative nature.

Transformative: Life cycle thinking prompts a shift in understanding of how sustainability challenges are addressed. It requires a long-term, big-picture view, with a detailed understanding and evaluation of the process, inputs, and outcomes of a product, asset, or system from idea conception to disposal (Icawat 2018). Life cycle thinking promotes a mindset of optimisation from the early stages of problem solving based on environmental and social impacts.

Troublesome: Life cycle thinking is difficult for learners, as they are generally exposed to discipline-specific learning, which promotes single solutions to narrow predefined problems (Icawat 2018). In contrast, life cycle thinking requires learners to define the problem, which may have multiple possible solutions.

As with transdisciplinary approaches and design thinking, life cycle thinking can be troublesome because of the need to engage with multiple stakeholders with a range of perspectives and agendas. This requires an ability to accept and synthesise multiple points of view and may prompt reflection on and realisations about one's own knowledge and perspectives. The questioning of previous conceptions by learners (Strobel et al. 2009) may be transformative.

Interpreting and understanding the outputs of life cycle analysis has been identified as a troublesome area of knowledge. Strobel and colleagues (2009) highlight the challenges of complexity for learners. Life cycle thinking and its application are complicated and detailed, requiring large amounts of data. Learners may become overwhelmed by the amount of information required and generated. Further, they may be challenged in understanding and interpreting outputs from life cycle tools and effectively applying or integrating outputs to create problem solutions (Lin et al. 2012).

Integrative: Life cycle thinking requires an understanding of system thinking and of the triple bottom line concept and enables access to design thinking (see Figure 3.3.1).

Design thinking

Concept overview

Design thinking is a philosophy and process of problem-solving with a human-centred design ethos (Brown 2008). It translates design methods and modes of inquiry, traditionally seated within disciplines such as engineering, innovation, and product development, to the broader business and societal context.

Adopting a design thinking approach involves a shift from analytical thinking and decision-making to abductive problem framing and questioning. This can be thought of as replacing 'what-is' thinking with 'what-if' and 'what might be' questions (Buhl et al. 2019).

Design thinking requires problem definition based on stakeholder needs and an iterative process of identifying possible designs and comparing them against requirements. This contrasts with the more natural approach to jump to detailed development of a solution before identifying the problem and requirements.

Brown and Wyatt (2009) describe design thinking in terms of spaces of inspiration, ideation, and implementation. Design thinking is characterised as human centred, research based, having a broader contextual view, collaborative and multidisciplinary, and iterative (Young 2010).

Design thinking is proposed as a useful approach to solving complex problems or navigating new, uncertain, or ill-defined environments, characteristic of sustainability (Brown and Katz 2011; Buhl et al. 2019). Design thinking approaches problems with a systemic, life cycle perspective. Design thinking is collaborative. Collaboration is not transactional, but requires empathy to develop deep understanding of stakeholders and insights into the problem or issue.

Active stakeholder involvement occurs throughout the process, including building connection to identify and understand the issues and context; working together to generate a variety of possible solutions; and prototyping, testing, and adaptation of ideas. Stakeholders are co-designers rather than end users, resulting in the creating and sharing of new knowledge and perspectives (Kolko 2015).

For further information, refer to Chapter 3.4 and Chapter 4.4 in this volume.

Design thinking as a threshold concept

Design thinking is a threshold concept in sustainability due to its transformative, troublesome, and integrative nature.

Transformative: Design thinking, as a people-centred process, changes the way learners think about sustainability and impacts how they plan to approach future sustainability problems in practice. The emphasis on collaborative ideation creates a shift from relying on the 'first idea' to generation of a variety of possible novel solutions. As a result, design thinking positively impacts learners' perceived creativity and confidence in their creative ability (Clark et al. 2020).

Troublesome: "Design thinking can feel chaotic to those experiencing it for the first time" (Brown 2008, 4).

The participatory nature of design thinking presents challenges. Design thinking requires the 'designer' to adopt the role of co-designer and facilitator, rather than expert. To truly understand a problem or issue, design thinking requires the learner to develop meaningful connections with a range of stakeholders. This can be challenging for learners as these are counterintuitive positions requiring humility, empathy, and the ability to appreciate multiple perspectives (Kolko 2018). This demands a level of maturity from learners and may be more difficult for those with limited life and professional experience (Earle and Leyva-de la Hiz 2020).

Dealing with the ambiguity of complex issues can be troublesome for learners. Novice design thinkers have been observed taking a 'depth first' approach to problem-solving (Razzouk and Shute 2012). In efforts to understand the problem, learners can get trapped in gathering information and lack the ability to move forward without a complete, logical understanding of the problem. A further challenge is the move from analytical (linear) to abductive (divergent) reasoning. Design thinking requires learning to move between these modes of reasoning freely (Kolko 2015).

Integrative: Design thinking requires transdisciplinarity and understanding of systems thinking and life cycle thinking, thus integrating and utilising many of the identified threshold concepts in sustainability (see Figure 3.3.1).

Designing curricula based on threshold concepts

Having identified threshold concepts, curricula can be designed to focus students' learning activities and assessments on the threshold concepts. Curriculum designers should avoid clustering threshold concepts in the curriculum. Only three to five threshold concepts should be in any unit of study. It can be helpful to identify threshold concepts to students so that they are alert to the significance of the threshold concepts to future learning and practice and the need to allocate time to becoming comfortable with the threshold concepts.

The nested nature of threshold concepts should be considered in specifying the program structure and prerequisites for subjects. For example, systems thinking and multiple ways of knowing are gateways to transdisciplinarity and design thinking.

Learning activities should be designed to focus on the most troublesome features of threshold concepts. For example, the shift from focusing on only economic or environmental impacts of a product or initiative, to identifying, considering, and balancing environmental, economic, and social impacts and their interactions, as required by the triple bottom line threshold concept.

Students' development of understanding of the identified threshold concepts should be monitored during the semester through various means such as low-stakes quizzes, tutorial questions focusing on the troublesome features of threshold concepts, and minute papers in which students note aspects of concepts that are clear or still murky (Angelo and Cross 1993).

Threshold concept theory describes common elements of students' experiences of overcoming threshold concepts. Within threshold concept theory, the state experienced by a student when a threshold concept or capability has come into view and before the student is comfortable with the concept or capability is called the 'liminal space' (Meyer and Land 2003, 10). Traversing the liminal space is usually arduous and rarely direct. It can take many years for a student to traverse the liminal space.

When a student first encounters a threshold concept such as triple bottom line, they often mistakenly believe that they have understood it and only discover the troublesome features of the concept upon applying it. At this point the student enters the liminal space. After an extensive mental struggle, the student may transform their thinking and become truly comfortable with the concept. Unfortunately, some students never enter the liminal space, and some never completely traverse the liminal space.

It is important to provide students with opportunities to revisit threshold concepts within units of study and across the years of a degree program. For example, educators should provide multiple opportunities across the degree for engagement with holders of diverse ways of knowing, including those outside of the academic disciplines, such as Indigenous elders.

The state experienced by a student before a threshold concept comes into view for the student is known as the 'pre-liminal space' (Meyer and Land 2003, 10). 'Pre-liminal variation' refers to the different backgrounds and learning of students. Sustainability is taught to students in many disciplines. Because these students have diverse educational backgrounds, their pre-liminal spaces are different. This means that students will connect threshold concepts to different prior understanding, and students will see different relevance depending on their disciplines. For example, engineering students might connect systems thinking to approaches involving systems thinking in fluid mechanics or solid mechanics. However, software engineering students might not have a similar point of reference. Educators should be aware of the diverse pre-liminal spaces of their students and the diverse applicability of a threshold concept in sustainability depending on a student's background. Kuzich (see Chapter 9.2 in this volume) argues that it is insufficient to bolt sustainability education onto curricula and argues that a reflexive process of learning is necessary. This is consistent with supporting students through the liminal space.

Accreditation

Many education programs around the world are accredited by professional bodies to provide credibility so that communities can trust their graduates. Engineering programs are one example. Accrediting bodies stipulate accreditation criteria including the expected attributes of graduates. Institutions offering engineering education programs apply for accreditation by submitting documentation about their programs. Visit panels determined by the accrediting body visit the institutions to interview stakeholders and view resources and report to a board of the accrediting body. Based on confidence that graduates will meet expected criteria until the next visit, the accrediting body then awards accreditation to specific education programs with or without recommendations.

Accreditation may be important for graduates' international mobility and as part of the path to registration. Therefore, many education institutions invest heavily in securing accreditation for their programs. Consequently, educators pay attention to accreditation criteria, and changes to accreditation criteria can have a significant influence on curricula. For this reason, it is important that capability to practice sustainably is among the accreditation criteria for education programs. Furthermore, we propose that capability to apply the additional threshold concepts in sustainability that we have identified above should be among the expected graduate attributes for accredited programs. In the engineering discipline, steps have been taken in this direction.

Many accrediting bodies of engineering programs are aligned with the International Engineering Alliance. For example, Engineers Australia, which accredits engineering programs in Australia, is a signatory to accords that commit to mutual recognition with accrediting bodies around the world that are also aligned with the International Engineering Alliance. The alliance stipulates graduate attributes and professional competencies, which were updated in 2021 (International Engineering Alliance 2021). Accrediting bodies stipulate substantially equivalent graduate outcomes. The 2021 update increased the emphasis on sustainability. Two graduate attributes for professional engineering degree programs are (p. 11–12):

WK5: Knowledge, including efficient resource use, environmental impacts, whole-life cost, re-use of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area

WK7: Knowledge of the role of engineering in society and identified issues in engineering practice in the discipline, such as the professional responsibility of an engineer to public safety and sustainable development.[1]

WK5 will motivate engineering educators to teach the threshold concepts of triple bottom line and life cycle thinking. WK7 points directly to sustainability and therefore indirectly to all the threshold concepts identified in this chapter.

Simply including sustainability in accreditation criteria will not immediately lead to effective teaching and learning in sustainability. In this chapter we have explained how sustainability is a threshold concept and relies on other threshold concepts. Even the educators are likely to find the concepts troublesome. Therefore, educators need support in designing and implementing sustainability education.

Supporting educators to both understand and focus on sustainability threshold concepts

Educators need to encounter and become familiar with threshold concepts before they can effectively teach them (see Chapter 9.2 in this volume). Therefore, sustainability education needs to be part of pre-service teacher training for teachers of students at all levels from kindergarten to secondary school, and university academics also need experiential learning for the sustainability threshold concepts (see Chapters 5.1 and 9.4 in this volume). University academics are not always supported with capability development, and universities have an imperative to provide capability development in understanding sustainability threshold concepts, curriculum design to integrate sustainability across the curriculum, and effective pedagogy for teaching sustainability.

Conclusion

Sustainability education involves supporting students to significantly transform their thinking. We recommend that educators identify the threshold concepts within sustainability as a way to enhance the transformative learning that must be achieved in successful sustainability education. By identifying and focusing on threshold concepts, educators can focus students' learning activities and assessments on the most transformative, challenging, and critical learning necessary in sustainability education, rather than spending precious time on concepts that are relatively straightforward. Some threshold concepts in sustainability are the term sustainability, systems thinking, multiple ways of knowing, transdisciplinarity, triple bottom line, life cycle thinking, and design thinking. Others could be identified. Accreditation provides an opportunity to drive curriculum reform, and sustainability is being strengthened by accrediting bodies. Sustainability threshold capability development for educators of students from kindergarten to postgraduate and continuing education is an imperative.

Note

1 Represented by the 17 UN Sustainable Development Goals (UN-SDG).

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3.4
TRANSDISCIPLINARY SUSTAINABILITY COURSES

Design principles and facilitation techniques to aid remote and hybrid learning environments

Kateryna Pereverza and Hayley Ho

Key concepts for sustainability education

- Transdisciplinary courses focused on sustainability transition challenges are an integral part of sustainability education.
- The chapter describes ten design principles for developing and facilitating sustainability courses that involve addressing how students work and learn, the use of spaces, different interactions and collaborations, processes, communication, and design approaches.
- Design principles are illustrated with examples of their use in remote digital and hybrid learning environments, which include course activities, course design, and the use of materials and tools.
- The implementation of the principles can help to increase reflexivity, strengthen collaborations, and foster the creativity of students.
- The design principles can be used as a basis for reimagining transdisciplinary courses in ever-evolving hybrid environments.

Introduction

This chapter addresses the design of transdisciplinary courses aimed at advancing the competencies and skills of their students to deal with complex *sustainability transition challenges*. Such courses are an integral part of sustainability education. They can help to equip students with methods and approaches to address wicked challenges and steer transformations in societal systems. Collaboration skills, reflexivity and the ability to work in non-linear and open-ended processes are important learning outcomes of such courses. By describing ten design principles and illustrating them with examples from a transdisciplinary university course “Transdisciplinary Approaches for System Innovations”, run at KTH Royal Institute of Technology in Stockholm, this chapter contributes to the understanding of how such transdisciplinary, project-based and problem-solving oriented courses can be designed and implemented so that they can lead to the desirable outcomes, be they conducted in physical, remote digital or hybrid spaces.

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To motivate the need for these ten design principles, we first introduce four qualities that, we propose, transdisciplinary courses for sustainability transitions should strive towards. We then describe the remote digital and hybrid environments in which these courses exist, highlighting the specificity of remote interactions to be considered when designing transdisciplinary courses. To provide a background on *sustainability transition challenges*, the interlude that follows summarises insights from transition studies – a research field that explores transitions in socio-technical systems and brings insights into how such processes unfold and might be steered.

Transition studies (TS) – a research field that contributes to the understanding and steering of system transformations toward sustainability

Socio-technical transitions are understood as substantial changes in the ways important societal functions (such as energy, mobility, food, education, healthcare, etc.) are provided (Geels, 2004). Such transitions are deemed to happen through a co-evolution of technologies and institutional structures and are regarded as "large-scale disruptive changes in societal systems that emerge over a long period of decades" (Loorbach et al., 2017). In the case of *sustainability transitions*, these changes are intended to lead to more sustainable system configurations.

TS is a research field focused on such transition processes. It aims not only to develop insights useful for improving our understanding of change processes but also to advance capacities to steer transitions toward sustainability. One of the prominent frameworks developed in TS is the multilevel perspective on socio-technical transitions, *MLP* (Geels, 2004). MLP explains transitions through the interaction of three 'levels': *niches* – protected spaces where alternative socio-technical configurations emerge, *regimes* – established socio-technical structures and *landscape* – factors of the wider exogenous environments (such as climate change, globalisation and cultural changes).

Transition management (TM) (Kemp et al., 2007; Loorbach, 2010; Hebinck et al., 2022) and *participatory backcasting* (PB) (Dreborg, 1996; Vergragt and Quist, 2011; Pereverza et al., 2019) are governance approaches that are built upon the ideas from TS, but they also embed ideas and methods from future studies (e.g. Godet, 2006; Van der Heijden, 2005) and complex systems (e.g. Meadows, 2008). Important features of these approaches are their long-term orientation, participatory nature, reflexivity and cross-sectorial, holistic perspective. They differ, however, in their take on participation; while TM relies upon selective participation of frontrunners through so-called 'transition arenas', PB assumes the possibility of consensus among a wider range of societal stakeholders.

TS contributes to sustainability education with these and other ideas, methods and frameworks for understanding and steering system transformations needed on the way to sustainability. Capacities and skills developed in courses that embed TS would be relevant for the governance of complex societal systems under the conditions of uncertainty. This, for example, is necessary for achieving the mission recently launched by the EU Commission: "100 climate-neutral cities by 2030 – by and for the citizens".

Qualities transdisciplinary courses for sustainability transitions strive towards

Transdisciplinary courses for sustainability transitions are expected to be project-based, assume collaboration with societal stakeholders and are focused on solving real-life challenges and wicked problems. Furthermore, processes of transdisciplinary courses rarely fully repeat themselves from year to year, since they evolve and adjust depending on the problem chosen, backgrounds and prior knowledge of stakeholders and students involved and other factors. What qualities should such courses strive toward given that these aspects can be used and leveraged in various ways and to different extents? In this chapter, we focus on four qualities we find important to promote in transdisciplinary courses for developing the competencies and skills of students to deal with complex *sustainability transition challenges*. These qualities are:

- Collaboration of students with diverse backgrounds
- Interactions between students and stakeholders
- Different layers of interactions: class/project groups/individuals
- Open-ended problems and iterative processes

Collaboration of students with diverse backgrounds

Courses targeting the ability to solve sustainability transitions challenges are often introduced on the master level in universities where it is possible for students from different backgrounds to join. This creates an opportunity to capitalise on the diversity in the classroom and in project groups. Collaborative and peer learning becomes central for project-based courses when students jointly address a given transition challenge.

Such a context reflects real-life situations of transition governance when collaborations of individuals and organisations from a variety of backgrounds and across different sectors play a crucial role. This can take the form of participatory processes organised for (re)imagining futures, developing visions and creating transition pathways. The abilities to build upon the diversity of perspectives and problem framings, engage in cross-silo collaborations, practice reflexivity and continuously learn from experience are required to successfully perform such processes.

Interactions between students and stakeholders

Sustainability transition challenges are often taken from real-life contexts and are therefore tightly connected to specific actors who affect or can be affected by those challenges and the various ways of addressing them. A degree of collaboration with relevant actors becomes an important component of transdisciplinary courses.

With this, in such courses, the roles of teachers are shifting to those of facilitators of learning and moderators of interactions between stakeholders and students. The forms and approaches of interactions between students and stakeholders can take different formats. For example, societal stakeholders can be approached for data collection or be invited to key events within a course (e.g. introduction to project work, final presentation of projects' outcomes). Students can also meet stakeholders when visiting (in person or virtually) relevant places. Interactions with real-life stakeholders can help students learn about the diversity of perspectives and problem framings present in society. Such interactions are also beneficial for the motivation of project groups, as their work can potentially be used in practice in the future.

Different layers of interactions: class/project groups/individuals

In courses that are based on project work in groups, different layers of interactions naturally emerge. During course activities, teachers can focus on interactions with individual students on the level of the entire class or with and between project groups. Each layer of interactions brings different learning dimensions, and depending on the dynamics of the class and the set-up, it may require more or less facilitation.

We specifically highlight these different layers to later suggest how they can be used for increased collaboration and collaborative learning, not only within a single project group but also between students from different project groups. This helps address what often is a limitation of project-based courses where students mainly meet their immediate group mates but not students from other groups.

Open-ended problems and iterative processes

Sustainability transition challenges can be regarded as wicked problems. They are complex and open-ended with no one single correct answer; there is not even a single problem framing to be used as a starting point. To address such challenges, iterative processes are required. By gradually getting to know the context, collecting data and exploring the perspectives of different stakeholders, students can gain insights which can help them to address those challenges. Reflexivity becomes an important part of this process that can enable continuous learning from experience.

However, such processes in university courses can be unexpected for students and be perceived as frustrating and stressful, especially for those who want to see or have expectations of fast progress towards a solution. Therefore, it is needed to facilitate the ability of students to work in open-ended, non-linear processes of problem-solving. And for this, to foster amongst them an attitude to learning as exploration, understanding that sometimes they need to take ‘a step backwards’ to revise and improve outcomes of earlier stages. Reflexive learning can be encouraged to help students to understand their insights and important learnings during these iterative processes.

Remote digital and hybrid learning environments

Already now and even more in the future, the design and facilitation of transdisciplinary courses will take place in various remote digital and hybrid environments. We are currently part of what in itself is a transition that was accelerated by the onset of restrictions due to the COVID-19 pandemic, where study and work shifted away from designated physical locations to become spread remotely over different localities. During the restrictions, we were forced to change from the previous norm of shared activities taking place in a physical space, where participants meet physically together, to everyone sitting remotely on their own, connecting through digital tools into a shared virtual space. With the lifting of restrictions, however, adaptations that were initially necessary have the potential to become long-lasting as collaborations have been set up more internationally, and all participants have grown accustomed to the expectation that interactions can occur flexibly from different places to best suit the individual. This will drive the evolution of more hybrid environments, where participants will mix and match physical in-person interactions with remote digital interactions due to practicality or preference.

The use of digital tools is not new in learning environments, and their use has increased over time and become more intrinsic for documentation, presentations and collaborations. The COVID-19 pandemic accelerated digital literacy in both teachers and students, increasing the availability and adoption of new tools, especially those for remote interaction and collaboration. These skills and tools enabled the transition to remote learning and brought with it new norms in learning behaviours and dynamics. These remote interactions have enabled the participation of more diverse perspectives from lecturers, stakeholders and students from different parts of the world. This freedom to participate from anywhere, however, can shift our relationship with the activity of learning as it becomes embedded into other parts of our life, for example, our home. It allows us to multitask and anonymously participate less actively. We have had to reflect on how we communicate and form social connections given the limitations of and our attitudes towards using available digital tools, finding alternative ways for teachers to feel the atmosphere of the classroom and for students to have side chats away from the main conversation and opportunities to network.

As we embrace digital tools and the advantages of remote learning, we also seek to address pitfalls in combination with non-remote and non-digital environments. This future hybrid learning environment will evolve with diverse formats depending on what is desirable and possible. This chapter focuses on the design of transdisciplinary courses on sustainability transitions in this ever-evolving hybrid learning environment. To promote the four highlighted qualities of transdisciplinary courses (Figure 3.4.1), we suggest ten design

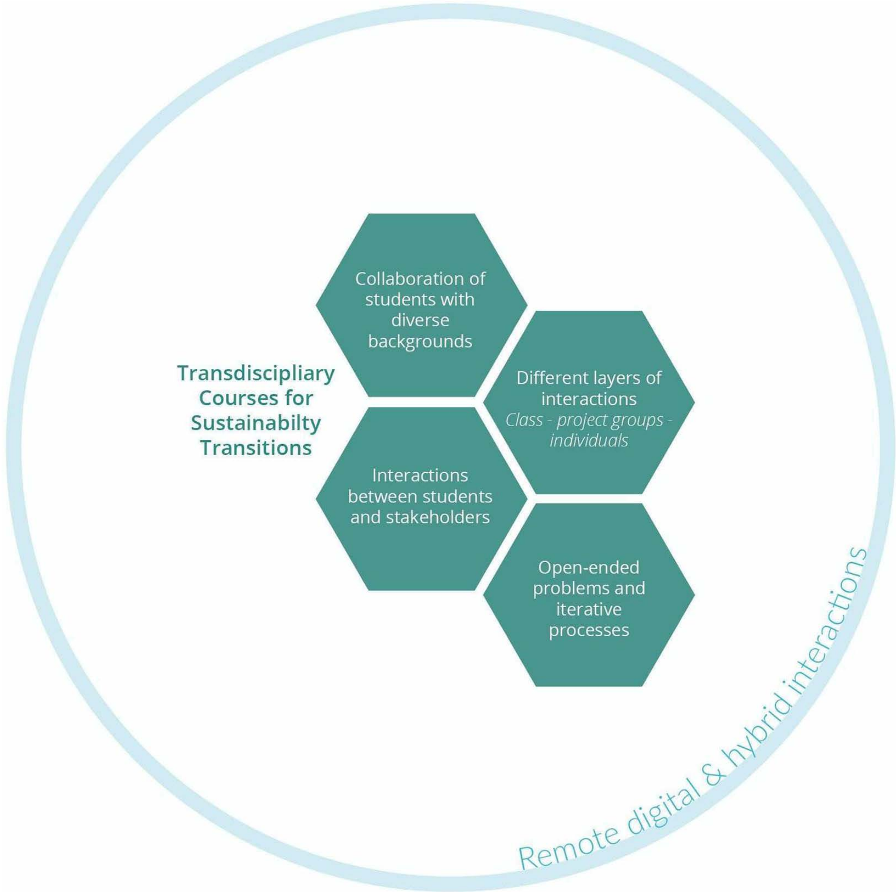

Figure 3.4.1 Four important qualities transdisciplinary courses should strive towards discussed in this chapter in the evolving context of digital and hybrid learning environments

principles. Our starting point is that the design of remote facilitation techniques and digital spaces for collaboration is not only about trying to re-create what worked in a physical classroom. Moving into remote digital spaces opens up the opportunity to rethink approaches to teaching and learning and to experiment with new techniques and spaces. We approach this challenge with an exploratory mindset with the aim to discover needs prior to rushing to solutions.

Principles for designing transdisciplinary courses in remote digital and hybrid learning environments

The specificities of transdisciplinary courses and qualities to achieve in them (Figure 3.4.1) make designing and implementing such courses a challenge in itself. We therefore aim to contribute with a set of *design principles* that can be used by teachers and facilitators, aimed at creating efficient learning environments in such courses as part of sustainability education.

When describing the principles we show how they were operationalised with the help of facilitation techniques in a course "Transdisciplinary Approaches for System Innovations" (TASI), run at KTH Royal Institute of Technology in Stockholm. We reflect on the use of each principle in the context of this course and how it could be implemented under different conditions or limitations. This is to show that in the ever-evolving landscape of sustainability education in hybrid and digital spaces, these principles can remain valid. Figure 3.4.2 visualises the ten principles against the set of four qualities we strive to achieve in transdisciplinary courses, assuming they can be given in various hybrid learning environments.

Ten design principles

1. Fostering and encouraging reflexivity during and beyond course activities
2. Balancing guiding and enabling creativity during course activities
3. Fostering active use of (digital and physical) spaces by students
4. Creating alignments of asynchronous interactions
5. Fostering a collaborative mindset and shared outcomes
6. Working with different layers of student interactions
7. Guiding students through an open-ended and iterative process of problem-solving
8. Fostering non-verbal communication and empathy to strengthen collaborations
9. Adjusting course process with responsive design approaches
10. Fostering student agency and co-ownership of the process

"Transdisciplinary Approaches for System Innovations" course, KTH (Sweden)

The course aims to provide students with insights about socio-technical processes of systems transitions and equip them with participatory methods to steer sustainability transitions. For this, it focuses on a set of competencies and skills important to address complex challenges of systems transitions for sustainability, including critical and systems thinking, long-term thinking, ability to work in a transdisciplinary context, personal involvement, conflict resolution and consensus-building, dealing with complexity and uncertainty, creativity, practical problem-solving and action skills (Kordas et al., 2015).

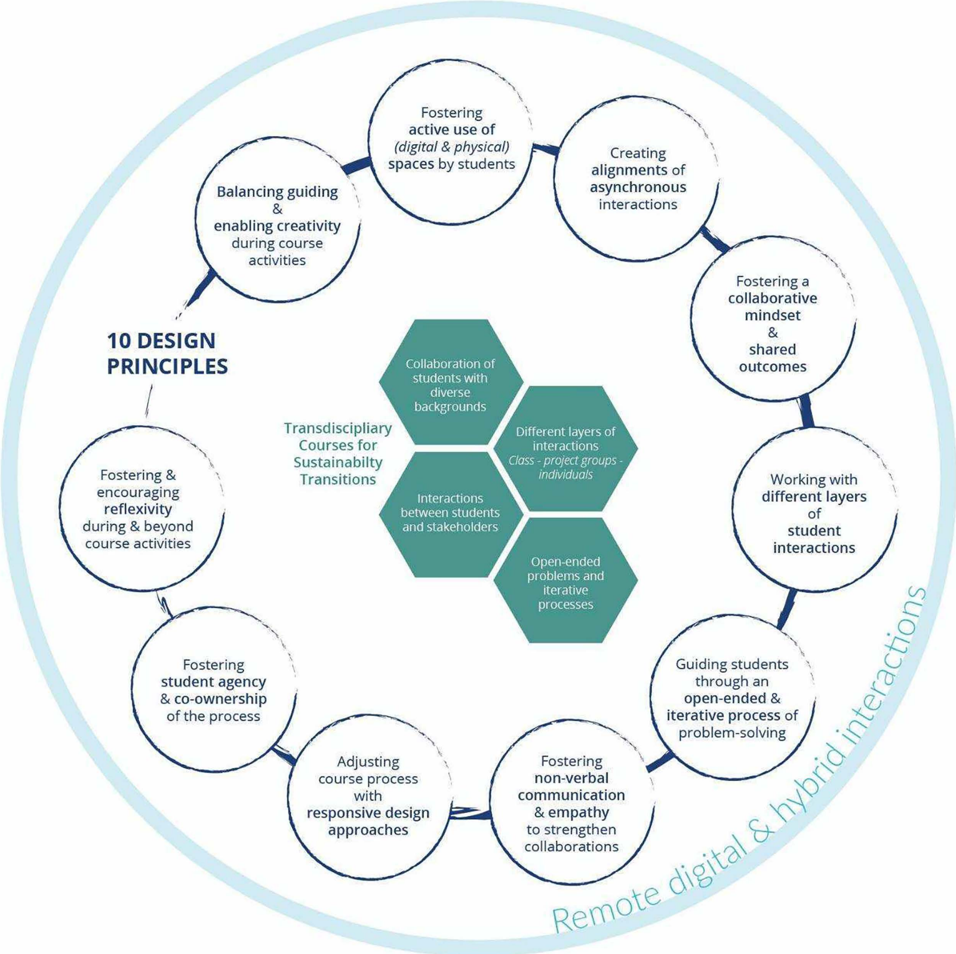

Figure 3.4.2 Principles for designing and facilitating transdisciplinary courses in remote digital and hybrid learning environments

The course was introduced for the first time in January 2017, and since then it has constantly developed and provides a platform for learning and exploration for involved teachers, students and societal partners. During the course, students design and implement transdisciplinary projects based on the modular participatory backcasting (mPB) framework (Pereverza et al., 2019) addressing a complex real-life socio-technical challenge. The challenge is given in collaboration with societal partners of the course. For example, the course collaborated with stakeholders of the KTH campus, Hammarby Sjöstad city district in Stockholm, Järfälla municipality, Skellefteå municipality and Stockholm urban food actors.

In 2021, the course was conducted fully remote and digitally due to the restrictions introduced in relation to the COVID-19 pandemic. In 2022, the course was conducted in a hybrid format while digital remote education dominated, but some of the restrictions were already lifted, enabling the opportunity for project groups to meet in person and join course activities together as a group if they wanted to. Examples from the course will be used to illustrate the suggested ten design principles.

More information about the course: https://urbant.org/tasi/

Online mPB manual: http://mpb.urbant.org/

(1) Fostering and encouraging reflexivity during and beyond course activities

The structure of academia with set outcomes and linear processes (reflected in course modules and grading criteria) means that students often need to overcome certain biases and attitudes towards learning, for example, being bound by predefined outcomes, undervaluing the process and overlooking unexpected insights. Learning as exploration and spaces for reflexivity have to be intentionally supported in order for a more flexible and dynamic mindset to emerge. Reflexive and explorative learning approaches are required to foster transformational mindsets and capabilities to work in transdisciplinary teams.

In transdisciplinary courses, this principle can be implemented through specific elements of their design and dedicated facilitation approaches. Thus, in the case course "Transdisciplinary Approaches for System Innovations" (TASI), we *allocated time at the end of most seminars* for personal reflections that were then shared and discussed with the whole class. Often we had to highlight insights that were overlooked by students. We also encouraged students to allocate time to reflect on their learning journeys beyond classes when they are working by themselves. When there was a lack of time for discussion during the course activities, reflections were documented by students in online collaboration spaces or on physical Post-its to be read by others later on.

Students were also encouraged *to document and reflect* on their group's working processes during the course and share them during interim and final presentations. When working with physical materials in person, this sometimes needed to be done retrospectively as students were not in the habit of documenting their process, while with digital tools this would often naturally emerge. This systematic documentation enabled students and teachers to go back in time and also build on reflections.

(2) Balancing guiding and enabling creativity during course activities

As students are going through an open-ended and iterative process of addressing sustainability transition challenges, the task for teachers is to not pre-determine the outcomes by over-guiding. For this, teachers have to accept a level of discomfort to allow students to struggle and work through their confusion to come up with their own creative ways to approach each activity. It is therefore important to give space and time for students to figure out processes that are suited to their group, their challenges and their team dynamics.

In the TASI course, we developed exercises based on the methods and tools of the mPB framework. For each exercise, template examples and guiding questions were created for students to learn how to apply a particular method for a specific problem. We always left the possibility for students to carry out the exercises with a *degree of flexibility where they can adjust and modify templates*. In digital environments, we avoided detailed templates and often provided *blank frames or even completely blank spaces on digital collaboration platforms* for students to work in. While this can be uncomfortable for students when first confronted with this, over time they became accustomed to coming up with their own ways of structuring and visualising their ideas and thoughts. They always found creative and meaningful ways to work together in their groups, using the spaces in their own ways and often in ways that we had not anticipated. By balancing the guiding, it allowed space for insights from students that we would not have thought of.

(3) Fostering active use of (digital and physical) spaces by students

Spaces, physical and digital, play an important role in creating a learning environment in transdisciplinary courses. Active use of spaces by students can help to exploit their full potential for stimulating creativity, activating interactions and sharing outcomes and insights.

In the TASI course, we operationalised this principle by *changing the layout of the classroom* and by *encouraging the active movement of students* during group work in seminars. The layout of a physical room can be adjusted for the purpose of a particular activity by moving objects (e.g. tables and chairs) around, using windows and walls for taking notes on paper posters, using available whiteboards for brainstorming, etc. We asked students to help reformat the room at the beginning of every seminar, which they then became accustomed to doing themselves later on. We also provided materials (e.g. large paper, coloured pens, Post-its) for every seminar and found that while students had to be encouraged to use them to begin with, they themselves would get them when required as the course progressed. Active dynamic use of space can also be encouraged in specific exercises so that students are not fixed to their desks or one location. For example, for students to share interim outcomes of their projects with other groups, we organised a “walk-around” exhibition where students were encouraged to move in the classroom to explore outcomes and learn across groups.

In the remote classroom, a shared digital space was created using video conferencing software in combination with an online digital platform for remote collaborations. This online platform was co-created with students over time as the course evolved. As students became familiar and thus more confident with the tools of the platform, we gave less guidance and instructions on how to use the space and left it for each group to decide for themselves where and how to structure their work. We created *shared virtual spaces* within the online platform that simulated that of a physical space in which we could meet and work in certain activities and presentations. We put up virtual posters and tried to re-create the feeling of wandering around, using the associations that we still have with physical spaces to encourage different types of the dynamic movement within the digital space and to bring an element of physicality into the remote setting. Every group was also encouraged to create their own space in the digital collaboration platform to use when they met to work outside class activities. We gave them no instructions on how they should work within these spaces and the choice of whether we as teachers could go in to see their progress or if they preferred this to be private for their group.

Already there are early signs of how the operationalisation of this principle will need to be reimagined in hybrid spaces. We observed changes in what is considered the ‘norm’ for spaces and setups for learning in universities. Now with hybrid formats, we see students themselves decide if they meet physically as a group to call in and join a remote online course activity together. For teachers, this could imply certain challenges and opportunities with regard to how exercises and interactions are designed. For example, how do you send students into random non-group break-out rooms when a project group is joining from a single space and perhaps even a single laptop? Not being constrained by a single type of space or location, however, could in the future mean that some students could be partly situated in the context of the project, e.g. in a municipality or a community space. New questions will become important, e.g. how can we make better use of the flexibility of students and stakeholders sitting in different places?

(4) Creating alignments of asynchronous interactions

The nature of transdisciplinary courses means that they include a variety of interactions that occur asynchronously in the sense that project groups and individual students are concurrently going through their own learning journeys. The result of enabling creativity and encouraging a diversity of projects is that groups move at different paces and take on different directions. They only meet with other groups and with teachers during designated course activities (e.g. seminars, supervision meetings). Without any good documentation of processes outside these joint activities, it can be difficult for teachers to provide support and for groups to contribute to each other's learning. Therefore, attention is needed to create alignments between such asynchronous interactions so that teachers can provide relevant feedback to project groups, adjust the pace and content of seminars or simply enable conversations around the same topic.

In the TASI course, we encouraged students to adopt *the practice of creating good documentation* that can be shared with others and with teachers to let them better understand the processes the group is going through. For creating alignments and preparing relevant content as teachers, for example, we asked groups *to formulate questions or topics in order of priority* that they would like to be addressed in upcoming supervision or coaching sessions. This strategy provided an opportunity for students to influence what kind of feedback they received. We used this input to decide what questions should be discussed with the whole class, what should be addressed during individual supervision meetings with groups and what could be dealt with asynchronously before or after. It also revealed that sometimes students were struggling with issues that were not seen as problematic by teachers and vice-versa. By having students become accustomed to sharing their processes with each other, they were also able to address shared issues together and support each other with input.

With digital spaces, documentation was made easier and asynchronous interactions more convenient and acceptable. Students could drop in and out of seminars or listen to recorded talks later on. It forced us to reflect on the value of synchronous and physical interactions. What additional benefits can it bring, and what makes it worth our time to show up? What activities could be done asynchronously so that we can free up time during seminars for activities that would benefit more from synchronous participation? This could in the long term result in richer and more considered interactions.

(5) Fostering a collaborative mindset and shared outcomes

A collaborative learning mindset is required to jointly address complex sustainability challenges and find ways forward to reimagine the future, develop visions and shape pathways. However, in a classroom, a competitive mindset can dominate, both on the individual level and as competition between project groups. It is therefore important to help students move away from the competitive mindset to create shared outcomes, while still appreciating individual contributions based on the diversity of backgrounds and perspectives.

In the TASI course, we introduced *peer learning and crowdsourcing-based approaches* to encourage collaborations and to create shared outcomes. We also actively questioned the relationships of the interactions and hierarchies between us as teachers and the students, between students and stakeholders and between the students themselves. We emphasised the importance of input, feedback and support from fellow students and not just that of the teachers who instead hold the role of guides and facilitators.

Crowdsourcing of ideas was a technique we used in several exercises and in both remote and physical settings. Students individually bring pictures onto a shared online space to visualise their ideas for a certain topic. These ideas were then taken through a shared sense-making process with the entire class, exposing students in a short time to many diverse ideas that they could use in project work. Students were always impressed by how quickly they collected and organised so much knowledge, and this was very helpful for creating a mindset of collaborative learning between the groups rather than one of competitiveness.

Other types of techniques we used for fostering a collaborative mindset were those based on *peer feedback and learning*. During the interim and final presentations, each group was assigned to another group to lead the feedback and discussion instead of the teachers. Groups responsible for asking questions always initiated interesting points, which often led to follow-up questions and a longer discussion in the class. The progress of every group and individual learning therefore became shared responsibilities. We wanted to give students the confidence to give feedback to each other and activate discussions. We also wanted students to become aware of the learnings that they gain from each other and challenge the myth that teachers hold the 'most correct' answer or viewpoint. In addition, posters were also put up for every group where students could individually leave *Post-its with feedback, questions and encouragement to others in the form of what learnings they gained*.

(6) Working with different layers of student interactions

As described in the characteristics of transdisciplinary courses, they usually involve different layers of interactions: class/project groups/individuals, all of which are required for successful collaborations to address complex sustainability challenges. Collaborations are built on the sum of individual contributions and require the activation of individuals to work in different constellations and to flexibly shift between them. In the learning context, it is important for students to engage in activities from their own individual perspectives and have the opportunity to express them in order to connect to those of others in their group or class. The confidence to contribute in different layers creates more opportunities for mutual learning, both within and across project groups.

When developing activities in the TASI course, we intentionally *activated interactions on all different layers*. In some cases, an exercise was designed to specifically target one layer of interaction, while in other cases it was possible to activate all the layers. For example, we often used an approach where students began an exercise by generating and noting down their own individual ideas before sharing and making sense of these ideas as a group. Following that, groups would share their joint insights with other groups, spreading the interactions to the level of the entire class. Previously mentioned techniques, for example, peer learning and crowdsourcing, also serve well for increased interactions on the level of the entire class based on individual contributions.

One technique that we used in both physical and remote digital spaces was a *'walk-around' exhibition in non-group pairs*, where two students from different project groups together explore and reflect on activity outcomes that all the groups had previously prepared. This enabled these two students to work and learn from each other in a new constellation that is different from their usual group. Afterwards, these two students would return to their project groups to share their learnings. In the remote digital setting, this was done using break-out rooms in a video conference and virtual space within the online remote collaboration tool that simulated that of physical space. In the context of remote learning, since students never have the chance to meet in a physical space all together where unplanned interactions between individuals are more likely without facilitation, students said that they really appreciated the chance to work and interact closely with someone outside of their team.

(7) ***Guiding students through an open-ended and iterative process of problem-solving***

Addressing sustainability transition challenges requires an iterative process of problem-solving. Such challenges are often described as wicked, i.e. complex and multifaceted, with no single right answer and that can be differently perceived by different stakeholders (Ackoff, 1997). By exploring the challenge in a context, students improve their understanding of it and might reframe a problem to be addressed. Further in the process, after project groups engage with diverse data sources and opinions of various stakeholders, they advance their understanding of the challenge further and might need to get back to the problem formulation again. This creates iterations in the process that can lead to learning and improved understanding, as well as helps in finding more relevant and impactful solutions. However, this process might not be familiar to students and feel ‘wrong’ and stressful to them. The linear process of a course can additionally mislead students and create the expectation of a gradual progression without the need to revise and improve their understanding of previous steps. With this, facilitation of the ability to work in iterative processes becomes a very important and rather challenging task for teachers.

In the TASI course, we used different approaches to prepare students to work in iterative processes. We discussed the nature of problem-solving processes *early in the course by using visualisations and by describing possible situations that they may encounter* (e.g. a need to revise previous steps, relevant data or insights coming later in the process, an idea not working that needs to be left behind, etc.). We would then return to this discussion when students inevitably encounter these situations in their own processes. *Process documentation combined with reflection activities* helped groups to acknowledge that these challenging situations were part of creating the learnings required as part of the problem-solving process. To add value to this, *grading criteria included the requirement and emphasised reflection on the process* rather than just the outcome as part of the group interim presentations.

We wanted to acknowledge and support students through the changing levels of stress that they encountered as they experienced these convergent and divergent processes. As discussed in the next design principle, it can be difficult, especially in remote digital settings, to get a sense of student emotions. One activity which proved to be helpful for this was an *‘emotion wheel’ in a shared online space*. The wheel contained a variety of emotions organised in a way that those that are related are grouped together. Students and teachers independently put a dot on the emotion they are feeling, and this was followed by a joint discussion.

(8) Fostering non-verbal communication and empathy to strengthen collaborations

Communication is key for high-quality collaborations, with the role of non-verbal communication and empathy often overlooked as integral for creating robust and efficient teams. Building empathetic connections and encouraging social interactions beyond the formal exchange of information should therefore be an aim of facilitators in transdisciplinary courses.

In the TASI course, we wanted to activate students regardless of which form of expression they preferred. We provided *different methods to contribute to the same discussion*, for example, students could give feedback to another group *either by speaking up in the main discussion or by writing notes on a poster*. This resulted in more equal and balanced contributions that did not favour only those who were most confident to speak up. We also addressed the challenges of being defined by the tools in communication during the final presentations of the projects' outcomes. We proposed that project groups come up with *more creative and unusual ways of communication, which was also reflected in the grading criteria*. This led to the use by students of all forms of storytelling, video and animation, interactive visualisation and so on. Finally, in a follow-up to the final presentations, students were asked to reflect on the limitations of different forms of communication and the potential of combining them.

Empathy between classmates and between students and teachers was among our main goals to build trust for collaboration and shared learning. Thus, we introduced different cues and means beyond the regular informational exchange. It is an oversimplification to assume that being physically present builds trust faster since we are able to read each other's body language and therefore more easily empathise. The reality is that this needs to be fostered by a combination of techniques described in previous design principles, such as creating alignments of asynchronous learning, fostering collaborative mindsets and shared outcomes and working with different levels of student interactions.

However, *remote interactions do pose additional challenges and can magnify the lack of and the need for consciously facilitating empathy*. We are currently more accustomed to reading non-verbal cues physically in the context of the classroom, and the lack of body language communication, the possibility of not using cameras during the class activities and other interactions can make it harder to foster empathy. Approaches that emerged to address this on a basic level included the adaptation of communication forms from other digital communication, such as the use of emojis (e.g. claps, thumbs up) and the exaggeration of existing body gestures that can be easily seen on screen (e.g. thumbs-up, nodding).

To build empathy for deeper emotions, the previously described 'emotion wheel' and variations based on the same principle were used throughout the course to encourage students and teachers to communicate how they were feeling. Since this took place in a shared space, everyone could also get a sense of how the group was feeling from where clusters of emotions were pinpointed. Students appreciated the opportunity to express their feelings, and it provided them with another way to relate to the rest of the class and discuss the concerns behind the expressed emotions. Groups were also encouraged to use these activities when they met outside the class.

While on the one hand, remote participation in video conferences permits anonymous non-participation (e.g. by turning off the video), visible real-time activity on shared online collaboration tools (e.g. moving cursors with names and content being added) can show how others are fully participating. New remote and hybrid settings will give us the possibility to rethink previous ways of communication for learning and collaboration. In the same way that text messaging created a whole new language of emojis that can convey emotions and trigger empathy sometimes even more than speech or writing, these new settings will force us to adapt in creative ways to communicate and build relationships.

(9) Adjusting course process with responsive design approaches

One of the characteristics of transdisciplinary courses is that they are never identical from year to year. While the backbone logic and structure can remain the same, many adjustments are needed depending on the backgrounds of students, the transition challenge chosen, the extent of stakeholder engagement, etc. Addressing complex issues in real life, for similar reasons, also requires tailored approaches each time. To tailor transdisciplinary courses and their processes to a specific context, responsive design approaches can be of help.

In the TASI course, *we created feedback loops to collect signals and insights which we could then use to adjust the course process and content*. We dedicated time to talking with stakeholders the course partnered with to better understand their take on the challenge and their expectations from the course. From this we adjusted the content of the course, the methods we introduced to students and the examples we provided so that project groups could develop outcomes relevant to the context. We organised physical or virtual study visits where stakeholders were invited to present and share data with the students so they can learn about the diversity of perspectives on the challenge they address.

Another need for responsive design is *to tailor the course to the pace and needs of different project groups*. As part of the allocated time at the end of most seminars for personal reflections, we also included *space for feedback and questions*. As part of the interim and final presentations, there were also posters for all students to add *Post-its for reflections and feedback* on the process of the course and additional support they needed. In addition, students were invited to form a *'student representatives group'* that collected insights from other students. They met with teachers halfway and after the course ended to provide feedback, share how they experienced the course and suggest how it could be improved for the remainder of their course or for other students in future courses.

In the remote digital setting, for some activities, it can be more challenging to encourage students to actively provide feedback, as anonymous non-participation removes the social pressure to do so. Thus, in future remote and hybrid settings, new approaches and communication methods will need to be developed to motivate increased student participation with regard to feedback.

(10) Fostering student agency and co-ownership of the process

Transdisciplinary courses have an evolving nature. They are characterised by emerging group dynamics and unexpected changes and challenges on the way. Teachers are unable to control all aspects in such complex environments. As students greatly influence the course process, as discussed in the previous design principle, it would be logical for them to develop co-ownership of their process and outcomes. It is therefore important to both enable students' agency and foster such co-ownership.

In developing the TASI course, we consciously gave the possibility for students to make their own choices and flexibly adjust the spaces and tools we introduced to them. This is reflected in the many examples of facilitation techniques described in the previous design principles. Course activities are designed in a way, for example, by *incorporating documentation and reflection*, so that students are attentive to their processes and progress so that over time they can take ownership of their learning. It is also important to *make students aware that through responsive course design, they as a group drive the process and influence how the course is designed*. In the shared digital collaboration space that we returned to every time we met the students, it clearly visualised how the course evolved over time depending on their input and feedback.

In remote classroom settings, digital tools make it possible for students to participate wherever they are located and to choose easily whether to leave, multitask, mute or have the video on or off. *For informal voluntary interactions, one approach we used during breaks was to open up one or several breakout rooms for students to join if they wish to meet some of their classmates*. As online digital spaces become more sophisticated and as teachers (and students) become more confident using different tools, there will be more opportunities for students to shift between different interaction constellations and for alternative types of selective interaction to emerge in future remote and hybrid settings.

Conclusion

In this chapter, we suggest *ten design principles* that teachers and facilitators can use when developing and running transdisciplinary courses focused on sustainability transition challenges. These kinds of courses are essential in sustainability education, as they prepare students for complex problem-solving in real-life situations. The complexity of a context that emerges in such courses requires dedicated approaches and facilitation techniques to be introduced to leverage their potential as environments beneficial for learning. The suggested principles were piloted and refined in a university course where they helped to increase reflexivity, strengthen collaborations and foster the creativity of students learning to address complex sustainability challenges. The operationalisation of the proposed principles is illustrated with examples from this course, covering the physical, digital, remote and hybrid learning environments it was conducted in.

As seen from the descriptions of the principles, they overlap in their operationalisation through specific facilitation techniques and design choices. Having these principles in mind can help to find synergies and intertwine them in a way best suited to a particular context with its eventual limitations and opportunities.

As it appears currently, remote digital environments will become increasingly used in education. This is not only because of the shift that happened over the past few years with regard to digital literacy in universities but also due to the changes in other areas of work and life. Thus, more people are going to continue working remotely, which would call for a need in developing the capacities of students to work in such settings.

It is exciting to imagine what possibilities the future of blended and hybrid environments could bring to the future of education and course design. How could these design principles be taken forward to come up with radically different ways of conducting transdisciplinary courses? Could future transdisciplinary courses, for example, leave university campuses and be conducted closer to where a challenge is coming from? What effects would there be if future students were involved in the design of the course in which they had enrolled? What would it require of the established processes of course planning in universities, and what benefits could it bring? How far would it be possible to push beyond the current limitations and constraints of academic structures?

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3.5

THE IMPORTANT ROLE OF ENVIRONMENTAL IMPACT ASSESSMENT METHODOLOGIES IN SUSTAINABILITY EDUCATION

Wahidul Biswas and Michele John

Key concepts for sustainability education

- Understanding our local and global ecosystems is foundational knowledge in sustainability education across all disciplines.
- Sustainability education should provide a fundamental introduction to ecosystems services and the anthropogenic environmental impacts from human production and consumption activities on: climate change, air pollution, ozone depletion, biodiversity loss, soil quality, freshwater resources, land use change, land degradation and waste creation.
- Sustainability education must focus on the critical wellbeing, protection and conservation of the ecosystem services that support human life.
- Sustainability education should provide examples of the 'cause and effect' of broadscale environmental impact across disciplines so that all students can directly understand the connection between human activities and their environmental impact.
- Environmental impact assessment (EIA) methodologies are essential in measuring the impact of our human activities on the environment and are critical learning concepts in sustainability education, given their ability to highlight the causal link between the environmental impacts from our production and consumption decisions and our ability to measure and manage the impact.
- Sustainability education should focus on providing a multi and trans-disciplinary understanding of how to estimate and assess these impacts so that in the 21st century we can design better production systems, regulations, policy and management tools to prevent their occurrence and ensure a more sustainable future.

Introduction

All professions and academic disciplines have a role to play in reducing our anthropogenic environmental impacts. Scientists and engineers should design processes, technologies and products and deliver services in such a way as to avoid or minimize environmental impacts

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from production and consumption activities. Sociologists and psychologists can contribute to our understanding of human behavior and how to influence behaviors focused more on reducing environmental impacts from our production and consumption activities. Lawyers and policy makers can also assist in the development of regulations and laws that help to reduce unintended externalities and environmental impacts like greenhouse gas (GHG) emissions. Physicians and epidemiologists can help determine how these environmental impacts affect our health and offer solutions to cure or alleviate these affects.

Environmental impacts arise from changes to the natural environment due to human induced activities typically adversely affecting air, land, water, biodiversity and ecosystems. The pollution, contamination or destruction of natural ecosystems that occurs because of human activities can have short-term or long-term ramifications and are known as environmental impacts. Adverse environmental impacts, like climate change and soil eco-toxicity, also have a direct impact on human health, our quality of life and the health of global ecosystems.

Overconsumption in developed countries and population growth in developing countries are simultaneously responsible for very significant environmental degradation. Both consumption and population growth are responsible for increasing the demand for goods, services and natural resources. This growth in consumption negatively impacts the 'critical capital' of our life support system ecosystems, through air and water pollution, soil contamination and deforestation (see Chapters 2.2, 2.3, 2.4, 2.5, 2.7 and 2.8 in this volume).

Thomas Malthus theory on population growth postulated that continued human population growth would eventually outstrip the planet's food supply unless very significant and ongoing technological innovation was developed (Kent State 2018). Rapid technological development has indeed created a double-edged sword for the world's inhabitants: with our standards of living improving but subsequent increases in environmental impact together with decreasing resource levels. Today's food supply chain can support more lives than ever before, and the advancement of medical science has led to increased longevity in human lives. Malthus was focused on the inherent trade-off between resource efficiency and the planet's carrying capacity (see Chapter 2.3 in this volume). The limits to growth modeling presented by Meadows et al. (1972) also investigated the critical trade-off between population growth, resource efficiency and environmental pollution (see Chapters 3.2 and 3.7 in this volume).

The world's current GHG emission challenge began with coal burning in the industrial revolution (1750-1850 and 1850-1914). The industrial revolution significantly scaled up our resource use (coal) with mechanization and technology changes to enable large scale production, which resulted in the rapid exploitation of natural resources and accelerated environmental degradation. The significant rise in our global standards of living, particularly in developing countries, has however come at a significant cost to our environment. A holistic understanding of our environmental impacts is needed in order to redress the unintended consequences of our production and consumption activities.

In addition, global resources are finite. We only have one Earth but a burgeoning population which has been steadily growing since the industrial revolution started in the 18th century. The exponential growth of the world population began after 1950 with the rapid development of modern technologies. A classic example of this trade-off between population growth, resource efficiency and environmental degradation can be seen in our overuse of nonrenewable resources, like fossil fuels, and the attendant but unintended consequences of GHG emissions, global warming and declining fossil fuel resource levels. While these growth activities have resulted in substantial increases in our standards of living, they have also resulted in significant unintended global environmental impact.

Environmental impacts like global warming, air pollution, marine pollution, soil erosion, biodiversity loss, waste production and deforestation are significant and can be measured through a number of environmental assessment methodologies that help us to reframe and balance current population and production growth in terms of their global environmental impact, with the triple bottom line sustainability challenges of balancing economic, social and environmental needs.

Ecological systems

Understanding our local and global ecosystems is important foundational knowledge in sustainability education. Maintaining ecological balance is a prerequisite for long-term sustainable growth. Our ecosystems involve interactions and interrelationships between climate, soil, water, sunlight and other physical resources, across a variety of chemical, physical and biological environments. These relationships need to be sustainably managed and require the flow of energy through the ecosystem and the cycling of nutrients within the ecosystem. The sun is our fundamental source of energy, as it is used by *autotrophs* in the ecosystem, consisting largely of green vegetation capable of photosynthesis, who use the energy of sunlight to convert carbon dioxide and water into simple, energy-rich carbohydrates for their own sustenance and which are then ultimately consumed by *heterotroph*s, who cannot make their own food. The microorganisms in soil use, rearrange and ultimately decompose complex plant-based organic materials (i.e., leaves, twigs) built up by the autotrophs into simple inorganic materials or nutrients, which are easier for other plants/vegetation to then – utilize. Animals, fungi, bacteria and many other microorganisms, are known as heterotrophs. Our human activities, including urbanization, manufacturing and our general consumption and waste habits, can negatively impact these important, complex and sensitive interrelationships and interactions between autotrophs, heterotrophs and the ecosystems they inhabit.

For example, consider the biogeochemical cycle that involves the external transfer of elements among different components in a forest ecosystem. Uptake of nutrients from the soil, which is actually returning these nutrients to the soil from dead leaf fall, branch shedding (vegetation waste), and root growth. Nutrients returned to the soil in this way are not available for plant reuse until decomposition by the microorganisms in the soil. These nutrients are converted from organic to mineral or inorganic materials by a process known as mineralization. Mineralisation of nutrients from organic matter on the forest floor plays an important role in the supply of nutrients available for forest growth (Bridgham and Ye 2013). The deforestation associated with activities like mining and urban settlement can affect these nutrient cycles and can cause ecological imbalance (see Chapter 7.4 in this volume). This ecological imbalance could affect the entire food chain for ecosystem services including impacts on food, water and mineral availability. Scientific innovation is needed to minimize human impact on our ecosystems and to establish an inverse relationship between socio-economic outcomes and human well-being and the ecological footprints we create.

DPSIR framework for assessing human impacts on the environment

The resources and services provided by global ecosystems are being degraded by our increasing population and consumption growth. The DPSIR EIA framework below helps us to explore the link between human activities, their associated environmental impacts and the responses required to address the environmental impacts. The DPSIR framework (Patrício et al. 2016) provides the following assessment components:

- Driving forces of environmental change (e.g. industrial production)
- Pressures on the environment (e.g. waste water loading)
- State of the environment (e.g. water quality in rivers and lakes)
- Impacts on population, economy and ecosystems
- Response of the society (e.g. watershed protection)

The 'driving' forces resulting from human activities can include air, soil and water pollution, and all exert 'pressures' on the environment. Socio-economic and socio-cultural activities are also responsible for driving human activities. Social drivers of environmental impact can include the need for food, shelter, water, employment and economic wealth. A 'State of the Environment' report (Australian Government 2021), often produced by governments or non-governmental organizations (NGOs) can help disclose details on the condition of an environment and often refers to the actions or the mitigation measures that need to be to be taken by society to reduce the associated environmental 'impacts'.

For example, irrigators have accessed too much water from the Darling River system in Australia in order to increase their cotton production (i.e. driver). This reduced the water flow into the river system (i.e. pressure). The remaining water in the river, without freshwater entry, can become stagnant. Stagnant water has less oxygen content than flowing water due to the decomposition of organic matter in still water. As more oxygen can be consumed than is produced in still water, dissolved oxygen levels can decline. Thermal stratification can also occur during summer where the warmer surface layer of about 1 meter (m) of river water sits above a cooler deeper layer (2–3 m) of water with very low dissolved oxygen (i.e. resulting in a change in 'environmental state'). This can cause the death of fish (i.e. 'impact') as they can't move to the top of the water, as it is too warm to inhabit, or move towards the cooler bottom layer with its reduced oxygen levels. For example, it is estimated that over a million fish were killed in the Menindee Lakes in New South Wales, Australia, in the summer of 2018/2019 due to reduced river flow and thermal stratification (https://www.mdba.gov.au/community-updates/why-did-menindee-fish-deaths-happen). The 'response' to reduce the over-extraction of water could be to more tightly regulate water licenses, reduce cotton production activities (and therefore water use from the river), or by using more efficient irrigation systems in cotton production.

Causes and effects of anthropogenic environmental impacts

Environmental impacts are broadly categorized as atmospheric (increasing the concentration of pollutants in air), land (soil erosion and contamination), loss of biodiversity (impacts on habitats causing loss of species), solid waste (increased waste production, increasing landfill areas and the resultant land/air/water system pollution) and water use (increased water scarcity, drought and salinity) (see Chapter 2.2 in this volume).

Atmospheric impacts

Global warming impacts, photochemical smog and ozone layer depletion are major atmospheric impact categories. Specific gases emitted from different sources are responsible for causing these impacts.

Global warming impact

Increased global uptake of fossil fuel–based energy has resulted in the combustion of hydrocarbons, releasing harmful CO_2 emissions that have contributed significantly to global warming. Carbon dioxide levels have now surpassed the highest recorded concentrations in human history. Since the industrial revolution, the global average concentration of CO_2 in the atmosphere has increased from about 277 parts per million (ppm) to 414 ppm in 2020 (up 49%) (Global Carbon Project 2021), and global average temperature has increased by about 1.2° Celsius above preindustrial (1850–1900) levels. The year 2020 was one of the three warmest years in global records, despite a cooling La Niña event (WMO 2022). Global temperatures are increasing, contributing to sea level rise and extreme weather events like heatwaves, flooding and droughts (see Chapters 1.3, 2.1and 2.2 in this volume). With a global temperature increase of 1.36° C, bushfire, wildfire, flooding and drought events occur more frequently (NASA 2023).

It will increasingly be the responsibility of the current generation to move towards more resource efficiency, renewable energy and pollution control technologies to further limit global temperature increases to not more than 1.5° C above pre-industrial levels, as world leaders committed to in Paris in 2015 (Climate Analytics 2019). If there are no policy, institutional, technological and behavioral changes made towards reducing our GHG emissions, the concentration of CO_2 in the Earths atmosphere could increase up to 1000 ppm, which could correspond to an increase of 4.5° C in global temperatures above pre-industrial levels.

The consequences of not fully addressing climate change pressures include water inundation of coastal cities, increasing risks for food production-potentially leading to higher malnutrition rates, dryer and wetter regions across the globe, unprecedented heat waves in many regions – especially in the tropics, substantially exacerbated water scarcity in many regions, increased frequency of high-intensity tropical cyclones, and an irreversible loss of biodiversity, including coral reef systems (Climate Facts 2022).

Global warming is caused by the trapping of GHGs close to the Earth's surface. The percentage breakdown of GHGs are as follows: chlorofluorocarbon (CFC) (15–25%), methane (CH_4) (12–20%), ozone O_3 (8%), N_2O (5%) and carbon dioxide (CO_2) (50–60%) (Olivier and Peters 2020). Atmospheric retention time is higher for CO_2, CFC, and N_2O (50–200 years), which means these gases have the capacity to accumulate and move to the stratosphere to form a layer of GHGs. CFCs are created from the use of refrigerants and aerosols. They are the main cause of ozone layer depletion. Methane is a powerful GHG resulting mainly from the livestock industry. Methane gases that are emitted from these industries are from enteric emissions and some through the anaerobic digestion of manures. Enteric methane emissions are the single largest source of direct GHG from the beef and dairy industries and are a substantial contributor to anthropogenic methane emissions globally. This methane has 28 times the global warming potential of CO_2, with a shorter atmospheric retention time of approximately 12 years. Enteric fermentation takes place in the digestive systems of ruminant animals (e.g. cattle, buffalo, sheep, goats and camels), within which microbial fermentation breaks down food into soluble products and CO_2 is released as part of this digestion process. In the case of flood plain nations like Bangladesh, methane is also emitted from paddy fields and wetlands (Alam et al. 2019).

Nitrous oxide emissions are predominantly due to the application of Ntrogen (N) or urea-based fertilizers to crop and pastureland for agricultural production. N_2O is one of the most powerful GHG, as it is 265 times more powerful than CO_2. This means that 1 kg of N_2O can produce the same amount of global warming impact that would be produced by 265 kg of CO_2. Substantial efforts have been made by soil scientists to reduce N_2O emissions by using crop rotation systems where leguminous crops are grown before grains. The nitrogen that is stored in the legume of leguminous crops is then transferred in the soil to the grain crops the following year, therein reducing the requirement for urea fertilizer application.

About 90% of the world's carbon emissions come from the burning of fossil fuels – mainly from electricity, heat and transport applications. For the global mean temperature increase to remain at 1.5° C (2.7° F) above the pre-industrial levels, we need to achieve net-zero carbon dioxide emissions globally by the early 2050s. However, a 2° C increase above pre-industrial levels (3.6° F) is likely to be reached in the early 2070s (IPCC 2022). The potential impact of a 2° C increase on Earth's ecosystems is likely to be very significant, and the full human and biodiversity ramifications are not yet fully understood (The Conversation 2020).

Sea level rise and extreme weather events are also an outcome of global warming and will result in significant environmental impacts including altered ocean and land ecosystems, impacted food chains, biodiversity loss and intensified desertification. Even if dramatic reductions in emissions were made today, some human-induced changes are likely to persist beyond the 21st century given the slow response of the climate system (IPCC 2023) and the long residence times of many GHGs in the atmosphere. Considerable attention has focused on measures that could be taken by the energy sector (see Chapter 2.6 in this volume). Land use change and forestry activities (see Chapter 7.4 in this volume) have also been proposed as a means of moderating the effects of climate change, either by increasing the removal of GHGs from the atmosphere or through carbon sequestration.

Global warming impact is a global issue and requires the collective action of all nations to achieve emission reduction targets. COP27 concluded in Egypt in November 2022 with nearly 200 countries agreeing to the Egypt Climate Pact to limit temperature increases to 1.5° C above the pre-industrial levels (UNCCC 2022). COP27 launched the first high-level ministerial roundtable on 'pre-2030 ambitions', where it was agreed that limiting temperature rises to 1.5° Celsius was a 'red line' that could not be crossed (UK Parliament 2022). A COP27 work program was launched to accelerate the deployment of transformative climate technologies to tackle climate change. However, it was also announced that $2.67 billion of the $12 billion committed at COP26 to protect and restore forests between 2021 and 2025 had already been spent (UK Parliament (2022).

By way of example, Australia is a fuel-hungry young nation with a large land area and a relatively small population (26 million (ABS 2024)). It is a sparsely settled nation in which long-distance road and air transport is needed to connect capital cities across a country that is 4000 km wide and nearly 4000 km long. It has many low-density cities that depend significantly on motor vehicle transport. Australians have a high standard of living that allows them to have one of the highest car ownership rates in the world. They export large quantities of grain and livestock that produce significant quantities of CO_2. Australia also has huge reserves of coal which it uses in its power generation, and successive Australian governments have been slow to replace coal-powered electricity generation with renewable energy generation (see Chapter 2.6 in this volume). Australians are among the world's greatest per capita producers of CO_2 emissions (currently the 16th highest per capita emitter of CO_2 in the world according to the Worldometer (2024). Australia's failure to produce a coherent emissions reduction plan has resulted in it being 59th out of 65 countries in the 2022 Climate Change Performance Index (CCPI), a new ranking for climate policy performance. The index is jointly assessed by Germanwatch, the New Climate Institute and the Climate Action Network. Performance rankings are measured against four index categories – emissions, renewable energy use, energy use, and climate policy. Unfortunately, despite its young country status, Australia is seen as a laggard in relation to its national climate change policy development (CCPI 2024).

Photochemical smog

There are two distinct types of smog produced depending on the location. Sulfurous smog results from the emission of high concentrations of sulfur oxides (i.e., London smog in 1952). This SOx was emitted due to the combustion of sulfur-bearing fossil fuels, particularly coal (The Guardian 2012). This type of smog is aggravated by dampness and the existence of highly concentrated, suspended particulate matter in the air. Smog, like air pollution, is trapped higher in the atmosphere and can persist as atmospheric brown clouds, which can then cause climatic and health effects.

Photochemical smog, often known as 'Los Angeles smog', occurs most prominently in urban areas. This smog mainly originates from the emissions of nitrogen oxides and hydrocarbon vapors from automobiles and other sources. The resulting smog causes a light brownish discoloration of the atmosphere, reduced visibility, plant damage, irritation of the eyes, and can cause respiratory disease.

Like Los Angeles, the increasing trend of NOx emissions in Delhi has caused serious photochemical smog in recent years, resulting in New Delhi being referred to as the most polluted city in the world, given the increasing number of vehicles on the road and significant emissions in the capital city from nearby industrial zones and thermal power plant operations (Sharma et al. 2024). China also has significant photochemical smog (i.e. sulfurous smog and Los Angeles smog) resulting from the existence of high levels of NOx, O_3, soot, SOx and organic particles in the air (Hallquist et al. 2016).

Ozone layer depletion

The use of CFC-11 ($CFCl_3$) has been well noted in the manufacture of aerosol sprays, 'blowing agents' for foams and other packing materials such as solvents and as refrigerants. However, CFC was found to have high ozone depletion potential (ODP), acting on the stratospheric ozone layer. N_2O emissions are currently the single most significant ozone-depleting emission (Ravishankara et al. 2009).

The ozone layer is a highly concentrated form of ozone found around 15–30 km above the Earth's surface in the stratosphere. It covers the entire planet and protects life on Earth by absorbing harmful ultraviolet-B (UV-B) radiation from the sun. There are three types of ultraviolet rays, including UV-A, UV-B and UV-C. The energy intensity of these ultraviolet rays increases with a decrease in the size of wavelength of the radiation. The wavelength of UV-A is between 0.3 µm and 0.4 µm and can pass through the ozone layer. UV-B of wavelengths between 0.2 µm and 3 µm is partially absorbed by the ozone layer. The dangerous UV-C with the lowest wavelength between 0.1 µ and 0.2 µ is also absorbed by the ozone layer. The destruction of the ozone layer or the creation of ozone holes (like the one in Antarctica) allows UV-C rays to enter the Earth's biosphere and can negatively impact both vegetation and human health.

Ozone depletion can also cause skin cancer and affects the important growth of ocean phytoplankton which are critical in marine environment food chains and in oceanic oxygen production. The critical loss of phytoplankton has two very significant environmental impacts – firstly it affects marine life by reducing important food chains and secondly, it reduces the very important carbon sequestration capacity of the ocean.

The gases that are mainly responsible for the destruction of the ozone layer are halogen gases such as CFCs, halon, carbon tetrachloride (CCl_4), methyl chloroform (CH_3CCl_3), hydrobromofluorocarbons (HBFCs), hydrochlorofluorocarbons (HCFCs), methyl bromide (CH_3Br) and bromochloromethane (CH_2BrCl). These chemicals are responsible for converting O_3 in the ozone layer to O_2. CFCs have a 50–100-year residence time in the lower atmosphere. As CFCs rise into the atmosphere, the UV releases single atom Cl from the CFCs and this single atom is highly reactive with O_3 and destroys the O_3 ozone by converting it to O_2 oxygen. CFC compounds were previously used as refrigerants to run efficient refrigeration cycles. After the Montreal Protocol in 1988, 46 countries signed an agreement to ban these chemicals in refrigerators and aerosols. Although the use of halogen gases has reduced significantly in recent times, N_2O from fertilizer use in agricultural applications has replaced it as another gaseous emission with significant environmental impact. In the presence, of sunlight, N_2O releases a highly reactive single atom of oxygen which also reacts with O_3 to produce O_2 oxygen, and like halogen, reduces the stratospheric ozone layer. Global fertilizer application is expected to increase with growing demand for food production and exponential population growth (see Chapter 2.5 in this volume). While N_2O is not as powerful as halogen as an ozone depleting agent, over time it does significantly affect the ozone layer.

Land impacts

Land use has generally been considered a local environmental issue, but is becoming an environmental impact of global importance. Worldwide changes to forests, farmlands and waterways are being driven by the need to provide food, fiber, water and shelter to more than 8 billion people globally. Croplands, pastures, plantations and urban areas have expanded rapidly across the world in recent decades, accompanied by large increases in energy, water and fertilizer consumption, along with considerable loss of biodiversity. Such changes have undermined the capacity of ecosystems to sustain food production, maintain freshwater and forest resources, regulate climate and air quality and ameliorate infectious diseases. We face the challenge of managing trade-offs between immediate human needs and maintaining the capacity of the biosphere to provide the goods and services needed for future generations. Dryland salinity reduced productivity in crop production in Western Australia that could threaten 2.8–4.5 million hectares of highly productive, low-lying and valley soils, with potential damage estimated to be around $519 million per year (Department of Primary Industries and Regional Development's Agriculture and Food, 2022).

Freshwater resources

Land use can disrupt the surface water balance and impact precipitation and evapotranspiration rates, runoff and groundwater flow. These impacts, mainly attributed to the clearing of natural vegetation, are especially harmful where forest areas are cleared to make way for land use development. For example, the impervious pavements and buildings commonly used in densely populated urban areas prevent the percolation of water into groundwater aquifers. Water demands associated with land use practices, especially irrigation and earth works, directly affect freshwater supplies and water table levels through water withdrawals and diversions. Global human water withdrawals doubled (i.e. from 1700 to 4000 km^3 per year) between 1960 and 2010 and are projected to increase further to 6000 km^3 annually by the end of this century (Wada and Bierkens 2014).

Forest resources

Since 1990, 420 million hectares of forest have been lost as a result of land clearing for agricultural farming and timber production (Earth.Org 2024). Effective forest management can improve forest conditions. For example, nitrogen fertilization, peatland drainage and direct management efforts increased the standing biomass of European forests by 40% during 1950–1990, and these forests have become a substantial sink of atmospheric carbon (Nabuurs et al. 2003). (See Chapter 7.4 in this volume.)

Regional climate

Large-scale clearing of tropical forests may create a warmer and drier climate. Global forests, trees and plants have sequestered about a quarter of all fossil fuel emissions since 1960. However, in the past 3-4 decades, this capacity has been significantly reduced due to fires and land clearing for beef and soy production in countries such as Brazil. The fires in the south-eastern Amazon have become a source of CO_2, rather than a sink (The Guardian 2021).

Deterioration of soil quality

Soil plays a crucial role in nature's cycles, storing elements such as carbon, nitrogen and phosphorous. Soils provide physical support for plant roots by maintaining a porous structure, allowing the passage of air and water. In addition, soils also possess important constituents such as water, minerals and biological components (fungi, invertebrates, mollusks, bacteria, protozoa) to support plant growth. Human activities, including mining, construction, road transport, agricultural production and farming, have all contributed to soil degradation.

Biodiversity impacts

Biodiversity refers to different kinds of animal and plant species that can be found in a specific area, where they are interdependent to form a community or ecosystem. A wide variety of animals, plants, fungi and microorganisms (e.g., bacteria) make up an ecosystem. Each of these species and organisms work together in an intricate web to maintain a balanced ecosystem and support life on Earth.

Biodiversity includes (Hoban et al 2022):

Genetic Diversity: is the total number of genetic characteristics in the genetic makeup of a species. It spans widely from the number of species to the differences within species. Strong genetic diversity can lead to a healthy ecosystem, by enhancing the interaction and the interrelationship between species.

Habitat Diversity: which describes how different habitats within ecosystems facilitating each other both structurally and through the exchange of material and energy across habitats.

Species Diversity: This refers to the number and abundance of species found in an ecosystem.

Species within an ecosystem can be classified as (Feest et al. 2010):

- Species richness: A measure of the abundance of each species. Species richness helps support a balanced ecosystem.
- Species evenness: This is a measurement of the relative abundance of different type of species within a community. For the sentence after explaining what species evenness is, this can be crossed out. In some cases this can be problematic, as predators need more prey than their own species numbers to survive. A python, for example, needs three to five rats a month to survive.
- Species dominance: Similar to above, this needs a sentence to explain what species dominance is. Dominant species are the most abundant species in a community, creating a strong influence over the occurrence and distribution of other species, which can sometimes lead to resource scarcity or disrupt the food chain.

The main species categories are (Rakotomalala et al. 2021):

Exotic – a plant species that is non-native but can cause harm to local species. For example, 'sleeper' weeds (established species that are yet to become a widespread problem) are considered to be of major concern in many parts of the world.

Endemic – plants and animals found exclusively in a particular area. For example, kangaroos in Australia and zebras in Africa.

There are many factors that influence biodiversity health. The interaction between living organisms and their environment plays an important role in enhancing biodiversity. Types of interaction include competition (competition between predators for prey), symbiosis (human beings and bacteria benefit from each other as the former gets their food digested by the latter in exchange for the energy) and predation - which is important as predators sometimes control the growth of their prey which keeps the ecosystem balanced. For example, the population of rats in Indian paddy fields are controlled by rat snakes and parasitism (the existence of one species in another species' body).

The factors that enhance biodiversity include genetic diversity, resources (food and water for a species to survive), climate, variability, physical substrates (soil, water, where species find places to create habitats to live) and other species.

Factors that negatively impact or disturb biodiversity health are also present such as, land and soil disturbance. Land disturbance, commonly from mining activities, can change the soil habitat and affect ecosystem fauna and insects, such as ants, termites and beetles. Soil disturbances can cause the destruction of plants and animals and habitat fragmentation.

Other examples include the pressures of water pollution, climate change, overfishing and acidification on marine waters. Experts say that one-fifth of global reefs are already destroyed and one-fourth of reef species might be extinct by 2050 (UNEP 2023).

Invasive species are another significant disturbance sometimes brought on by transporting species either intentionally or accidentally from other regions of the world. This can be detrimental to local species and can result in the decline or extinction of local species and an overpopulation of invasive species. These species may not have any natural predators in the new ecosystem, causing an imbalance. Problematic invasive animal species in Australia have included foxes, rabbits and cane toads. Destructive invasive plant species in Australia have included lantana and blackberry and a major destructive fungus species called *Phytophthora* (often called 'dieback' or root rot fungus) which after accidental introduction, has caused serious impact across the world in agricultural and horticultural industries.

Solid waste impacts

Waste generation is increasingly becoming a global environmental challenge due to rapid population growth, rising standards of living, increasing urbanization and the global economic rise in affluence (see Chapter 2.4 in this volume).

There is a linear relationship between income and waste generation (van Beukering et al. 1999). As income increases, people desire a higher standard of living and purchase more, thus generating more waste. Often this waste cannot be recycled, reused, recovered or remanufactured and as a result, is typically disposed of in landfill or waste incineration. From a conservation of materials and energy perspective, we should be focused on zero-waste production and consumption, and all 'wasted' materials should have a second life in being recyclable, reusable, recoverable or remanufactured. If the waste has no recoverable value, waste management alternatives must be considered. 'Upcycling' of waste is also preferred to the lower resource values gained from 'downcycling' (see Chapter 2.4 in this volume).

Solid waste management involves the collection, treatment and disposal of solid materials that have been discarded because they have served their initial purpose or are no longer useful. Improper disposal of municipal solid waste (including organic materials) can create unsanitary conditions, and can lead to pollution of the environment and outbreaks of vector-borne diseases i.e., diseases spread by rodents and insects. The management of solid waste presents a number of complex technical challenges. It also presents a wide variety of administrative, economic and social challenges (e.g. waste handling) that must be managed and or resolved.

Zero-waste management (Zaman and Lehmann 2013) can be achieved by minimizing waste or converting wastes to resources. By avoiding waste going to landfills, the conversion of waste to useful materials not only reduces the size of the landfill but also reduces the virgin resources required.

The diversion rates from landfills have increasingly become a benchmark for successful waste management planning. However, the waste diversion rate should not be considered a measure of 'zero-waste performance', as it does not account for waste avoidance through industrial design, effective waste policies and consumer behavior change.

Water body impacts

Only 3% of the world's water is freshwater, and 66% is trapped in glaciers (WWF 2022). Many of the water systems that maintain ecosystems and provide water for human consumption are declining. Many rivers, lakes and aquifers have become too polluted to use or have dried up, with around 50% of the world's wetlands already having disappeared (UNEP 2024)

Agriculture consumes more water than any other application with significant water wasted through inefficiencies. In addition, climate change is altering weather patterns and the potential recharging of water bodies around the world. By 2025, two-thirds of the world's population may face water shortages (United Nation 2024), with many ecosystems around the world being pushed to their limits under climate change induced drying or inundation pressures (WWF 2022). Oceans contain 97.2% of the Earth's water (NOAA 2021). However, the use of seawater through desalination is both cost- and resource-intensive. Most countries, with the exception of rich or developed nations are heavily dependent on underground water or surface water catchments, often requiring chemical treatment before consumption.

The over-extraction of water by irrigators, as with the cotton farmers in Australia mentioned earlier, are also putting significant pressures on water resource levels. Over-extraction in river systems can result in warmer water and lower levels of dissolved oxygen, which then puts significant negative pressure on the natural biodiversity of living things in the river. (Australian Government 2018).

Dryland salinity is a water challenge resulting from vegetation clearance and poor land and irrigation practice management, significantly impacting groundwater tables. In Western Australia, extensive native vegetation areas (about 35–40% of the state's total area) have been converted to annual pasture and cropping systems. These annual pasture and crop production systems only consume water during their four-to six-month growth cycle and have much shorter root systems than the native perennial plants they replaced. This has resulted in a significant percolation of annual rainfall down to the groundwater table, absorbing the soils salts along the way. Over time the water tables start to rise under the annual pasture and cropping systems and bring the stored salts to the soil surface, which then creates a hypersaline soil environment not suitable for traditional agricultural production (John et al. 2005).

In the case of urban catchments, cities and urban areas produce large volumes of runoff water through both point source (e.g., pipe or drain) and non-point sources (lawn, gardens, car parks), as urban infrastructures (i.e., roads and pavements) are largely made of impervious materials, which inhibits infiltration of water into the soil. While flowing over road and pavement surfaces, runoff water carries hazardous wastes, toxic materials and solid wastes to the ocean or surrounding rivers or creeks, which then contaminate both the water body and surrounding soils. In addition, during rainfall events, stormwater flows can rapidly enter urban streams carrying high levels of soil nutrients, sediment and heavy metals, which can also put pressure on local water and soil ecosystems.

When considering the above environmental impacts, it is important to consider how we can estimate and assess these externality impacts so that we can design better regulations, policy and management tools to prevent their occurrence. Some of these management tools are discussed below.

Environmental impact assessment tools

Tools for EIA have been developed over the past 26 years for environmental decision support and are rooted in systems thinking and analysis (Andersson et al. 2016). This systems perspective has provided a variety of commonly used assessment tools, including EIA, to help predict environmental impact in the planning stages from our production systems;

life cycle assessment (LCA) for assessing the environmental performance of products and services; eco-efficiency assessment (EEA), which focuses on increasing economic performance through resource efficiency; environmental management system (EMS), which help organizations establish their planning activities, practices, internal procedures and processes necessary to help achieve their environmental targets and regulations; and material flow analysis (MFA) for studies of both renewable and non-renewable material flows of a product or service (see Chapter 4.2 in this volume).

Environmental impact assessment

EIA is used to identify the environmental, social and economic impacts of a project prior to decision-making, to predict environmental impacts at an early stage in project planning and design as well as to find ways and means to reduce adverse impacts to suit the local environment. EIA can be undertaken for individual projects, such as a dam, motorway, airport or factory, to take actions to avoid any anticipated environmental impacts that will potentially affect the surrounding community, flora and fauna. Firstly, a screening operation is performed to determine the level of impact assessment required for a project. Secondly, scoping activity is carried out based on legislative requirements, international conventions, expert knowledge and public involvement to identify the relevant impacts of the project for assessment and to identify alternative solutions that avoid, mitigate or compensate for adverse impacts and finally to derive terms of reference for the impact assessment. Thirdly, the impacts and development of alternatives are assessed and evaluated to predict and identify the likely environmental impacts of a proposed project. Fourthly, an environmental impact statement (EIS) or EIA report, consisting of an environmental management plan for mitigating the identified environmental impacts, and a non-technical summary for the general audience are prepared. Fifthly, the EIS is reviewed through public (including authority) participation and is based on the terms of reference which were developed during the scoping stage.

Life cycle assessment

Life Cycle Assessment (LCA) is a very popular global EIA tool and covers a broad set of environmental impacts including accounting for pollutant emissions to air, water, and soil. This led to the methodological development of LCA (see Chapter 4.2 in this volume).

Three organizations have been involved in the development and standardization of LCAs: the Society for Environmental Toxicology and Chemistry (SETAC), the United Nations Environmental Programme (UNEP), and the International Standards Organization (ISO). Since 1990, SETAC has been offering a scientific exchange platform for LCA development and promotion (Jolliet et al. 2015).

The ISO produces international standards for the industrial application of LCA by involving experts from various backgrounds, including industry, technology, economics and academia (ISO 2006). ISO guidelines consists of ISO14041, 14042 and 14043, released in 2006, and describe four steps for LCA, including goal and scope definition, inventory, impact assessment and interpretation. ISO14046:2014 guidelines have specifically been developed for LCA-based water footprint assessment of products, processes and organizations.

LCA scrutinizes the environmental inputs and outputs of products across all life cycle stages, including 1) the pre-use stage (extraction of raw material to material manufacturing, transportation to construction sites, construction), 2) the use stage and 3) the demolition and disposal stages.

LCA methodology expanded significantly in Europe and Japan in the mid-2000s and is now increasingly used in America, Australia and developing countries. This is largely due to the interest of major international producers and manufacturers wanting to assess the sustainability performance of their products.

LCA assesses the environmental objectives and potential impacts associated with the production and use of a product or system by developing an inventory of relevant inputs and outputs of the product system, evaluating the potential environmental impacts and interpreting the results of the inventory analysis and impact assessment phases. The first task of LCA is to compile and evaluate the inputs and outputs and the potential environmental impacts of a product system throughout its life cycle. Secondly, it identifies the impacts of a product across all stages of the life cycle. Thirdly, it determines the environmental impact (across a wide group of category impacts) of those impacts for comparative or improvement purposes. For example, the replacement of diesel with biodiesel does not necessarily reduce GHG emissions given the emissions from the production of chemicals and their application to soils for biodiesel feedstock production. The GHG emissions from canola production in Western Australia is significantly lower than other regions in Australia and overseas due to a lack of denitrifying bacteria in the soil. The LCA work of Biswas et al. (2011) confirmed that Western Australian canola in the biodiesel supply chain produces half the GHG emissions of canola produced in Europe. LCA tools are typically referred to as environmental life cycle assessment (ELCA) tools. Social life cycle assessment (SLCA) and life cycle costing (LCC) are additional tools to further assess social and economic impacts. Life cycle sustainability assessment (LCSA) uses LCA, SLCA and LCC to assess the triple bottom line sustainability of products (Janjua et al. 2019). As LCA, LCC and SLCA are all based on the ISO 14040 (2006) framework and address the three sustainability objectives or triple bottom line objectives (i.e., environmental, economic and social) in a complementary way, it is possible to integrate these techniques into an overarching LCSA framework to obtain a single sustainability score to compare the sustainability performance of different versions of the same product or different technological options or scenarios. For example, a garment factory makes good-quality trousers at a lower cost by involving child labor and by ignoring associated environmental impacts. The use of child labor and the absence of environmental mitigation strategies have helped the garment industry to achieve economic sustainability by reducing the operational cost of the production of the trousers. However, the social performance of the trousers has reduced significantly by exploiting the child labor and the associated poor wages. Furthermore, the environmental score is reduced further as the garment factory does not use any pollution control technologies for treating factory gaseous emissions and wastewater. In this instance, the economic objective is met but the social and environmental objectives are not met. Therefore, the overall sustainability score of the trouser production, including the integration of the social, economic and environmental objectives, results in a lower LCSA score. This LCSA analysis should enable the garment industry to reduce environmental degradation, prevent negative social impacts and increase social and economic benefits during the life cycle of the trousers.

In addition to calculating the overall sustainability score, LCSA can help identify triple bottom line hotspots or problematic areas in order to help develop sustainability solutions or strategies or to achieve an environmentally friendly solution in a socio-economically feasible manner. In the case of the current example, child labor and air and water pollution are sustainability hotspots, which can be mitigated by involving adult workers, providing standard wage rates, using clean fuels and adding wastewater treatment facilities to improve the overall sustainability score.

Eco-efficiency Assessment framework

An EEA framework assesses the eco-efficiency performance of products. Eco-efficiency is a sustainability concept that aims to increase economic performance through resource efficiency and 'doing more with fewer environmental impacts'(see Chapter 4.2 in this volume). This integrates the economic and environment objectives of sustainability assessment. The concept of eco-efficiency was first discussed by Schaltegger and Sturm (1996). Then in 1989, the World Business Council for Sustainable Development (WBCSD) recognized the value of EEA in a report entitled 'Changing Course' (Verfaillie and Bidwell 2000), which defined EEA as being achieved by: "the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle to a level at least within the earth's estimated carrying capacity".

EEA frameworks have a significant influence in helping to reduce environmental impacts, as they select the technological options or products that can offer reduced levels of environmental impact without resulting in excessive increases in cost (Arceo et al. 2019). The incorporation of environmental solutions can increase the cost of production, meaning that the product or technology could be environmentally friendly but could be very expensive to produce. EEA helps to determine the product/production options which best satisfy both economic and environmental objectives. For example, the use of photovoltaic (PV) technology to generate 100% electricity for a residential area can reduce the environmental impact significantly but may increase the cost of electricity generation. In this case, the energy supply strategy is not eco-efficient as the economic objective has not been met. An EEA framework will help determine the optimum electricity mix (e.g., X% conventional energy + Y% PV technology) that will reduce the energy cost whilst meeting environmental objectives. The practical application of eco-efficiency requires ongoing innovation to create more value-added products with reduced environmental impact via lowering material/energy inputs and emissions through recycling, reducing, recovering, remanufacturing, redesigning and reusing.

Environmental management systems

Environmental Management Systems (EMS) guidelines now follow ISO14001–4 that enables industries to be accredited by ISO to achieve their environmental targets through an EMS reporting framework (see Chapter 4.2 in this volume). EMS is defined as part of the organisations internal management reporting systems covering those activities, responsibilities, practices, procedures, processes and resources required for developing, implementing, achieving, reviewing and maintaining company targets required to achieve regulatory and the environmental policy performance (ISO 1996). Firstly, the EMS aims to identify and control environmental 'aspects, impacts and risks'. For a refinery, SOx and NOx are known as 'aspects', the acidification caused by these gases is known as the 'impact' and the reduction of food production due to associated soil and water acidification is known as the 'effect'. Secondly, an EMS helps to achieve the required environmental policy, including standards (e.g. reduction of CO_2 emissions), objectives (i.e. maximizing the use of renewable energy) and targets (i.e. reducing CO_2 emissions by 10% by 2025), including any compliance with legislation. Thirdly, industry-specific environmental opportunities are identified, as different industries emit different types of environmental emissions (e.g. mining industries produce a large amount of dust in the air while oil refineries emit SOx and NOx). Fourthly, environmental performance is monitored on a regular basis for documentation and auditing purposes.

An EMS can also demonstrate due diligence and suggests that the producer or industry is focused on environmental stewardship. ISO guidelines also help maintain compliance with environmental regulations which help industries anticipate problems and take preventative rather than corrective action.

Material flow analysis

MFA is the quantification and assessment of materials (water, food, wastes) and substances (nitrogen, sulfur, phosphorus, carbon) used in all processes in a product life cycle system (city, country, etc.) during a defined period (Liedtke et al. 2014). The material intensity of a product part (MIPS) is a common measuring unit in MFA designed by the Wuppertal Institute in Germany that monitors the material intensity of different products and services concerning a particular unit of a product (Saurat and Rittoff 2013). It is based on the understanding that the full extent of environmental impact from a product can be measured by the material input (MI) across its life span. Fewer raw materials utilized typically means less environmental impact often resulting in reduced- land use change, loss of biodiversity, deforestation and less water table destruction, amongst many environmental variables that could be impacted and measured. For example, for a passenger car, the number of service units is the number of kilometers traveled during the life span of the car. The lower the material input (i.e. the materials used in making, running and maintaining the car) per kilometer, the more eco-efficient is the vehicle. Lowering the amount of material means the reduction in land use changes or deforestation due to mining and processing of materials and other associated impacts like the loss of biodiversity and soil and water pollution. MFA also identifies problems and quantifies the impact of potential measures on resource recovery and environmental pollution and enhances waste management strategies. For example, MFA has been used to estimate both product and waste from a variety of industries. For example, an MFA for a Japanese produced electric car determined that 5.23 kg of raw materials and energy resources were required from mining to material production to produce 1 kg of vehicle resulting in an MIPS of 5.23kg/kg (Sato and Nakata 2020).

Conclusion

Significant environmental impacts resulting from population growth and human activities are putting future generations at risk. The quality of global air, soil and water systems is declining, and yet they are critical natural capital in providing essential ecosystem services that sustain the carrying capacity and long-term sustainability of our Earth.

Both measuring and managing environmental impact reduction are essential concepts in sustainability education. These impacts are not discipline specific and engage with a broad array of both natural and man-made systems. LCA and EMS assessment frameworks can play an important role in sustainability decision making to help identify and quantify the causes of environmental, social and economic impacts from our anthropogenic production systems.

Furthermore, providing an understanding of how fundamental environmental and ecological systems work and are impacted by human activity is also important in sustainability education development. Increasing community expectations from 'social licence to operate' and environmental stewardship in the 21st century are putting increased pressures on sustainability education to provide an understanding of environmental assessment methodologies. This level of environmental awareness will also require sustainability-focused technological innovation, behavioral change, policy development and institutional changes to be guided by environmental impact assessments and environmental management system methodologies.

Environmental impact assessment (EIA) education can help develop an understanding of the critical impact of human production and consumption on our global ecosystems and establish a more acute understanding of the mechanisms by which human activity in the anthropocene is impacting our future. EIA should be an integral component of sustainability education curricula.

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3.6

FUTURES THINKING AND REGENERATIVE SUSTAINABILITY

Sebastian Thomas

Key concepts for sustainability education

- Understanding complex systems is a critical tool in sustainability education.
- Futures thinking is an essential tool in sustainability management in considering potential futures and planning for different futures scenarios.
- Sustainability competencies include normative, anticipatory, and strategic capabilities, as well as interpersonal skills.
- Regenerative sustainability is a worldview that enhances the ability of living things to evolve, collaborate, and thrive.
- Future-focused sustainability education should include systems thinking, anticipatory and normative capabilities, strategic decision-making skills, and the ability to work collaboratively, productively, and equitably with a diverse range of stakeholders.
- Reaching net-zero greenhouse gas (GHG) emissions in the global economy must be understood as a milestone rather than a target. Global civilisation will need to go beyond net zero to draw down GHGs from the atmosphere and engage in long-term, large-scale planetary repair.

Introduction

The English author and humourist Douglas Adams once wrote that "All you really need to know . . . is that the universe is a lot more complicated than you might think, even if you start from a position of thinking it's pretty damn complicated in the first place" (Adams 1979). He was, of course, understating the reality. The world is certainly diverse and complex, and the rate of societal change has accelerated so that major technological innovations occur ever more frequently (Toffler 1970). This has led to some describing the contemporary era as an 'age of disruption' (Hartley et al. 2019).

This age of disruption is exacerbated by rapid and potentially catastrophic environmental degradation, intense political tension and social unrest, and dynamic and deadly public health crises. The contemporary world is an interconnected globalised society with huge disparities in health, wealth, education, and empowerment. We face an array of challenges: comprehensive transition to renewable energy systems; transforming industries

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and agriculture to be environmentally sustainable; providing food, clean water, and housing for people living in poverty; adapting to the impacts of climate change; and securing social justice for the disadvantaged (Bennett et al. 2019). There is an urgent need for education to ensure that those most affected by these transitions are not locked out of emerging social and economic opportunities.

We are also exploring incredible new technological frontiers in machine intelligence and robotics, genetic engineering, nanotechnology, communication systems, and most of all, in the integration of these technologies (Betz et al. 2019; Kimani et al. 2020). Technological progress and emerging cyber-biological systems have profound implications for individuals, society, governments, and businesses. There are exceptional opportunities to create new products, services, and business models that create social, environmental, and commercial value in innovative and sustainable ways.

Meeting these challenges and creating new opportunities is a key role for modern sustainability practitioners. Education programs must equip graduates with relevant and necessary knowledge and skills to understand complex systems and design responses that apply in multiple locations or circumstances and contribute to improved positive outcomes for people and environments that endure through space and time.

This chapter discusses future-oriented sustainability concepts relevant to practitioners in this time of rapid disruption and opportunity: systems thinking, transdisciplinarity, transition theory, and regenerative sustainability. These provide a futures thinking toolkit to optimise well-being and justice for people, places, and organisations. Throughout the chapter concepts are illustrated with examples of climate change impacts and policy responses. The chapter concludes with a call for regenerative approaches to climate change and wider sustainability practices in future planetary stewardship.

Systems thinking

Human beings are natural systems thinkers. We recognise patterns and create organised events, works of art, and social structures. We design and operate processes that respond to complexity through space, time, and environmental components, as do many other species. Systems thinking is fundamental to our existence and evolution (see Chapter 4.1 in this volume).

To survive as hunter-gatherers in prehistoric periods, humans needed to observe and describe the behaviours of prey animals, to communicate among themselves, and to debate potential courses of action. Seasonal dynamics demanded understanding of how resource availability varied with climatic conditions and changed through time. Humans met these challenges and have since mastered complex physics and technologies powerful enough to engineer planetary climate dynamics. It is fascinating to consider that the intelligence necessary to fashion a stone knife was also sufficient for later generations to build a spacecraft that could land on the moon and return with its human crew alive and well. We are systems thinkers by nature.

Yet our success in engineering environments has led to linear and reductive ways of thinking. We divide ourselves by discipline or faction, focus on specific objectives and key performance indicators, and conduct boundary-setting exercises that exclude issues or stakeholders relevant to or affected by our decisions. We describe the uncosted impacts of business activities on society as externalities. We focus on current affairs rather than historical trends and describe disruptive events as ‘black swans’ – unpredictable events with profound impacts, explained afterwards as having been inevitable and predictable. Examples include the global financial crisis (GFC), the invention of the iPhone, or Brexit (Nassim Taleb 2007).

Systems thinking understands that events are driven by patterns below the surface – influences that are not immediately seen. Consider driftwood floating in the ocean. From the beach it may be clear that a strong wind is blowing in one direction, yet the log is moving in the other because an unseen tide is running below the waves. Tides, however, are governed by stronger, systemic forces – temperature dynamics at different depths in the ocean and the gravitational influences of the sun and moon. And even this level of understanding is structured through a particular worldview, the modern scientific paradigm.

This multilevel explanation of systems thinking builds on the work of ecologists, anthropologists, and many others (Sweeney and Meadows 2010; Maani and Cavana 2007; Ali et al. 2022). The iceberg graphic (Figure 3.6.1) is a simple but effective representation of the multilevel understanding of systems thinking.

Scientific or performance measurements are often made at the event level and consider historical occurrences (Ackoff 2006). This can constrain learning and limit the ability of an individual or organisation to understand the drivers of poor outcomes (Sweeney and Meadows 2010). An example is the GFC of 2007–2009, which saw stock markets crash and banks fail. Financial systems have become stronger since the GFC at little additional cost, but contemporary reporting described the crash as a random and surprising event

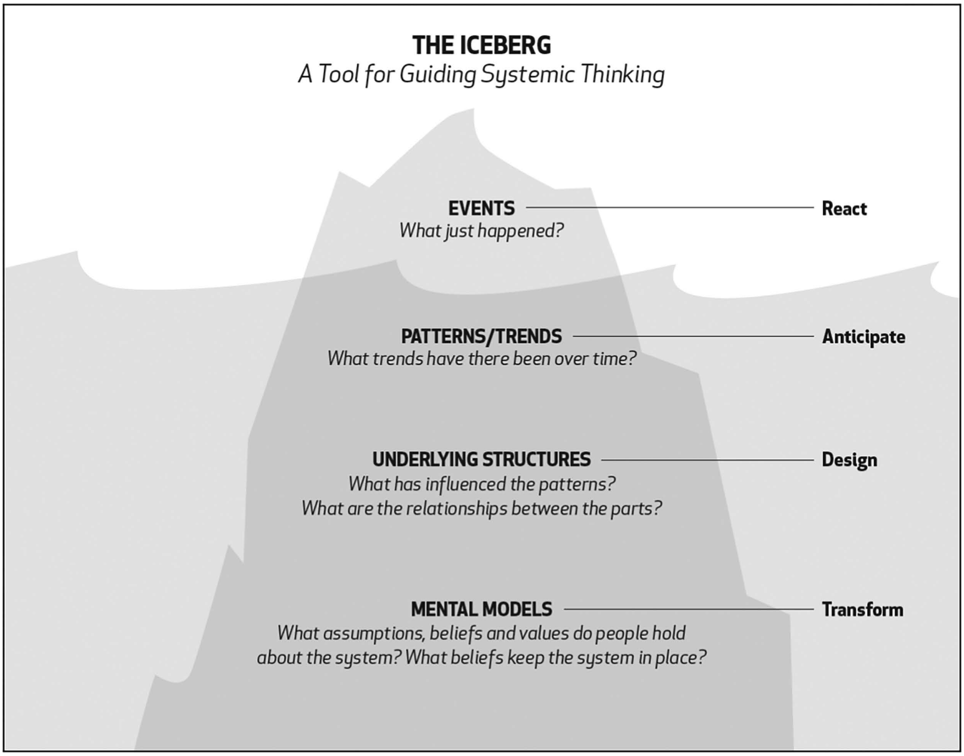

Figure 3.6.1 Iceberg model of systems thinking from EcoChallenge.org – Creative Commons Attribution ShareAlike 3.0 Unported License.

rather than the result of structural issues (Adrian et al. 2018). The arguments of commentators who predicted and warned against the impending collapse were drowned out by the more powerful voices of major investment banks and financial institutions.

Recognising different levels of patterns reveals how events or other data points are linked together (Nguyen and Bosch 2012). Pattern recognition provides more meaningful information about dynamic trends through time. Some argue that this level of analysis has been fundamental to the success of humans through history (Jordan 2013). In the case of the GFC, the patterns that the drove the events included more people borrowing money at lower rates over several years, rising household debt across the United States, reduced consumer spending as a result of this growth in debt, and eventually a surge of loan defaults that disrupted investor confidence and overwhelmed institutional liquidity (Bernanke 2018).

Like tides, patterns are created by systemic structures that underpin the nature of patterns and how they interact – the interplay of values, intergenerational beliefs, experiences, old and new orthodoxies, and economic conditions. The ability to engage with this deeper level of thinking allows for analysis of the interactions between economic, social, cultural, political, or natural factors and how these generate the outcomes we observe. The institutional, systemic patterns of rising debt that caused the GFC were caused by a long-term structural approach by US financial institutions that provided low deposit loans, meaning more people could borrow money and invest in property. In a market lacking stringent regulation, lenders were able to make credit available to greater numbers of people, including many without the ability to service those loans (Adrian et al. 2018; Bernanke 2018).

The systems view goes further to ask why these systemic structures exist as they do. What are the assumptions, the worldviews, the mental models that generate these structural functions and determine that they are the most appropriate, or natural, or logical way for institutions and systems to work? The social and economic paradigms that allowed the GFC to occur were built on fundamental economic assumptions that markets are rational, property ownership is a commercial activity rather than a human right, banks are commercial institutions, more loans means more profit, and profit is good (Laybourn-Langton and Jacobs 2018; Hunt and Stanley 2019).

The GFC occurred because of the pattern of widespread, excessive household debt built on the systemic provision of cheap loans, underpinned by the assumption that generating profits for banks is a good and appropriate societal goal.

Understanding the complex and interconnected nature of the world allows systems thinkers to address wicked problems in varied and nuanced ways (Rittel and Webber 1973). The world is perceived not in terms of its components but as something greater than the sum of these parts. Like a spider's web, every part of the system has some connection to all the others, and pulling on one strand has effects elsewhere. Humans and nature are not separate from each other but integral components of a single social-ecological system (Folke et al. 2016; Dearing et al. 2014; Ostrom 2009). This planetary system comprises the lithosphere of core, mantle, and crust that drives tectonic and volcanic forces; the atmosphere that provides life support and the dynamics of weather; the hydrosphere of ocean, rivers, and rain that shapes landscapes and harbours countless organisms; the cryosphere of glaciers and ice sheets that regulate our climate; and the biosphere that teems in every environmental niche and makes our planet the richly diverse world that it is (Pörtner et al. 2022, 2019; Costanza et al. 1997; Steffen et al. 2018).

Without this complex global reality, human societies could not have developed as they have. Sustainability is not the nexus of environmental, social, and economic success, as described in the triple-bottom-line model (Elkington 2008). No economy can exist without a society to create it, and no society can function without a viable environment to sustain it (Elkington 2018; Raworth 2012). This is demonstrated in the excellent interpretation of the Sustainable Development Goals image by the Stockholm Resilience Centre, which divides the 17 SDGs into 8 biosphere goals, 4 social goals, and 4 economic goals, with the 17th goal – Partnerships – providing an axis that connects them all (Folke et al. 2016). See Figure 3.6.2.

It is ironic that in English humans and nature remain separated by language. We use the term 'social-ecological system', yet there is no easy way to describe the unity and interconnectedness of the whole. People and nature remain separated, if only by a hyphen. There are better terms – Lovelock's 'Gaia', *vanua* in Fiji, the *aski* of the Indigenous Cree people in northeast Canada – that describe concepts of place comprising living landscape and ocean, humans, animals, and spiritual beings (Ommer and Castleden 2014; Lovelock 1989). Sustainability practitioners should understand the nature of the planetary social-ecological system and work in ways to support and enhance its integrity, resilience, and well-being at all levels and in all components (Steffen et al. 2011; Folke et al. 2011). Humans have become harmful to the planet – to Gaia – and must change to be genuine

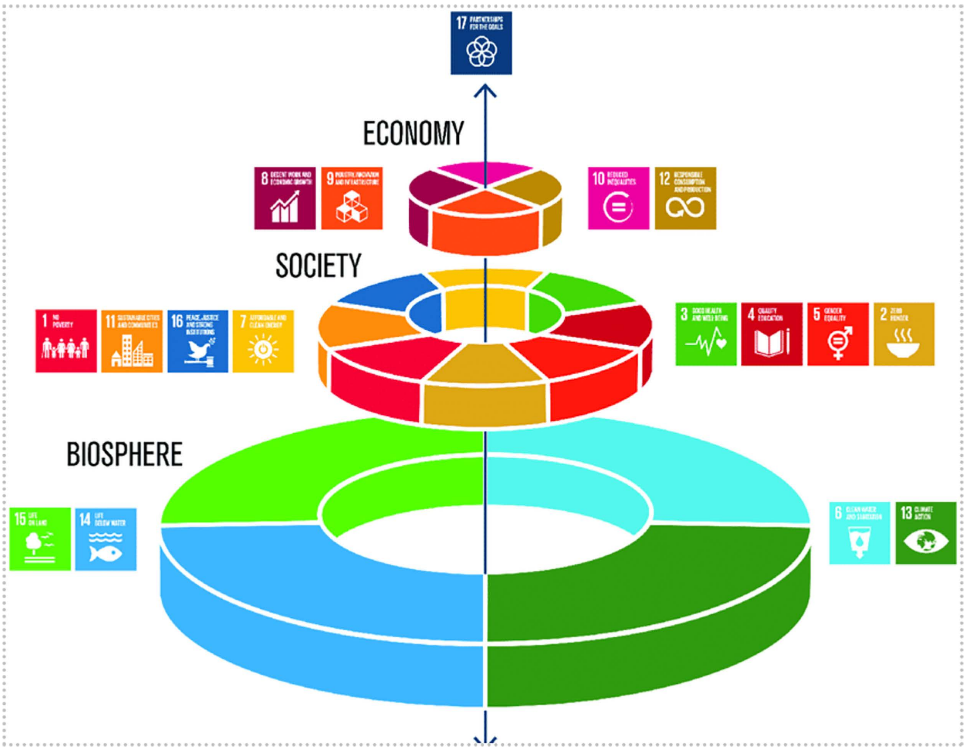

Figure 3.6.2 The 17 Sustainable Development Goals positioned in relation to the biosphere foundation and the safe operating space for humans on Earth.

Credit: Presented at the 2016 EAT Forum and published in Folke et al. 2016. Azote for Stockholm Resilience Centre, Stockholm University CC BY-ND 3.0. See https://www.stockholmresilience.org/research/research-news/2016-06-14-the-sdgs-wedding-cake.html.

stewards and work to restore its ecological well-being. The alternative is that our capacity to continue as a coherent civilisation will fail (Kemp et al. 2022; Rockström et al. 2009; Thomas 2021).

Systems thinking is a fundamental competency for sustainability practitioners. It is however only one part of a larger skill set that all sustainability education programs should develop. In addition to a systems thinking capability, sustainability practitioners should have advanced competencies in anticipatory thinking (or foresight), normative awareness (meaning the ability to understand different worldviews and perspectives across cultural, linguistic, gender, religious, disciplinary, and other divides), and strategic analysis and planning. Finally, sustainability practitioners should also have strong interpersonal skills and the ability to work collaboratively in diverse settings and structures (Wiek et al. 2011).

To explain these different competencies and how they apply to the work of sustainability practitioners, let us consider the framework shown in Figure 3.6.3 (cf. Talberg et al. 2018). This involves six steps.

1. ***Describe*** the current situation. What are the system components, actors, and factors? What is the state of the system now?
2. ***Forecast*** probable future scenarios. How will the current situation develop and evolve? What will the future look like in this case? This results in . . .
3. ***Anticipatory*** analysis.
4. Explore ***normative*** alternatives. What future states might be desirable or attractive to different stakeholder groups? Build consensus with different stakeholders.
5. Conduct a ***backcasting*** exercise. Begin with the desired future scenario, then identify what necessary precursor or prerequisite would come immediately before that. Repeat back through time until the present is reached.
6. Implement interventions to shift the anticipated business-as-usual scenario towards the preferred normative future. This is the work of ***transformation*** (Westley et al. 2011; Bennett et al. 2019).

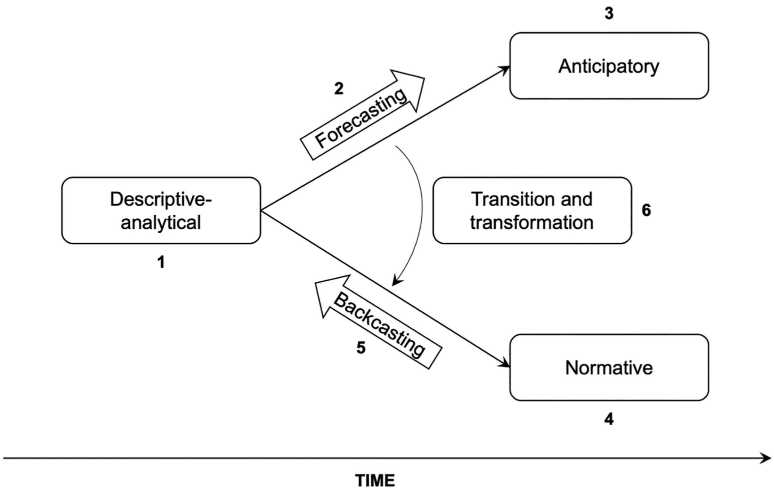

Figure 3.6.3 Sustainability science process adapted from Talberg et al. 2018.

This process requires the full toolkit of sustainability science and practice: systems thinking, anticipatory and normative capabilities, strategic skills, and the ability to work collaboratively, productively, and equitably with a diverse range of stakeholders.

Transdisciplinarity

Disciplinary thinking is a powerful tool for specialisation and developing expertise, but it can be the case that different disciplines apply not only specific skills, jargon, and tools but distinct assumptions and mental models as well. Specialisation can make it difficult to collaborate with others who use different vocabulary or worldviews. An ecologist and a forester may look at the same forest and see different things. For the ecologist, the forest may be the source of fresh water and pollination services for the local community; for the forester, the forest may be the source of jobs and building materials if it is logged. They can both be correct but require different outcomes (see Chapter 7.4 in this volume).

It is useful to distinguish between multi-, inter-, and transdisciplinary approaches (see Chapter 3.4 in this volume) to research and practice. Multidisciplinary work involves experts in different fields separately addressing the same problem using their own tools and methods (Max-Neef 2005). For instance, an engineer, a lawyer, and biologist are all tasked with building a new bridge. The engineer measures the width of the river and calculates the structural load-bearing capacity of the ground on each side. The lawyer investigates planning laws and community consultation requirements. The biologist conducts an environmental impact assessment to determine what species might be affected by the work and new infrastructure. They each come to different conclusions about the costs and benefits of the project.

An interdisciplinary project would bring these experts together in a coordinated effort. An expert in planning provides project oversight and combines the findings into a joint report with sections representing each component and a summative conclusion.

Transdisciplinarity is different. To begin with, transdisciplinary projects do not start with the objective; they establish a shared and common goal between all stakeholders, including experts from different disciplines and – importantly – community groups, traditional owners from Indigenous or First Nations peoples, industry associations, civil society organisations, and others (Angelstam et al. 2013; Schaltegger et al. 2013). The problems a project should address, the questions to be asked, and the methods to be applied are decided in a collaborative process involving everyone (Thomas et al. 2018). Working in this way also means that participants in the process will have full ownership of the activities and outcomes of any project, and all stakeholders will somehow be changed through the work (Brandt et al. 2013).

Transdisciplinarity requires that several important questions drive project conceptualisation, design, and implementation:

- Who should be involved in research, in designing policies, and in making decisions?
- Have Indigenous and First Nations peoples been involved from the beginning? Do they have agency and ownership of project design and deliverables? What other cultural, linguistic, disability-based, or other groups might be affected or marginalised by the project, and how are they being included? It is here that the principle of 'Nothing about us without us' must apply ((see Chapters 5.6 and 7.6 in this volume) *et al.*, in this volume).

- What is expertise? Does the project recognise that local, traditional, and Indigenous knowledges are all important and relevant types of science?
- What disciplines can and should be involved, and how can they be coordinated and integrated? How can the project establish a common language and collaborative process that harnesses and balances different academic and technical expertise, community knowledge and leadership, practitioner skills and resources, and other organisational tools and perspectives?

Transdisciplinary methods should be applied by sustainability practitioners as they engage in the transformation processes described previously. Let us now consider the nature of the transitions with which sustainability practitioners must engage.

The transition from past to future

The world is in a time of extraordinary change and upheaval, with unprecedented disruptions resulting from rapid technological development, extreme and accelerating environmental crisis, and high-stakes political contests. The nature and role of business are changing, and organisations and governments must find new ways to address social and environmental priorities while building economic and cultural value (Sullivan et al. 2018) (see Chapters 4.5 and 8.4 in this volume).

The convergence of digital, mechanical, and biological technologies provides extraordinary new opportunities for innovation. Robotics, advanced computing, internet connectivity, bio- and nanotechnology, machine learning, and decentralisation are among the 21st-century tools that are changing how we live, work, and trade (Betz et al. 2019; Hartley et al. 2019). This period is referred to as the fourth industrial revolution – a time of rapid and significant social and technical change across industries including manufacturing, energy, finance, transport, textiles, healthcare, real estate, and security (Morrar et al. 2017; Dean and Spoehr 2018) (see Section 3, Korevaar, in this volume). This type of systemic change is described as a socio-technical transition and can be usefully understood using the multilevel perspective (MLP) (Geels and Schot 2007; Geels 2012; Köhler et al. 2019).

The MLP is a powerful conceptual tool for understanding and describing shifts in complex societal systems driven by the evolution of technologies. These transitions are increasingly focused on sustainability, and the work of sustainability science is moving from understanding socio-technical transitions to steering and managing them, as discussed earlier in this chapter. The basic premise of the MLP is that socio-technical transitions occur as a result of the interactions between three key levels of a socio-economic architecture, each level being defined according to different configurations of power, dynamism, and stability.

The highest level in this conceptual framework is the *landscape*, the larger environmental, social, and economic context that includes material resources, technical processes and capabilities, demographics, and macro-economic structures. A nation, region, or industry sector could be assessed as the landscape level in MLP analysis.

The *regime* level is the configuration of dominant actors and their associated interests. The regime is stable and operates according to standard practices and established rules. Power is held by recognised incumbents. An example of the regime level would be a national electricity market, or a regional trade agreement, or a group of incumbent companies that share production and distribution of a particular resource.

Niches are the micro level of the MLP where innovation occurs, where radical and disruptive technologies appear to challenge the existing processes, technologies, or structures of the regime. An example of a niche in the MLP would be a new technology such as rooftop solar photovoltaics, a blockchain platform for trading, or a new approach to service delivery like Airbnb or Uber.

For transitions to occur, change must happen in all three levels of the MLP at the same time. Niche innovations and landscape-level pressures must simultaneously create pressure on the regime, destabilising it so that there are opportunities for niches to enter. As this diffusion takes place, technological path dependencies are challenged and the socio-technical system can be transformed.

The MLP is described in Figure 3.6.4.

Climate change presents material risks for all sectors, including primary producers, resource companies, energy suppliers and distributors, transport, tourism, finance and investment, and governments (Walenta 2020). The costs of climate-driven extreme events are significant, but the regulatory landscape is also changing rapidly, presenting 'transition risks' that demand extensive work in identifying, assessing, and reporting asset exposures and climate-related impacts on business performance (Fiedler et al. 2021). The existing socio-technical regime comprising fossil fuel–based energy generation and transport is facing all these pressures from the macro-level landscape. At the same time, change is being

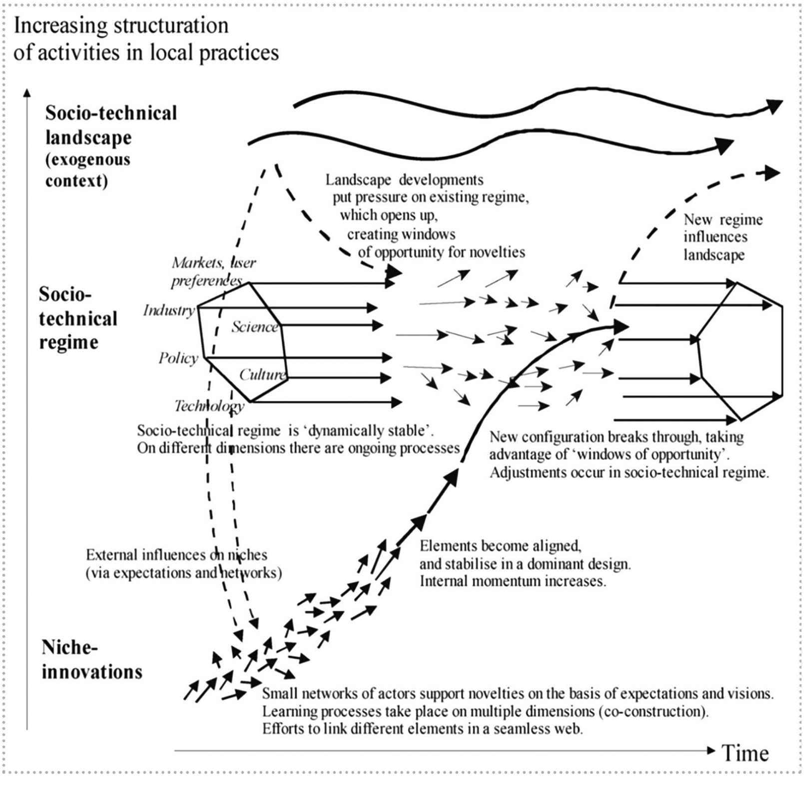

Figure 3.6.4 The multilevel perspective on socio-technical transition from Geels and Schot 2007.

driven by niche innovations in renewable energy generation, consumer behaviour (in the form of virtual power plants, for instance), and even community movements supporting independent political candidates focused on climate action (Brummer 2018; Asmus 2010; Hornsey et al. 2022).

While governments work to establish effective regulatory parameters, the private sector must proactively and ambitiously find ways to decarbonise investment portfolios and establish new metrics of value creation and financial performance (Breitinger et al. 2019). Board directors increasingly understand the diversity and seriousness of the risks posed by global heating and over the last decade have consistently rated climate change, extreme weather, and the failure to act on climate change as the most severe global risks in the next ten years (World Economic Forum 2022). A socio-technical transition is underway across all sectors of society.

Decarbonisation, environmental change, and social dynamics are not only risks but also opportunities (King 2016; Thomas 2014; Fine et al. 2020). Further impacts of climate change are inevitable, but this means strong returns on investment in climate solutions are also expected. Global capital is now mobilising at an unprecedented rate to develop sustainable finance taxonomies, invest in climate solutions including renewable energy and natural capital, and reap the benefits of circular economy practices. Carbon markets are growing rapidly as a key tool of the transition to net zero and beyond (Donofrio et al. 2021; Thomas 2021). Finance is also being steered into wider sustainability goals as business and industry increasingly recognise the linkages between environmental health, social well-being, and economic prosperity (Langley et al. 2021).

There is a substantial momentum toward the opportunities of this sustainable future society and economy, but the transition must be constantly accelerated.

Regenerative sustainability and climate action

It is said that there are two kinds of people: those who see a glass of water as half empty and those who see it as half full. This is a simple description of two different ways of thinking about the world. Seeing a glass as half empty can be described as *deficit thinking*, a focus on what is absent, on how a situation is lacking or incomplete. Seeing a glass half full, in contrast, is *abundance thinking*, a positive focus on what is present, what is available, and what opportunities exist.

Thinking in absolutes is problematic –the world is nuanced, complex, and relational – yet these two ways of describing and understanding situations offer useful insights for sustainability science and education.

Sustainability is a wide and diverse concept but can be interpreted through either lens – as ***deficit*** or ***abundance***. Most often, however, mainstream sustainability thinking takes the deficit approach. In this sense, sustainability is about being ‘less bad’, reducing environmental impacts or financial losses, minimising negative outcomes. An example from climate change discourse is the concept of net-zero emissions. Global warming is driven by the increasing volume of greenhouse gases that trap solar radiation as heat in the atmosphere. These greenhouse gases are released when fossil energy sources such as coal and oil are burned to generate power. Land clearing, agriculture, industrial chemicals, and other human activities also contribute. The net-zero concept means that greenhouse gas emissions from these sources should be reduced as much as possible, but where they cannot be eliminated, they can be offset by removing greenhouse gases from the atmosphere by growing trees or other means.

A fundamental issue with this idea is that a net-zero target does not address the causes of global warming: greenhouse gas emissions. Rather, a net-zero target assumes the problem is perpetual and can only be solved by offsetting the harms it creates – offsets will be needed forever. We become less bad as much as possible, and then do extra good elsewhere to balance things out.

An abundance view of global warming would take a different approach. Here, the problem would be understood as an unintended consequence of a previous, and incredibly successful, solution. At the beginning of the first industrial revolution, fossil fuels provided a clean, green alternative to existing systems. At the beginning of the 19th century in London, foul-smelling manure clogged streets travelled by horse-drawn carts and carriages, making walking and commuting most unpleasant indeed. An entire profession – street sweepers – became redundant as horses were replaced by diesel-, petrol-, and steam-driven engines. Fossil fuels brought prosperity, unprecedented economic growth, technological innovations, and improved hygiene and public health.

Centuries later the impacts of fossil fuel use are more fully understood, and there is a clear need for transition to cleaner forms of energy. Yet an abundance worldview would suggest that we not abandon everything of the past, but keep what is necessary, inevitable, and good. For example, to build the infrastructure of a sustainable future requires steel and until we have industrial alternatives this means metallurgical coal. Oil-derived plastics can make remarkable products that last for centuries yet we frequently treat them as single-use items.

What happens once we have become less bad? Net zero is not a target but a milestone. After net zero we must reach true zero, and from there become climate friendly, or carbon positive. In other words, we must repair historical damage by drawing carbon out of the atmosphere, and in doing so establish a new worldview that is focused not on harm mitigation (deficit thinking) or efficiency and utility (abundance thinking), but on comprehensive value creation – on building thriving systems that function without constant additions of new energy sources, other than the natural supply of energy from the sun. This would require a ***regenerative*** view of the world.

Recognising that net zero is a milestone and not simply a target, Figure 3.6.5 shows the science-based conceptual approach for decarbonisation beyond net zero, to true zero, and then to a climate-positive position. This emissions curve is overlaid across a trajectory of conceptual sustainability positions, from a deficit perspective to a regenerative view.

Discourses of deficit and scarcity in sustainability theory have been criticised as being uninspiring and thus unlikely to compel action, limited in ability to counteract harmful trends and avert disastrous outcomes, and overly focused on biological limits and carrying capacity to the detriment of social and developmental priorities (Robinson and Cole 2015). In contrast, regenerative sustainability theory seeks new and alternative worldviews to guide the transition to an existential model that does not degrade and destroy the natural capital on which human civilisation depends (Mang and Reed 2012). Regenerative sustainability has been born from disciplines including ecology and systems thinking and applied in fields from design and architecture to urban planning, economics, information theory, medicine, and agriculture (Robinson and Cole 2015; Schreefel et al. 2020; Elkington 2020; Mang and Reed 2020; Fath et al. 2019; Karbassi et al. 2020).

Regenerative sustainability can be defined as a conceptual position that embraces the logics of ecological thinking to build healthy, self-sustaining social-environmental systems. Regenerative approaches enhance the ability of living beings to evolve together and continue to express their potential for complexity, diversity, and creativity (Mang and Reed 2020).

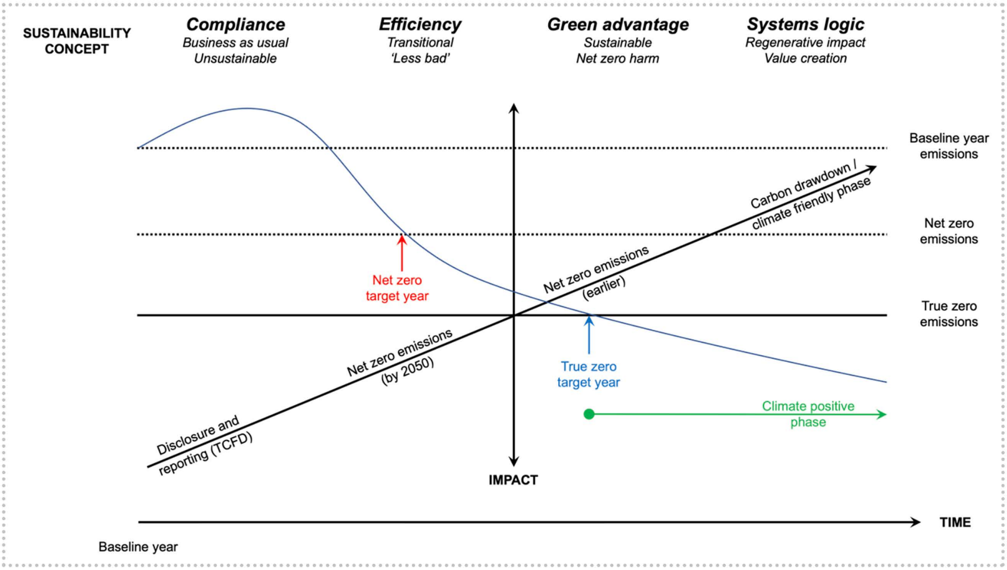

Figure 3.6.5 Beyond net zero to a regenerative view of the climate.

Regenerative thinking means stewardship of ecosystems and communities to optimise health, well-being, opportunity, and productivity. Regenerative approaches also seek to restore damage and degradation, whether environmental, social, economic, or cultural. Recognition and restoration of Indigenous science, cultural practices, and environmental management systems is a key example of the regenerative paradigm (Fischer et al. 2022; Ayre and Mackenzie 2013; Sangha et al. 2019; and (see Chapters 7.6 and 7.7 in this volume)).

A practical mainstream example of regenerative management is the use of natural and constructed wetlands to filter wastewater and recycle chemical nutrients such as nitrogen and phosphorus (Mitsch and Day 2004; Vymazal et al. 2006). Expanding implementation of this type of natural systems engineering offers an opportunity to restore degraded rivers and larger systems, providing nutrient cycling, habitat, improved biodiversity, micro-climate regulation, and other critical services such as food provision and pollination (Mitsch and Day 2004; Thorslund et al. 2017). The same thinking can be applied in agriculture, when objectives (such as improving soil quality) and associated activities (such as the use of perennials) will result in better soil health, improved resource management, climate change mitigation, better nutrient cycling, enhanced water quality and availability, greater food security, and even improved human health and economic prosperity (Schreefel et al. 2020).

In built environments regenerative approaches require safe and non-toxic materials, re-use or recycling, renewable energy and carbon management, water stewardship, and social justice (Attia 2018). Natural light is harnessed effectively, insulation is key to managing heating and cooling, green walls provide contact with nature and air quality, indoor and outdoor spaces provide for physical and social activities and well-being, and building products can be sourced locally from natural materials such as straw, clay, and loam (Hes and du Plessis 2014; Attia 2018).

A comprehensive example of regenerative practice is the Indigenous savanna burning methods applied within Australia's emissions reduction and carbon farming policy framework. First Nations Aboriginal Australians have been managing the country using fire for millennia (Russell-Smith et al. 2013). This involves small burns of forest and savanna detritus during cooler months to reduce fuel loads during the hot seasons. This practice was suppressed during the colonial period, but has been revitalised as part of the national carbon farming market (Russell-Smith et al. 2013, 2015). Avoided emissions resulting from savanna burning generate carbon offset credits that are sold at premium prices into the national carbon market. Savanna burning projects have created high-status jobs and livelihoods and brought new incomes to many remote communities that have had little economic opportunity in the past. Restoration of these vital practices has restored cultural traditions and pride, and Indigenous Australians have seen additional environmental and social outcomes – as well as economic and cultural ones – that can be considered 'core benefits' rather than simply 'co-benefits' to the carbon emissions mitigation (McMurray et al. 2019).

Deficit and sufficiency thinking both reflect a traditional understanding of the world that is ***mechanistic***, functional, and reductionist. This view assumes that systems can be divided into separate components and that productivity is a result of the sum of these parts. The behaviour of people, natural environments, and societies is predictable because it is governed by universal laws, and changes in the system are the result of external phenomena that can be understood through objective empirical analysis. Mechanistic thinking is fundamental to the natural philosophy of Descartes and the behavioural psychology of B.F. Skinner, among other disciplines and theorists.

Through the course of the 19th century the consensus among contemporary scientists was that the universe was – generally speaking, by and large, and with some minor matters to be resolved at the edges of knowledge – understood. Building on the heretical revelations of Galileo's astronomy, Newtonian physics provided an empirically robust and mathematically described model of the cosmos. The Earth and other planets orbited a star that was one of millions in space. Moons orbited planets, comets travelled their own unique paths, and the Milky Way galaxy was the full extent of the universe, several thousand light-years across. Celestial bodies moved in a vast and majestic dance governed by the laws of gravity and motion. An unproven but important assumption was the existence of the 'luminiferous aether', a hypothetical medium through which light travelled.

By the turn of the 20th century, however, tensions were growing within the scientific consensus. The investigation of electromagnetism, the failure of experiments seeking to demonstrate the existence of the aether, and other problems arising in the standard model of physics led to the 1905 publication of Einstein's paper proposing special relativity, a scientific theory about the relationship between space and time. This – and many other remarkable advances in scientific fields – shook the scientific establishment, thoroughly disrupting the mechanistic view. It became clear that things were much more uncertain than had previously been understood, and the way opened for new ideas to enter the mainstream – or at least the dominant Western perspective.

In contrast to the mechanistic worldview, which describes people as automata that act in response to external stimuli, ***organismic*** perspectives see humans as living organisms making considered choices with a focus on the future. A ***contextual*** worldview defines individuals in terms of the environments and events that structure daily experiences. Both underpin the paradigm of regenerative thinking, in which humans are understood as part of the planetary social-ecological system discussed earlier, a complex web of interactions between Earth systems – geological, cryological, hydrological, biological, atmospheric, and ecological – and historical, social, cultural, and political processes. We are not separate from the world, but part of it. We are not at the top of an environmental ladder, but enmeshed in an ecological web. We do not govern nature, but rely on it for our existence and affect it through our actions.

Machines can be built and operated; they can break down and be repaired. They require fuel and produce waste. A garden, in contrast, can be tended or neglected, but unlike a machine, a garden will grow and flourish with its internal energy sources and the natural input of sunlight, eventually achieving a stable state. The relationships in a garden exceed those in a machine by orders of magnitude. The world is not a machine, but a garden, and we are not engineers, but both ants and caretakers. This is the worldview of regenerative sustainability.

Conclusion

As we have begun to re-imagine the world in these social-ecological terms, we have been able to recast our own roles. Machines need maintenance and repair, which require technicians and engineers. Gardens, however, must be tended, and so the role of humankind becomes one of stewardship and care.

Recognising the negative impacts of many human activities on natural and social systems has led us to think of sustainability as reducing negative impacts until we achieve a state of causing no harm. Yet damage has already been done, so restoration is in order. As we move from a mechanistic and utilitarian view to an ecological one and go beyond being sustainable to being regenerative, the argument is that our understanding evolves as well. From a human-centred perspective to a biocentric view, and from there to an integrated and holistic understanding of humans and nature as part of a single whole (Schreefel et al. 2020; Mang and Reed 2020).

These are not new ideas. As noted earlier, many Indigenous cultures demonstrate stewardship rather than dominance of social-ecological systems. Notwithstanding the possibility that they have caused the extinctions of some animal species, Indigenous peoples have been sustainably managing terrestrial and marine estates for millennia, yet the rapid changes of the Anthropocene era are challenging traditional management protocols. Western science is well placed to assist in addressing modern-day sustainability questions yet often lacks the holistic understanding of the environment that Indigenous science and traditional knowledge provide.

Sustainability practitioners require a future-oriented repertoire of conceptual tools that include systems thinking, transdisciplinary approaches, and a focus on transition. Embedded in a regenerative paradigm of environmental, social, and economic practices, this repertoire will empower practitioners to address the legacies of negative historical impacts, build on established processes of value creation, and transform communities, organisations, and environments into more thriving and resilient systems. It is the role of these practitioners to not simply help us become less bad, but to create thriving, just, and equitable futures for all people and our natural world.

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3.7
BEYOND JARGON
The language of sustainability

Joseli Macedo

Key concepts for sustainability education

- The concepts of ecological footprint, eco-design, and biomimicry have become paramount for sustainability education.
- These concepts help students understand, and in some cases visualize, the true impact of human activity on Earth and the consequences of unbridled growth.
- Other concepts include life cycle analysis and low-impact design, which allow us to better plan and design our environments whilst evaluating impact holistically.
- Whilst biomimicry considers nature at a more molecular level, entire natural systems are now being used as design inspiration.

Introduction

"Earth provides enough to satisfy every man's need but not every man's greed."
–*Mahatma Gandhi*

The way we talk about sustainability, the words we use to communicate the status of the planet, and consequently, the language we use in sustainability education are all relatively new. In the 1960s and 1970s there was a surge of environmentalism, but it was not until the late 1980s that "sustainability" entered the imaginary of most people once the global conversation turned towards sustainable development. Since then, there have been three iterations of United Nations Conferences (Rio '92, Rio +10, Rio +20) and two versions of global goals (Millennium Development Goals [MDGs] and Sustainable Development Goals [SDGs]) that should help us achieve the still elusive state of sustainable development. Sustainability today is an issue of public concern.

During this trajectory, several concepts, approaches, methods, and strategies have been created, tested, and implemented, and it has become important to understand them. Some of them are outlined in this chapter with the intention of giving educators a baseline for teaching sustainability, policy makers an understanding of their meaning and broader impact, and students a springboard for their further studies.

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Ecological footprint

The concept of ecological footprint is related to that of urban metabolism, which approaches the city as an organism, taking in resources and discharging wastes (Wolman 1965). Initially developed as a planning tool to "help to translate sustainability concerns into public action" (Wackernagel and Rees 1996, 3), ecological footprint analysis is "about humanity's continuing dependence on nature and what we can do to secure Earth's capacity to support a humane existence for all in the future" (Wackernagel and Rees 1996, 3). Despite early warnings, the world's carrying capacity has now been exceeded (Wackernagel et al. 2002); the global ecological footprint crossed the sustainable threshold of production of resources around 1980 when the world's population was 4.5 billion (Figure 3.7.1).

Wackernagel and Rees (1996) first developed the methodology to calculate humanity's ecological footprint with the intent to understand our ecological constraints on the planet. It attempts to assess the environmental impact of development on the Earth by quantifying resource consumption and calculating the amount of productive land and aquatic ecosystems necessary to satisfy human demand and absorb the wastes released into the environment. The "footprint" is expressed as the number of hectares needed to supply the environmental resources and ecosystem services demanded to fully sustain each individual (or city) indefinitely. It helps us understand the biophysical reality that our planet is finite and debunks the false paradigm of continuous and ever-expanding economic growth (Todaro 1989).

The ecological footprint analysis spurred the creation of several tools to estimate not only the size of various footprints but also the biocapacity of various places. To achieve sustainability, an individual (or city, or country) needs to keep its ecological footprint at or below its biocapacity, which is "the capacity of a given biologically productive area to generate a supply of renewable resources and to absorb its wastes" (World Population Review 2021). While the footprint represents the demand side, biocapacity represents the supply side. Biocapacity "represents the productivity of its ecological assets (including cropland,

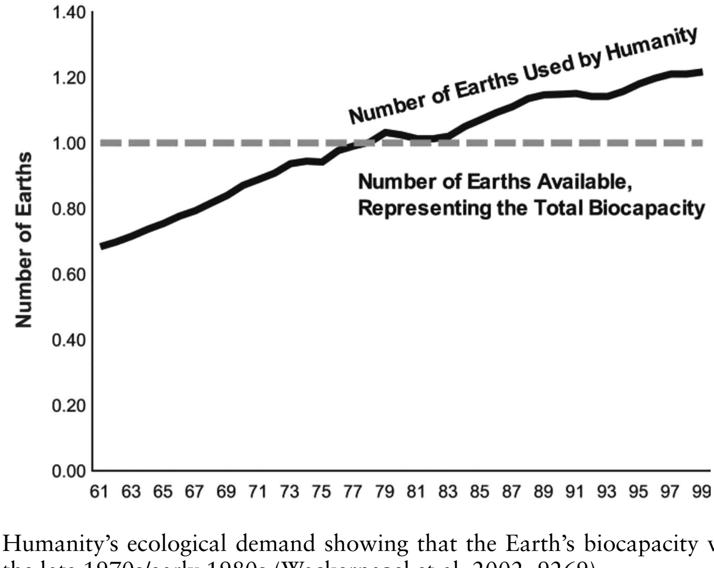


Figure 3.7.1 Humanity's ecological demand showing that the Earth's biocapacity was overshot in the late 1970s/early 1980s (Wackernagel et al. 2002, 9269).

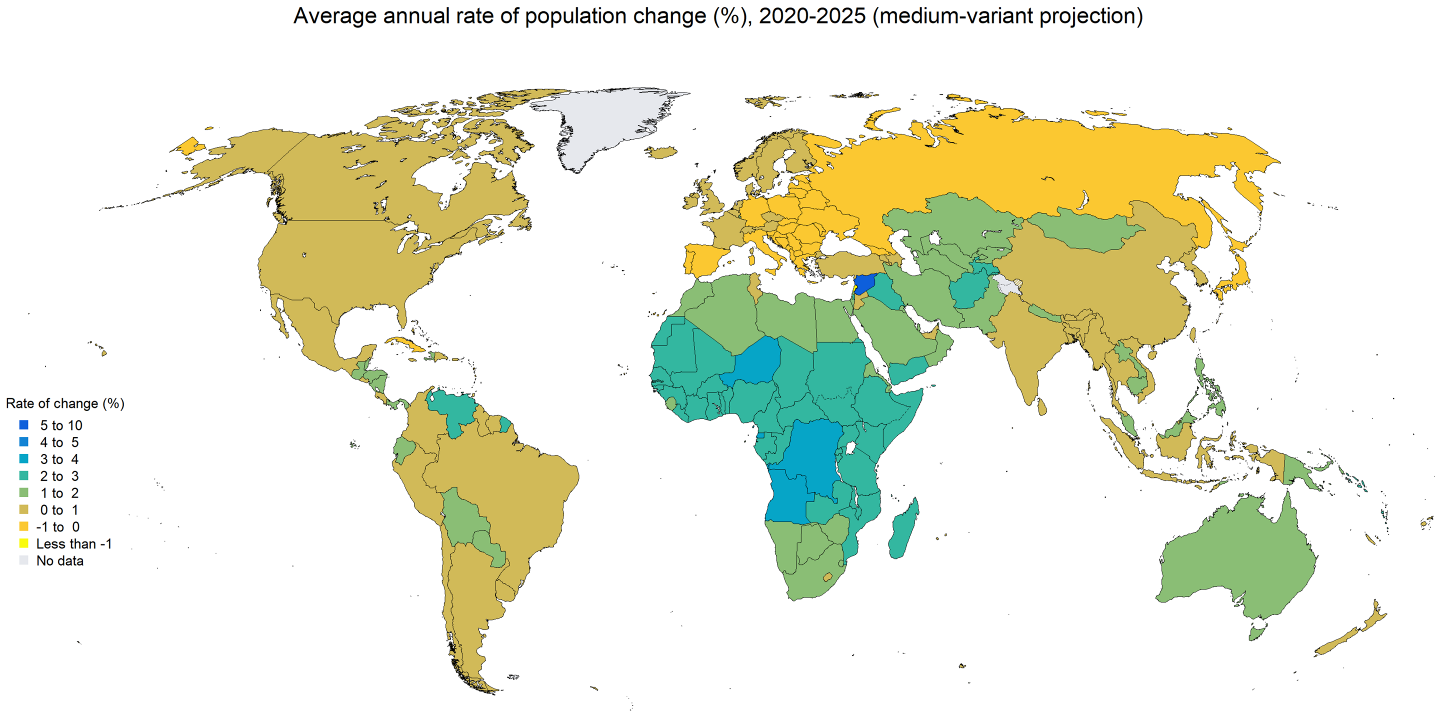
grazing land, forest land, fishing grounds, and built-up land). These areas, especially if left unharvested, can also serve to absorb the waste we generate, especially our carbon emissions from burning fossil fuel" (Global Footprint Network 2021).

With the popularization of the concept of ecological footprint, numerous tools emerged to calculate it. Examples of these ecological footprint calculators can be found on websites of several organizations, such as the Global Footprint Network, and are accessible to anyone interested in investigating the balance of supply and demand on natural resources. Some of them can be found on these websites: http://www.footprintcalculator.org; https://www.footprintnetwork.org/resources/footprint-calculator; https://footprint.wwf.org.uk. The Global Footprint Network has an open dataset that can be accessed at https://data.footprintnetwork.org and that tracks the footprints and biocapacity of every country, with more than 200,000 data points being tracked since 1961.

These calculations allow us to appreciate how different ecological footprints can be across the globe. For example, when comparing estimates between developed countries and developing countries, we realize that a North American city of 650,000 people needs about 30,000 square kilometres to satisfy its needs, whilst an Indian city of similar size would only require 2,800 square kilometres (GDRC n.d.). In addition, the geographical area of countries and the population distribution within them have a significant impact on the calculations for entire countries; the total land area and where the majority of the country's population is concentrated may completely alter local and regional results.

To wit, Australia and Canada both have "ecological reserves," that is, their ecological footprints do not exceed the biocapacity of the country. Evidently, a national average, particularly in countries with large land areas and small populations, could be misleading. The ecological footprints of urban areas in Australia and Canada extend far into unpopulated areas. According to World Population Review (2021), Australia's current per capita ecological footprint is 9.31 hectares. With a total area of 7,682,300 km^2 and a 2021 population of 25,788,215, Australia has a positive ecological reserve (biocapacity deficit) of 167.34 as a whole; however, the ecological footprint of its largest cities, Sydney and Melbourne, each with more than 4 million inhabitants, extends far beyond their respective geographical areas. Canada's current per capita ecological footprint is 8.17 hectares. With a total area of 9,093,510 km^2 and a 2021 population of 38,067,903, Canada also has a positive ecological reserve (biocapacity deficit) of 272.80. Like Australia, though, Canada's largest cities, Toronto with more than 5 million inhabitants and Montreal with more than 3.5 million, have a much larger ecological footprint than the average for the entire country.

The United States sits right between Australia and Canada with a per capita ecological footprint of 8.22 (World Population Review 2021); however, with a population one order of magnitude larger than that of those two countries (332,915,073), the United States has a negative ecological reserve (biocapacity deficit) of –1,416.05 despite the fact that its population leads similar lifestyles and has consumption patterns similar to those of Australian and Canadian populations. California is the only state in the United States whose ecological footprint approximates that of European countries, most of which have ecological footprints half as large as those of Australia, Canada, and the United States (World Population Review 2021). Spain's ecological footprint, for example, is 3.67 and Italy's 4.61, while the United Kingdom's approximates that of the United States at 7.93. The European outlier, and the country with the largest ecological footprint in the world, is Luxembourg with a per capita ecological footprint of 15.82. Not surprisingly, developing countries of the Global South have the smallest per capita ecological footprints (Figure 3.7.2). There are 15



Data source: United Nations, DESA, Population Division. *World Population Prospects 2019*. http://population.un.org/wpp/

The designations employed and the presentation of material on this map do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. Final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined. A dispute exists between the Governments of Argentina and the United Kingdom of Great Britain and Northern Ireland concerning sovereignty over the Falkland Islands (Malvinas).

Figure 3.7.2 Average annual rate of population change showing that more industrialized regions have lower population growth than less industrialized regions (UN 2019. Available at https://population.un.org/wpp/Maps/.

countries with a per capita ecological footprint smaller than 1.00, most of them in Africa; the smallest per capita ecological footprints in the world belong to Timor Leste and Eritrea, 0.48 and 0.49, respectively.

The ecological footprint of some cities surpasses the entire area of the country where they are located. For example, London's ecological footprint is equivalent to an area twice the size of Britain (Girardet 2004), and Tokyo's is almost three times the land area of Japan as a whole (GDRC n.d.). Evidently, ecological footprints are closely related to lifestyles and levels of consumption; thus, if all human beings had the same lifestyle as Londoners, three planets would be necessary to meet the demand for resources (Girardet 2004). Because cities are densely populated, they tend to generate the largest ecological footprints; nonetheless, city form is a decisive factor on how large a city's ecological footprint will be. For example, it is estimated that urbanites have one-third of the carbon footprint of suburbanites, and carbon is the largest contributor to ecological footprints. As large consumers of resources, cities can contribute to mitigating the impact of their needs and to reducing their ecological footprints by adopting circular resource flows and using the resources they consume more efficiently. Several cities are taking action to decrease their ecological footprint by restoring and maintaining the biological diversity of their ecosystems, protecting water resources, and weaving natural spaces through their urban fabric. The ultimate goal is to allow urbanization to occur whilst protecting the environment and profiting from the ecosystem services offered by nature.

Eco-design

Eco-design, the 21st-century version of ecological design, is defined somewhat differently by each of the design disciplines that use the term. In architecture, it is the design of buildings that use materials and techniques with minimal environmental impact both in construction and deconstruction. In urban planning, it is the design of infrastructure and other features of the built environment based on urban metabolism and low-impact development principles. In landscape architecture, it is the design of the built environment, including landscapes and hardscapes, grounded on natural systems and environmental protection principles. In industrial design, it is the design of products using raw materials from renewable resources and recycled materials that can be manufactured by low-impact processes. Regardless of discipline, it is an approach that impacts the entire life cycle of a product, building, or entire city and that supports circular economies. Other names for eco-design that espouse the same principles include ecological design, green design, smart growth, ecological urbanism, and sustainable development.

Ecological design has been defined as "the capacity to understand the ecological context in which humans live, to recognize limits, and to get the scale of things right. It is the ability to calibrate human purposes and natural constraints and do so with grace and economy" (Orr 1994, 2). In their seminal book, *Ecological Design*, Sim Van der Ryn and Stuart Cowan define ecological design as "any form of design that minimizes environmental destructive impacts by integrating itself with living processes" (1996, 33). They further simplify the concept as "the effective *adaptation to* and *integration with* nature's processes" (Van der Ryn and Cowan 1996, 34). Eco-design is a relatively new label; however, the concepts embedded into it have been around for a while. Its foundation dates back to the late 19th century, when naturalists and visionary stewards of the environment wrote about the importance of conservation, among them George Perkins Marsh (1864) and Frederick Law

Olmsted (1870). Marsh was concerned about the degradation of landscapes and framed their restoration as social responsibility. In the early 20th century, Aldo Leopold (1987) initiated his lifelong quest for an ecological ethic. Several authors and scholars since then have pursued a more ecological and ethical approach to design and planning.

Another ecological approach that usually takes place in parallel to ecological design is ecological planning, defined as “the use of biophysical and sociocultural information to suggest opportunities and constraints for decision making about the use of the landscape” (Steiner 2008, 9). Most characteristics of physical environments have a related ecological aspect; thus most planning decisions have ecological consequences. Ian McHarg (1969), in his seminal book *Design with Nature*, outlined cooperation paths for human and ecological partnerships, suggesting that design principles can be applied purposefully, using natural conditions as the basic foundation for development plans and, in this way, embracing nature to create landscapes that are modified by men within limits. McHarg’s ecological planning method emphasized resource inventory, environmental analysis, and synthesis. In light of values brought to the fore by sustainable development, subsequent models took ecological planning a step further, creating more holistic and comprehensive methods that incorporate values and choices, involving citizens in impacted communities, and including administration and implementation into the whole of the plan (Steiner 2008).

Because eco-design is intrinsically multidisciplinary, it has to be taught through an interdisciplinary approach, integrating broader principles, and should be incorporated into general curricula. Institutions of education themselves could contribute by “leading by example,” an aspect of sustainability education discussed later in this sub-chapter.

Biomimicry

Biomimicry is a term that was coined in the late 1990s by Janine M. Benyus. In her seminal book by the same title, she defines biomimicry as “the conscious emulation of life’s genius. Innovation inspired by nature” (Benyus 1997, 2). In more detailed definitions outlined in the preamble to the book, she defines biomimicry within three different frameworks of nature: nature as model, nature as measure, and nature as mentor. Underlying all of these is a concept of conservation, a principle of echoing nature and working *with* nature, similar to McHarg’s (1969) mentioned earlier, rather than extracting from it and potentially destroying it.

Earlier in this sub-chapter, an explanation of ecological footprints made it clear that biocapacity needs to be increased so that cities and countries can decrease their ecological footprint. There is great potential to aid in that effort beyond the creation of circular economies, namely emerging technologies focusing on mimicking biological processes. One such example is the creation of “Sponge Cities” in China (Hansen and Macedo 2021). This concept mimics natural processes and works with nature to create built environments where urban infrastructure contributes to natural restoration of ecosystems instead of trying to control them.

To learn from nature and be able to mimic its processes to our advantage, we need to feel an affinity with it. This affinity has been described as being innate, and it is known as biophilia (Wilson 1984). In his seminal book thus titled, Wilson states that humans have “the urge to affiliate with other forms of life” (1984, 85) and questions humanity’s ability to love life enough to save it. Since this concept was put forth, several scholars have considered it in relation to design and planning (Kellert and Wilson 1993; Kellert et al. 2008; Beatley 2011) and also other disciplines. In fact, Orr (1994) argues that biophilia needs to underlie not only the way we do science but also how we train the next generation. Thus, incorporating biophilic principles and biomimicry as an innovation strategy into our curricula is a necessary step. Developing the knowledge and ability to work with nature will prepare our students for the challenges ahead; it should be ingrained in them that nature is something to be intimate with, not to dominate and conquer. For students growing up in urban areas, having access to a biophilic environment gives them a completely different outlook as to what a city is. They normalize the presence of green in the form of gardens, green walls, and green roofs. They learn to expect that creeks and rivers will run in naturalized riparian corridors rather than in culverts under streets and sidewalks. They acknowledge (and come to expect!) that size and density do not require environmental destruction.

In addition to feeling a close connection with nature, it is important to immerse ourselves in it so we can observe its systems and mimic their characteristics, replicating those that benefit us. Our "modern" lifestyles have created chasms between humans and nature, so much so that Richard Louv (2010) made an urgent plea to immerse children in nature again so that they can develop strong connections with nature early in life and avoid biophobia as adults. The benefits of immersion in nature are not only being recognized but also creating new trends. In Japan, people can get prescriptions for forest bathing (Wohlleben 2021), an ancient practice that consists of focused contemplation of forests, consciously observing and taking in the sounds, sights, and smells of these unique natural environments while relaxing and destressing. The positive effects of experiencing nature on psychological, biological, and physical health have been recognized for a while (Kaplan and Kaplan 1989). Linkages between well-being and contact with nature suggest that all human beings, but particularly those living in urban areas, can achieve a more balanced quality of life if they have the opportunity to be exposed to nature.

Biomimicry has the potential to not only revolutionize how we design products and entire built environments but also reverse processes adopted since the industrial revolution that do not serve the planet well. Using nature as model and measure, as biomimicry suggests, can be more easily done in multidisciplinary networks. When biologists and engineers collaborate to echo the designs we learn from nature, there is a better chance that conservation will happen. To respect the wisdom of nature and imitate the smart ways in which it feeds itself and processes its waste can only bring us closer to achieving balance on this Earth.

Impact of human activity on Earth

The approach taken since the Brundtland Report was released in the late 1980s, when sustainable development became a common cause and something people and governments wanted to strive for, requires responsible and numerous stewards of the environment. The idea that infinite economic growth is possible persists in some circles; however, there is more and more recognition that the planet cannot sustain life at high levels of development for the billions of people currently inhabiting it. The exponential growth experienced by some in the 20th century is not sustainable in a finite and vulnerable system such as the Earth's. The adverse impact of human activity, both locally and globally, and the resulting destabilization of ecosystems needs to be realistically addressed.

The intent to keep human demand within the limits of the resources that natural systems can provide aligns with the Gaia hypothesis put forth by James Lovelock in the late 1970s. According to this theory, the Earth is a self-regulating, living organism, and all living matter on its surface impact it and help regulate the biosphere (Lovelock 2000). Since it was first proposed, this idea that there needs to be a balance for life on Earth to prevail has taken hold. Actions towards equilibrium and sustainability will require humans to recognize the immediate and long-term impact that their actions impose on the planet and shift to a paradigm of sufficiency:

> We need to transform how and how rapidly we use the earth's endowment of land, minerals, water, air, wildlife, and fuels: an efficiency revolution that buys us some time. Beyond efficiency, we need another revolution that transforms our ideas of what it means to live decently and how little is actually necessary for a decent life: a sufficiency revolution.
>
> *(Orr 1994, 145)*

Living within the limits of our planet's capacity to sustain life will mean treading lighting on the Earth and striving for an indelible footprint. Reducing the pressure of human impact and its externalities on the biosphere will require a much less individualistic approach. More than 30 years ago, economists warned us that self-interested behaviour characterized the economic theory of the time and that it had "no real place for fairness, malevolence, and benevolence, nor for the preservation of human life or any other moral concern" (Daly et al. 1989, 159). The authors also recognise that, as an academic discipline, economics ignores "the complexities of the impact of economic growth on population, and of population growth on the economy" (Daly et al. 1989, 33).

Life cycle analysis and low-impact design

Life cycle assessment (LCA), sometimes referred to as life cycle analysis, emerged from efforts to measure energy expended in manufacturing products in the 1960s and evolved to costing models and environmental impact assessment models in the late 1980s and early 1990s (Bjørn et al. 2018; Guinée et al. 2011). Equated with cradle-to-grave measurements, which take into account the life of a consumer product from raw material to production to disposal, LCA continuously evolved into a methodological basis (see Chapter 4.2 in this volume). Its application broadened, and more recently it has taken a transdisciplinary approach and incorporated sustainability into a new framework of models referred to as life cycle sustainability analysis (LCSA). This new model takes a more holistic approach and can be used when sustainability of the built environment is assessed (Guinée et al. 2011). LCSA concepts consider the development of sites, the infrastructure required to sustain buildings on it, and the building itself. In addition, it considers the products, processes, and operations during the active life of a building and its eventual disposal, including refurbishment as a way to extend its life, or recovery of its reusable and recyclable components upon demolition. Through LCA, it is possible to keep energy consumption in check, reducing the total amount of urban waste generated in built environments. Comprehensive building environmental assessment methods have allowed builders and cities to be more environmentally responsible and reduce the detrimental environmental impact of urbanization.

Several elements at different scales work in concert to create a sustainable built environment. Buildings, comprising the bulk of a built environment, have the most impact. Infrastructure and other hardscapes surrounding buildings can add to or mitigate their impact. All man-made elements of a built environment present challenges to urban dwellers seeking to maintain and increase sustainability, and the selection of materials can make a significant difference. The environmental impact of construction materials goes beyond the production of the materials themselves and includes not only their transportation to the construction site but also their disposal at the end of the life of the building. Green builders use LCAs to measure the life cycle impact of buildings and attempt to reduce or make up for it by using green features such as green roofs, green walls, and renewable energy sources. Taking the entire life cycle of a product into consideration when analysing the impact of any product or structure is commonly referred to as a "cradle-to-cradle" approach (McDonough and Braungart 2002). This method considers not only production and disposal of materials but also their functional life. For example, most construction materials will have an impact on future energy use in a building, the quality of indoor air, and the costs to operate and maintain the building.

Beyond the buildings themselves, strategies that contribute to the sustainability of the built environment include low-impact development (LID), water-sensitive urban design (WSUD), low-impact urban design and development (LIUDD), sustainable urban drainage systems (SUDS), and the climate-proof city (CPC). Essentially, these are similar strategies that have been adopted under different names in the countries where they have been implemented (Hansen and Macedo 2021). Like biomimicry, all of these schemes mimic natural processes; some focus on stormwater design that replicates or maintains the hydrologic function of the natural system; others focus on renewable resources and on-site reuse and recycling to create circular, self-sustaining systems. The underlying concept of these approaches is to consider every input and output as a resource, not a disposal problem. A recent example is that of Chinese cities that have embraced a district-wide concept known as "Sponge Cities." The basic concept combines well-known low-impact principles into an integrated urban water management system and applies them to entire districts, some in existing urban areas, most in new planned cities and suburbs (Hansen and Macedo 2021). The goal is to adapt urban structures so that built environments will contribute to the restoration of natural environments rather than their replacement by the built environment with no regard for what was there before development.

From an urban design perspective, the reduction of impervious surfaces, retention of rainwater into rain gardens or rain barrels, and the use of bioswales for stormwater drainage offer affordable solutions. Rain gardens are an in situ alternative to centralized retention basins for the collection and treatment of stormwater, which still depend on networks or urban infrastructure. Perception and image are significant at this scale because naturalized areas are sometimes mistaken for areas with low or no maintenance. For this reason, some cities still operate under the limitations of building codes that present obstacles to the implementation of low-impact strategies. Integrating engineered and technological low-impact solutions is necessary for the success of green infrastructure initiatives to reduce the demand for water in landscapes, filter the pollution in runoff, and retain water – not only to mitigate the effects of flash floods but also to return rainwater to aquifers instead of channelling it into stormwater infrastructure.

Natural systems as design inspiration

Schools and universities are ideal places to advance the cause of sustainability education and develop in students the ability to speak the language of sustainability. Education plays a significant role in creating standards that become the norm. When children are exposed to environments that display the desirable qualities of a sustainable future, they adapt and grow up believing that what they do on a daily basis is the norm; it becomes part of their core values. An effective way to teach sustainability is through modeling. Incorporating sustainability concepts into the curricula is an important first step; however, exhibiting its benefits through school facilities and systems operations, governance and culture, and staff actions engages students in the practice of sustainability and encourages them to adopt the same behaviours (Higgs and McMillan 2006). Having schools that instill biophilic principles in children and young adults and that shows them the possibility of innovation through biomimicry helps advance the environmental mission. An American school that has become notorious for applying this philosophy not only to their environments but also their pedagogy for 15 years is Sidwell Friends School in Washington, DC (Sidwell 2021). Their belief is that students can better understand the impact that humans have on the environment when they study in spaces that display how Earth's resources are finite.

The school believes in using "buildings as teachers": students learn how rainwater is recycled, how electricity is generated, and how energy is conserved by simply experiencing the buildings they occupy daily and understanding what makes them "green" (Sidwell 2021). More proactive lessons are used in their curriculum; for example, science classes incorporate observation of how rainwater moves through the green roof system. Five of Sidwell Friends School's buildings incorporate biophilic elements such as green roofs; they also rely on renewable sources of energy with photovoltaic panels and reuse graywater to reduce demand for water resources. Other green building features comprise passive solar design, including natural ventilation and daylighting; the use of renewable materials, such as cork instead of linoleum on floors, and materials with recycled content and low chemical emissions; and the use of reclaimed wood for exterior cladding, interior wood paneling, windowsills, flooring and decking, gym bleachers, and barns (AIA 2021). Additional biophilic elements were introduced in the design of Sidwell's facilities, such as skylights added to existing buildings to increase exposure to natural light.

Sidwell's environmental ethic pervades not only the school but also the extended community. In addition to environmentally friendly buildings and a constructed wetland for recycling and treating its wastewater, the school is easily accessible by bicycle and transit. All materials used in the school, including electronic devices, are recycled, reducing their impact on the community at large. In addition to striving to reduce the impact of its physical facilities, Sidwell adopts other practices to make the school a biophilic environment. Students eat local in-season produce and hormone-free products and contribute their food scraps to compost piles used in their own gardens to fertilize the very food they eat. Only native species are planted throughout their grounds, minimizing the use of pesticides, reducing the need for irrigation, creating habitat for wildlife, and restoring native ecosystems in the periphery of the school.

If more schools adopted the practices implemented at Sidwell Friends School, our youth would become better stewards of the environment. Giving students, regardless of age or level, the means to personally apply sustainability concepts equips them with tangible knowledge to internalize sustainable practices and behaviours, which in turn has an impact on their families and communities at large (Higgs and McMillan 2006). Biophilic environments have a better chance to become the norm if future generations are brought up in them and learn from an early age that we can live in urban environments and still be part of nature.

Conclusion

Perhaps the best way to completely integrate the sustainability concepts discussed in this chapter into our daily lives is to play the economics card and increase their consumer appeal. If we succeed in making environmentally safe and sustainable products fashionable, and if we are able to make sustainable practices not only desirable but also commonplace, we may be able to achieve the lofty goal of having a sustainable society. This is not a revolutionary idea; in fact, we have seen this same approach taken and been successful in other matters in the recent past. For example, safety features such as seat belts, once resisted by drivers of all stripes, became the baseline and the law; no car manufacturer in the world today produces cars without seat belts, and very few drivers do not use them regularly. Likewise, cigarettes; smoking has become an unwelcome, socially unacceptable habit and may someday be a habit we only know about through history books.

These transformations require champions, time, political will, and, foremost, education. An educated society has a much better chance of becoming a sustainable society, one that respects global limits whilst working in unison with local ecosystems:

> A sustainable society would be interested in qualitative development, not physical expansion. It would use material growth as a considered tool, not a perpetual mandate. Neither for nor against growth, it would begin to discriminate among kinds of growth and purposes for growth. It could even entertain rationally the idea of purposeful negative growth, to undo excess, to get below limits, to cease doing things that, in a full accounting of natural and social costs, actually cost more than they are worth.
>
> *(Meadows et al. 2004, 255)*

Lewis Mumford (1944, 398–399) predicted that "an age of equilibrium" would greatly "affect the task of education and the procedures of science." If we are able to educate a sustainable society, a society that will do whatever it takes to achieve the balance required by sustainability, there is a chance the Earth will be treated as the finite complex system that it is and that we will all thrive.

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3.8

INDUSTRY 4.0 APPROACHES TO SUSTAINABILITY

Gijsbert Korevaar

Key concepts for sustainability education

- Industrial symbiosis needs design-driven research and education, best done by working on real-live case studies in student teams.
- Circular economy needs insight into the complexity of business model innovation, best taught with serious games and interactive role plays.
- Complex adaptive systems, like circular economy value chains or industrial symbiosis clusters, can best be described with computational tools that enable the practitioners to see the consequences of context, relations, and input settings.
- Industry 4.0 and industry 5.0 need practice-oriented research in strong collaboration with companies and knowledge institutes.

Introduction

The busy bees of our society are the factories that produce all the goods that we need for a modern life. Although industrialization has brought many benefits, it is also threatening the wellbeing of the planet in terms of resource scarcity, emissions, and inequity. On top of that, the main challenge to sustainability is the globality of industrialization. When we take a look at the Sustainability Development Goals (SDGs) as presented by the United Nations (see this hyperlink: https://sdgs.un.org/goals), it shows clearly that all 17 have a close link to industrial development, locally and globally. Some goals are more focused on the direct results, positively and negatively, of industrialization, for example, SDG-6 on clean water and sanitation or SDG-7 on clean energy. Some other goals can only be reached by even further industrialization, like SDG-1 on no poverty and SDG-2 on zero hunger, under the condition of an increasing global population. Other SDGs strongly relate to organization or acceptance of industrialization, for example, SDG-5 on gender equality or SDG-8 on decent work and economic growth.

Industrial revolution 4.0 takes our world forward in recognizing that since the first industrial revolution, which was powered by wood and cheap coal-fired energy in the 1760s, the world has externalized the environmental costs of our industrial production, which has

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resulted in significant levels of environmental destruction and climate change. Industrial symbiosis and circular economy are approaches that have considered the combination of environmental impact reduction and industrial development for many years. These issues present the context in which individually and collectively sustainability education must be considered and developed. They are invariably interlinked and together present some of the most critical resource issues that the 21st century will face, including the scale of environmental impacts that are associated with our increasing production and consumption decisions and the need to consider new paradigms in our economic business models and governance frameworks.

In this chapter the link between industrialization and sustainability is made by using the perspectives of industrial symbiosis, circular economy, industry 4.0, and industry 5.0. Industry 4.0 is another way of mentioning the concept of the fourth industrial wave that is connected to typical sustainability thinking about industrial ecosystems and circular economic systems. Therefore, in this chapter first industry 4.0 is introduced, then industrial symbiosis, followed by circular economy. On all subjects, reflections are made to discuss the importance of sustainability education and how that should look to be ready for a future with even more intense collaboration between human and machine.

Industry 4.0 and sustainability

Industry 4.0 refers to a fourth wave of industrialisation. Current innovations and improvements regarding reduction of the environmental impact of a system are often part of the fourth industrial revolution. Where the first industrial revolution, halfway the 18th century, is about the introduction of steam power, the second revolution is about electricity and mass production. Since the third industrial revolution, starting in the late 1950s of the 20th century, the technological innovation is dominantly about computerization and automation of production. From the start of the 21st century, industry 4.0 is a response to the digitization of manufacturing (Özdemir en Hekim 2018). This means that production can be made more flexible, for example, by using 3D printing techniques, and that production is also more personalized and available everywhere, for example, by using smart logistics and digital twinning of products and services.

More and more publications even continue into an industry 5.0 vision; this will be discussed at the end of the chapter. First, we limit ourselves to developments up to and including industry 4.0. Figure 3.8.1 is taken from a literature review that discusses industry 4.0 in relation to sustainability (Manavalan en Jayakrishna 2019). This figure nicely illustrates what the building blocks are for industry 4.0. The emphasis is on digitalization of production, maintenance, the internet of things (IoT), and supply chains. By making these steps more efficient and by creating more insight in potential bottlenecks, companies can save on energy and resources. Although the digitization and automation might lead to a steep increase in electronic devices, computers, sensors, and data centres, it still can be concluded from many case studies that the potential savings in terms of energy efficiency and resource efficiency outweigh this.

Besides being flexible and adaptive, industry 4.0 is also about the interwovenness of several system perspectives. Industry 4.0 contributes to social fairness, sustainability, and artificial intelligence–driven technologies to increase the efficiency and flexibility of business processes. The challenging issue here is that industry 4.0 certainly is about a vast complexity of big data and system perspectives, but how does that all lead to a regenerative

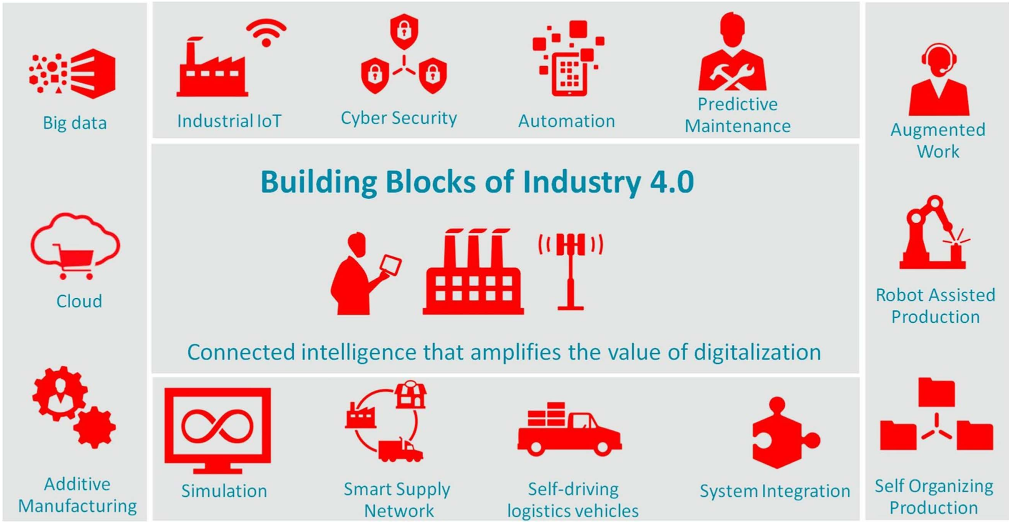

Figure 3.8.1 Building blocks of industry 4.0, taken from (Manavalan en Jayakrishna 2019).

economy that is needed for sustainable development? To answer that question, we first want to introduce two other aspects of sustainable thinking that have taken industrialization into account for many years already, being industrial symbiosis and circular economy.

Industrial symbiosis

From the start of the industrial ecology field, after the idea of 'industrial ecosystems' was launched by Robert Frosch and Nicholas Gallopoulos in 1989 (Frosch and Gallopoulos 1989), quite some attention has been given to eco-industrial parks (Yu et al. 2014). Industrial ecology research and education always has had a strong emphasis on the analytical side of 'metabolism of society', working on tools like life cycle assessment or material flow accounting (Ayres 1994). However, also from the start of the industrial ecology domain, the design of industrial parks or industrial clusters with an exclusive focus on sustainability has received quite some recognition. This focus on the exchange of materials, energy, and information in industrial locations has been labelled *industrial symbiosis* (Jacobsen 2008).

In industrial symbiosis thinking, the relationship between companies is compared to *symbiosis* in ecology. The concept of symbiosis refers to relationships in which at least two unrelated species both gain benefits by exchanging materials, energy, or information. Industrial symbiosis then describes the phenomenon of collaborations between traditionally separate, but geographically proximate, industrial agents to exchange materials, energy, and information for the competitive advantage of these agents, generally leading to environmental and social benefits as well (Chertow 2000).

The most elaborated and well-known example of industrial symbiosis is the eco-industrial park in Kalundborg, Denmark, also known as Kalundborg Symbiosis. This industrial cluster has shown over the years that it can reduce carbon emissions and can save water uptake by intensive exchange of material and energy. It also shows that industrial symbiosis is not only the result of technical innovation but also of strong collaboration between the stakeholders (see Figure 3.8.2).

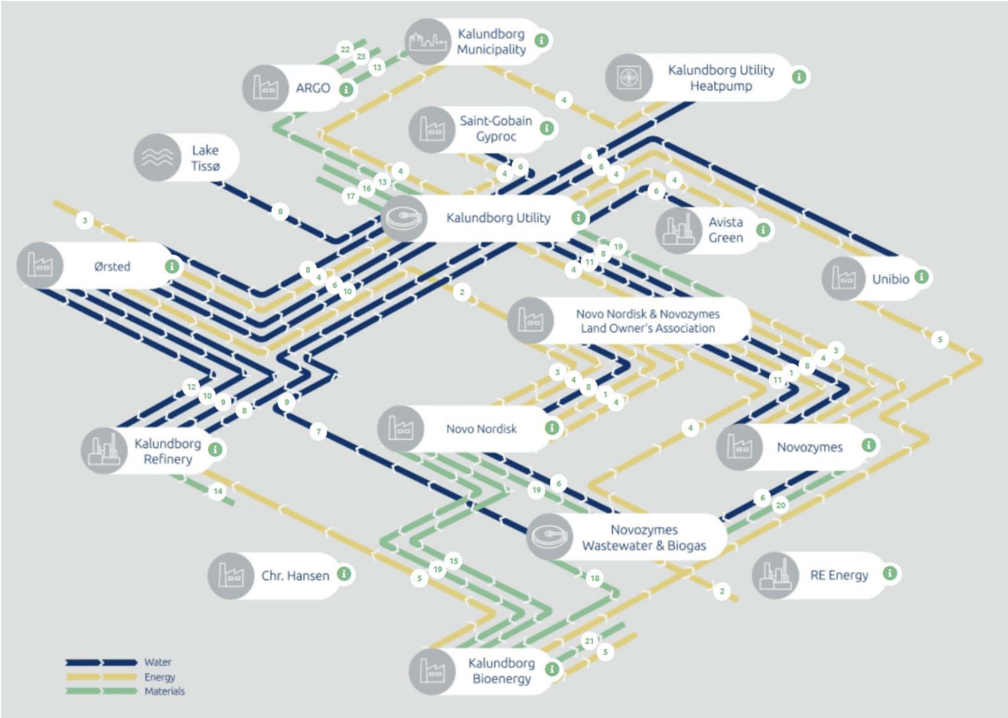

Figure 3.8.2 Kalundborg Symbiosis. Retrieved from https://www.symbiosis.dk/en/ on 31 May 2022.

Kalundborg is an excellent illustration of how a strong facilitator can stimulate exchange and collaboration because the facilitator here is a champion not only in business and engineering but also in social networking and information sharing (Jacobsen 2008). In the publications of Kalundborg Symbiosis it is stressed that the system has a substantial lower carbon emission than comparable industrial clusters, it has a lower intake of lake water for cooling and other processes, and it produces materials at a local level that otherwise should be imported. Overall the sustainability of the system is great example of how an industrial location can perform way above average. Therefore the example of Kalundborg Symbiosis has become an important inspiration for a multitude of industrial symbiosis initiatives in the world. For a good example of how this inspiration has led to many more activities, the reader is invited to take a look at the website and documents of the organization behind the National Industrial Symbiosis Programme (NISP) in the United Kingdom: International Synergies (https://www.international-synergies.com/our-projects/). The NISP initiative stimulated many industrial symbiosis activities throughout the UK and the world, from smaller local initiatives to larger industrial networks.

As an illustration to the global outreach of Kalundborg Symbiosis, an industrial symbiosis activity that is also worth mentioning is the development of the Kwinana Industrial Area (KIA). Located in Western Australia, the KIA is one of the largest documented eco-industrial parks in the world (Rosano and Schianetz 2014). The KIA case study is also mentioned in the report of the World Bank (The World Bank 2021), in which it is stressed particularly that the Kwinana industries show how firm-to-firm industrial symbiosis projects help to increase interaction among tenant firms and bring forward symbiotic opportunities. Public intervention was minimal in this case; all relationships were organically developed with a facilitator, being the Kwinana Industries Council.

In both the Kalundborg and the Kwinana cases, many exchanges between companies are bilateral at first and seem to be not very complicated, like the uptake of waste flows as part of the core processes of a neighbouring facility. However, factories and firms that have worked for some time in industrial symbiosis start to face external and internal factors that are not easy to manage (D'Souza et al. 2015). This increasing difficulty has led to an entire body of literature that describes industrial symbiosis as a complex adaptive sociotechnical system, see for example the publication by Dijkema et al (Dijkema et al. 2015). This means that industrial symbiosis networks can be defined as "systems composed of two deeply interconnected subsystems: a social network of actors and a physical network of technical artefacts" (Dam et al. 2013).

This concept of complex adaptive sociotechnical systems is important in two ways:

1. It helps designers and practitioners to understand and to act upon the complexity in these systems. This is important in education about sociotechnical systems, but also in discussions about topics like industrial symbiosis, circular economy, or industry 4.0 with companies and governments. The understanding of the complexity also avoids the exclusive focus on the engineering side of symbiotic connections, but instead finds a balance with the non-engineering aspects like behaviour, trust, awareness, etc.
2. The approach of sociotechnical systems, with the help of the concept of complexity, supports the way in which these systems can be modelled and studied. Therefore complex adaptive systems, like circular economy value chains or industrial symbiosis clusters, can best be described with qualitative studies on the system dynamics or with quantitative computational tools that enable the practitioners to see the consequences of context, relations, and input settings;

In order to achieve industrial symbiosis and support facilitation of it, several types of dynamics are considered (Boons et al. 2016; Sun et al. 2017). These industrial dynamics support the way in which industrial symbiosis can be understood and applied for the establishment of eco-industrial parks, not only in a technical way (exchange of materials, etc.) but also in an institutional way (for example, agreements, contracts, business models) (Lange et al. 2021a). Figure 3.8.3 shows the key aspects of industrial symbiosis that can be found in many case studies and practical examples:

1. Reduced Environmental Impact – Several indicators are developed or derived from system analysis tools like life cycle assessment to measure the potential environmental impact reduction by industrial symbiosis. Examples are the carbon footprint, water footprint, acidification potential, ecotoxicity, etc. Industrial symbiosis is not about all types of industrial synergies; it has a clear focus on only those synergies that really lead to sustainability. That's why this first key aspect is an essential and determining factor for deciding the potential of industrial symbiosis.
2. Improved Resource Efficiency – Industrial symbiosis mostly considers industrial production directly. Before any type of exchange can take place, it is advised to first find out how the resources can be utilized in the most optimal way. This could be done by finding alternative (bio-) chemical routes, or by valorisation of by-products, or by using the utilities (like clean water, cooling water, solvents, fuels, etc.) as efficiently as possible. Even

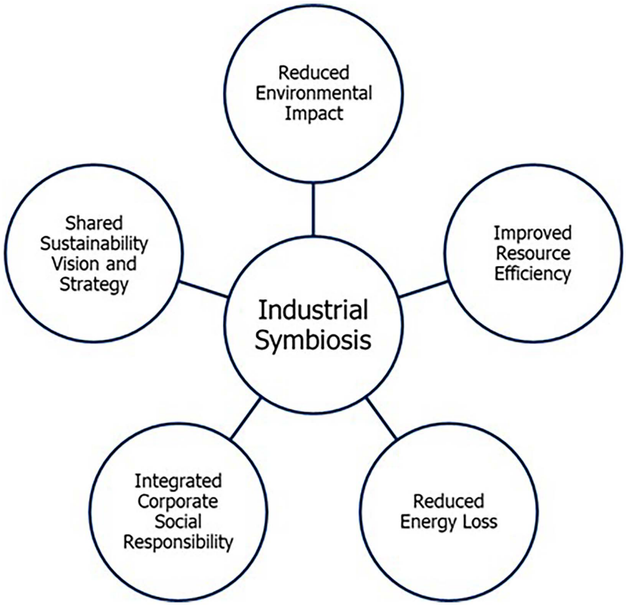

Figure 3.8.3 Key aspects of industrial symbiosis.

when the symbiosis takes place in a business park with little or no production, resource efficiency is still essential, because it directly links to supply chain management or business process optimization.

3. Reduced Energy Loss – Energy production and consumption are the main contributors to greenhouse gas emissions in industrial areas. To implement heat integration or energy integration in order to reduce the use of fossil feedstock or to create more openness to alternative energy feedstock is therefore a key aspect of industrial symbiosis as well. Further on the same arguments apply for the reduction of energy losses as given earlier for resource efficiency.
4. Integrated Corporate Social Responsibility – The first three key aspects focus on the technical performance of businesses, but in order to contribute to the sustainable development goals, non-technical aspects also play a role. Industrial symbiosis can lead to a different local human capital agenda where other skills and capacities are needed. It can also lead to a different relation with the neighbouring urban environment where other impacts are considered. Hence, the corporate social responsibility shall reflect that the company is not only taking measures to reduce the environmental impacts but also works on an alternative economy, resulting in sustainable business models.
5. Shared Sustainability Vision and Strategy – Industrial symbiosis means that companies have an intensive connection with each other and cooperate within an industrial area, or supply chain, or value chain. The symbiosis of physical flows are already mentioned sufficiently, but in order to create sustainable business relations that last for many years, a shared vision and a joint development of a sustainability strategy are also necessary.

Besides the benefit of industrial exchange and the possibility to make that exchange more efficient in terms of resources and energy consumption, industrial symbiosis also has another benefit. It creates the opportunity to connect water, energy, and resources in a systemic way. For water, energy, and food, this has been presented before as 'The Water-Energy-Food Nexus' (Food and Agriculture Organization of the United Nations 2014). This integrative framework applies not only to food networks but can also be applied broadly to various kinds of resources and therefore to industrial networks in general. In particular, the approach of industrial symbiosis is then equipped to design and execute such networks, as is visible already in the Kalundborg Symbiosis.

Circular economy

Circular economy as a term was first coined by David Pearce and Kerry Turner in their book *Economics of Natural Resources and the Environment* (Pearce and Turner 1990). The book proposed redesigning the economic model in such a way that "everything is an input to everything else". With the rise of global consumption and the growth of the global population, the transition to a circular economy becomes more and more urgent. In the World Economic Forum publication about industry 4.0, Klaus Schwab stated:

> At the heart of this promise is the opportunity to shift businesses and consumers away from the linear take-make-dispose model of resource use, which relies on large quantities of easily accessible resources, and towards a new industrial model where effective flows of materials, energy, labour and now information interact with each other and promote by design a restorative, regenerative and more productive economic system.
> *(Schwab 2017)*

From these quotes it becomes clear that the circular economy is the opposite of the linear economy, where resources are extracted and the products are discarded. The evidence of social, environmental, and economic disadvantages against these linear practices are piling up. The global waste production, which is expected to grow to 3.4 billion tonnes per year by 2050, is not only just a materials problem but also related to climate change. If no action towards circular practices takes place, the solid waste management sector is expected to increase its greenhouse gas (GHG) emissions to 2.38 billion tonnes of CO_2-equivalent per year (Kaza et al. 2018). Circular economy aims to create a long-term regenerative economy, that is an economy that is also in balance with ecology and its social context. Circular economy can also be seen as an alternative way to decouple economic growth from environmental impact and resource depletion (Ghisellini et al. 2015).

The circular economy, strongly advocated by the Ellen MacArthur Foundation (Ellen MacArthur Foundation 2013), is an economic and industrial system based on reuse and recycling of products and materials and the recovery capacity of natural resources. Based on cradle-to-cradle thinking by Braungart and McDonough, the Ellen MacArthur Foundation created the so-called 'butterfly diagram' that shows a green side for renewable and biobased materials and a blue side for technical materials (Figure 3.8.4). The two sides of the diagram have different types of feedback loops because in the blue part the materials are always part of the technosphere and should be governed by society at all times. The green part contains materials that are part of the technosphere but also can be part of the ecosphere, meaning that these materials can be treated and transported by natural cycles too.

Circular economy stands for a transition from a linear 'take-make-dispose' model, with raw materials on the one end and wastes at the other, towards a circular model, in which

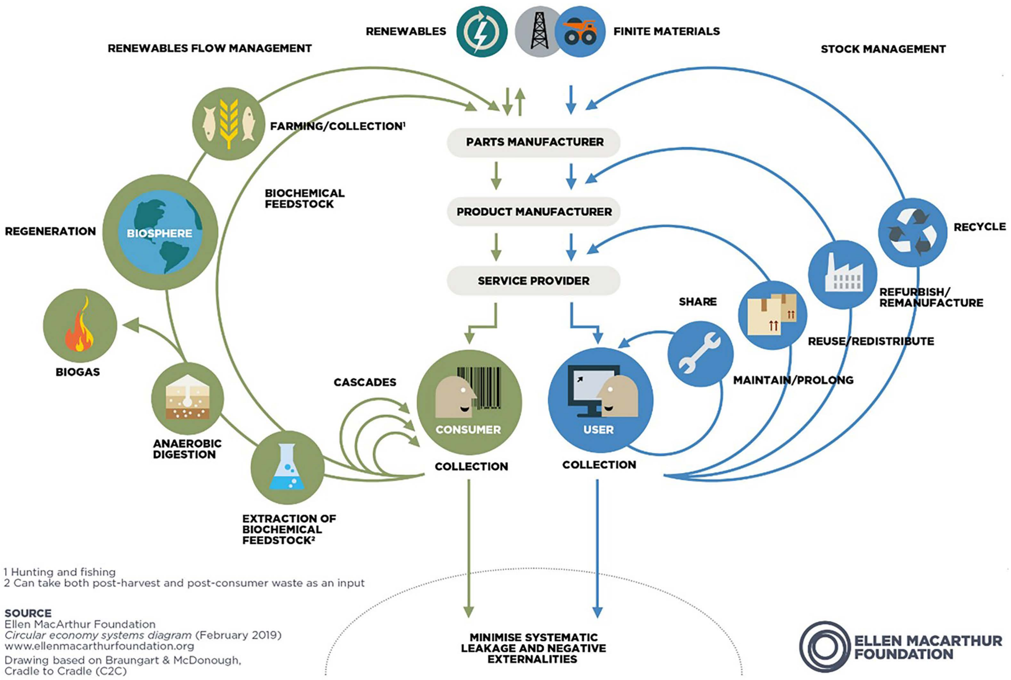

Figure 3.8.4 Circular economy according to the Ellen MacArthur Foundation (retrieved from https://ellenmacarthurfoundation.org/circular-economy-diagram on 31 May 2022).

waste is a resource that is valorised through recycling and reuse. Since industrial ecology can be considered one of the main roots of the circular economy (Lüdeke-Freund et al. 2018), a large communality between circular economy and industrial symbiosis literature is not surprising. Both industrial symbiosis and circular economy are based on the idea of closing energy and material loops in order to make an economically appealing reduction of the environmental impact of industries. This also means that the circular economy design principles overlap with the design principles of industrial ecology. As derived from these principles, circular economy has a strong focus on the development of strategic frameworks, both for the identification of potential closing of the loops and for business support for companies that want to close the loops.

Many companies around the world already have implemented circular economy principles in their business. Examples can be found in the built environment and industrial products, from small to big, from simple to complex. For inspiration and nice illustrations, we like to refer to the book *Products That Last* that offers (according to the title page) "An innovative and practical methodology to unravel product's afterlife and systematically evaluate if for new opportunities" (Bakker et al. 2014).

In 2021, the World Bank launched the report 'Circular Economy in Industrial Parks; Technologies for Competitiveness' (The World Bank 2021) in which the connection is explicitly made between circular economy and industrial symbiosis. Both approaches focus on the practical implementation of sustainability in the industrial setting, but also the circularity of material flows at industrial sites will offer great opportunities for impact reduction and energy efficiency. Circular industrial parks are therefore an important key to a successful implementation of circular economy in the industrial context.

Comparing industrial symbiosis and circular economy

In many academic discussions about sustainability, the attention is drawn either towards the ecological impacts and how they have to be monitored or towards new materials and technologies that can lower the ecological impact. Both approaches certainly add value, but seem to miss one other important aspect, and that is how production and services can transition into a system with less intake of resources, with lower energy consumption, and better environmental performance. These aspects are taken up by approaches as circular economy and industrial symbiosis that aim to support the transition to a sustainable sociotechnical system. In the paragraphs earlier it was mentioned that in this way not only products can be made in a more sustainable way but that especially industrial networks and industrial parks can be designed in a more sustainable way and thus act as a stepping stone for a regenerative industry 4.0 and by that a regenerative sustainable development of the industry.

From the overview provided earlier, we learned that industrial symbiosis is a collective approach in which separate industries create a cooperative network to exchange information, materials, energy, water, and by-products. It is not only about the technical elements but also the softer elements like skilled labour, sustainable strategies, business data, etc., that is exchanged as well. Circular economy refers to the concept that stimulates the circularity of materials, working towards a transition of a linear economy to a circular one. Circular economy is important for sustainable development, mostly because it emphasizes the material side of industrial production as an addition to the climate impact discussion, and it brings in the business side as well. In practice, circular economy is an important concept for regional resource management, taken over by municipalities and countries, because it has this profound notion of economic development.

Modified from the paper by Baldassare et al. (Baldassarre et al. 2019), Figure 3.8.5 summarizes the main components of both industrial ecology and circular economy. In both cases it is about a nested structure that goes from a concept to the practical side. Figure 3.8.5A shows how the academic field of industrial ecology has studied

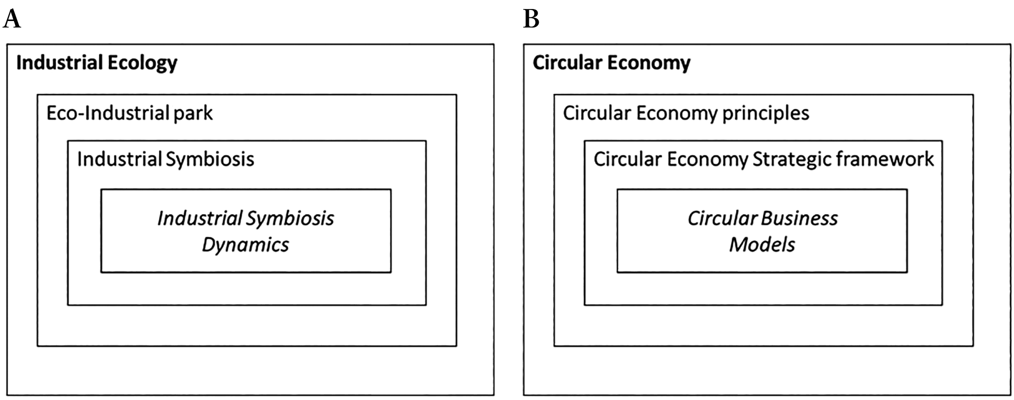

Figure 3.8.5 Nested structures of industrial symbiosis (A) and circular economy (B).

eco-industrial park developments since the beginning of the field. Besides this, industrial ecologists work on many more topics and tools, but in order to turn industrial parks into eco-industrial parks, the tool of industrial symbiosis is very important. And within this concept of industrial symbiosis, the description of how this symbiosis comes about, namely the industrial symbiosis dynamics, is important to steer and understand the transition process.

Figure 3.8.5B shows the same narrative for the circular economy. Here again, we like to emphasize that this is only a limited representation of what topics are important in this field. We describe here only what is needed to come to a transition, which is done by following certain circular economy principles, like those discussed by the Ellen MacArthur Foundation (Ellen MacArthur Foundation 2013). These principles can lead to a strategic framework that combines several insights of the companies and industries that are related to a certain location or supply chain. And within the strategic framework, the business models then lead the industry into a transition to become more circular (Lange et al. 2021a).

Industrial symbiosis, circular economy, and industry 4.0

Industries play a central role in the transition towards the circular economy, since their core activities involve the conversion of materials and energy into finished products and wastes (Ayres 1994). Industries that work towards a circular economy therefore develop business models for slowing, closing, and narrowing resource cycles (Bocken et al. 2016). The main insight of our comparative analysis so far is that industrial symbiosis and circular economy perspectives on sustainability are complementary. We argued that their differences in nature, features, and relevance should be leveraged in combination to get a more thorough understanding of both industrial symbiosis dynamics and circular economy business models. The circular economy perspective is more suitable to start or create a sustainable business operation; the industrial symbiosis perspective is more suitable to study business development over time and its impacts on the environment, the economy, and society. A different way of producing, using, and handling discarded materials is required to make the transition towards a circular economy, to minimize waste, and to maximize resource efficiency. System-level innovations are needed to tackle the mix of values, norms, interests, and motivations of the stakeholders involved.

These aspects of sustainable industrialization are not part of industry 4.0 per se. In many initiatives of industry 4.0 it is shown that production can become smarter, that flexibility is essential, and that social and economic aspects have to be taken into account. But that all can be done with even more use of resources, energy, or production of waste. It is a challenge for engineers and professionals that are also inspired by sustainability to bring the aspects of circular economy and industrial symbiosis into the debate about industry 4.0. It needs careful planning and smart design to work on several innovations at the same time.

This planning and smart design typically comes with the collection of big data and the use of IoT. The industrial development therefore needs to shift from an exclusive focus on production and products to a system in which not only products play a role but also services and the systems that combine several services together. For example, a company that decides to take back the products at their end of life not only has to develop a technology to use the returned products again during production (various types of recycling) but also needs to develop a system to make the taking back easy for customers or other companies in the supply chain. Such a system in practice will require data management of the characteristics of the products, ownership, location, use, etc., and it also needs a logistic or transportation part that enables the tack-back process. Industrial production becomes then more and more interwoven with logistics, storage, data management, etc. This chapter is not the place to discuss all the details of this, but it shows how industry 4.0 can develop into a whole other type of sustainable industry than we ever have seen before.

From industry 4.0 to industry 5.0

So far, we focused on industry 4.0, and the expectation is that this fourth industrial wave will continue for quite some years, but some discussions have already arisen on the next revolution that can be called industry 5.0. From big data and digitalization, the change is towards an industry that is even more focused on the desires of the people, citizens, customers, or employees. Where industry 4.0 is still about more flexibility and more smartness, industry 5.0 will be more focused on a collaborative approach of humans and machines. How this collaboration will shape is quite unclear, and it does not make sense to just present some ideas here on what the future will look like. Although one thing might be said for sure, and that is that industry 5.0 will become even more complex than industry 4.0. The behaviour of customers, companies, or the government; the financial system to support the circularity or flexibility of the economy; the adaptive regulation – all are needed to turn the industrial system into a next level of regenerative sustainability development.[1]

The European Union stated in 2020 that industry 5.0 will be the "economy that works for people". It will be stimulated by several policy initiatives, like the "adoption of a human-centric approach for digital technologies including artificial intelligence" or "resource-efficient and sustainable industries and transition to a circular economy" (Leyen 2019). It is clear that in this way developments such as the stimulation of a green deal, artificial intelligence, and circular economy are all combined, leading to a transition from industry 4.0 to industry 5.0.

Although this development sounds quite ambitious and at this moment not in reach for every economy in the world, it is good to realize what is at stake here. For decades, industrial development has taken its own course based on the latest innovations, inventions, or market demands. The complexity of that development has led to an industrial system that has irreversible impacts on the environment, society, and the economy in many ways. The complexity also shows that we are able to develop such a system in the first place. These two issues, namely the irreversibility of industrial development and the fact that the industrial development is still a human artefact, can help us to find ways to develop the industrial system in other ways. This would require new insights in terms of technological innovation but also in terms of governance of technology and alternative forms of economy.

It addition to new insights, it also requires understanding of the system behaviour in the longer term. What might be the consequences of actions taken today for future opportunities in the market or society? To answer this question, explorations of the future should be made, which is by definition not really accurate, or sometimes simply impossible, but can be supported in many cases by scenario planning.

Scenario planning

The method to explore possible future variations is scenario planning or scenario analysis, most famous from the scenarios that Dutch Royal Shell developed in the last part of the 20th century. Peter Schwartz worked on these scenarios for many years, and his book about how to perform scenario planning is still seen as the start of this method (Schwartz 1991). Scenario planning follows a strict method to ensure that not just personal preferences or blind spots are dominant in possible descriptions of the future. In this way, quite accurate consequences can be described of what currently is important in technological innovation and how these will lead to future development.

This means for sustainability education that students have to be taught about the interwovenness of various concepts and they have to understand how much of the technical innovation is a logical consequence of choices that have been made as a society, in businesses, and by policy makers. On the other hand, it also asks for creativity and smart thinking to find ways to see how these long-term trends can also be influenced towards sustainable development.

Scenario planning is a powerful tool to see the connection between industrial symbiosis, circular economy, industry 4.0, and industry 5.0. In itself the vision of industry 5.0 is actually a scenario, because most of it still has to be realized, but it is a consequence of developments in industry 4.0. But also industrial symbiosis and circular economy can be seen both as a practical implementation of new types of industrial production and a future vision towards which the current industry should develop. Industrial symbiosis can lead to alternative designs of business parks and industrial parks. Circular economy can lead to an entire new portfolio of industrial products with the consequence of different behaviour and alternative economic models. Industry 4.0 can lead to an industry that can much better predict maintenance and have a much more integrated and more efficient supply chain management. And on top of all three, industry 5.0 can lead to an industry and society that are more focused on values creation rather than on just economic growth or material prosperity.

Conclusion

The key message of this chapter is that several concepts are important to talk about with regard to the sustainability of innovative industrial systems. These concepts are therefore also of interest for a regenerative sustainability development. In terms of education, this means a couple of things that have to be taken into account. Based on years of experience in the MSc Programme on Industrial Ecology in The Netherlands, the following lessons learned can be identified.

The behaviour and dynamics of industries are of great importance to the realization of a regenerative sustainability development. Industries manage the intake of feedstock, the production of materials and artefacts, the potential recycling, and waste treatment. Industrial management therefore can break or make sustainable development. Industrial symbiosis, industry 4.0, and industry 5.0 should be aligned in such a way that the industrial development leads to less impact on the environment and even works to restore the natural environment of our human activities.

Consequently, industrial symbiosis needs design-driven research and education, best done by working on real-live case studies in student teams (Baldassarre et al. 2019). Circular economy needs insight into the complexity of business model innovation, best taught with serious games and interactive role plays (Lange et al. 2021a). These two remarks on industrial symbiosis and circular economy stress the need for contextual understanding of the sustainability issues and their potential solutions. In the practice of sustainability education, this means that many examples in class – but also direct relationship with surrounding systems both in industry and urban areas – support the students in becoming active and creative.

From this, it can be see that students and practitioners who have been trained in industrial symbiosis and circular economy can have a substantial effect on the way that the Sustainable Development Goals are reached. Both industrial symbiosis and circular economy lead to higher resource efficiency and improved energy efficiency, resulting in less waste, less emissions, cleaner water, and a healthier environment.

Complex adaptive systems, like circular economy value chains or industrial symbiosis clusters, can best be described with computational tools that enable the practitioners to see the consequences of context, relations, and input settings (Lange et al. 2021b). This also implies that for solid sustainability education, students can define what is needed for collective action and what can be done in an individual way. The sustainability of one production location, a factory, or a chemical plant, is most of the time impossible to define because of the embeddedness of that activity in a value chain or in an industrial park. The sustainability or circularity can then only be determined by a system perspective that takes into account several activities, a multitude of energy or material flows, and a diversity of stakeholders.

Both industry 4.0 and industry 5.0 need practice-oriented research in strong collaboration with companies and knowledge institutes (Schwab 2017). Industrial socio-economic modelling helps to focus our attention on the need for large-scale and rapid transformations in decarbonizing our industrial production and the critical need for renewable energy. The task in education programmes is to teach students about the complexities that are at stake here and to show them possible ways to increase system understanding also by scenario planning.

Scenario planning together with system analysis methods is fun to work with. It demands a lot in terms of creativity and personal involvement, but it also gives teachers and students a great opportunity to discuss what is important for individuals and societies. Sustainable development is not only indispensable for governments, education, or industry, it is also the only way to hand over our world to the next generations in a better shape than we found it.

Note

1 Highlights of Industry 5.0 by Frost and Sullivan, retrieved from https://www.frost.com/wp-content/uploads/2019/11/Exhibit_1.png.

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SECTION 4

Key competencies in sustainability education

"For many of us, water simply flows from a faucet, and we think little about it beyond this point of contact. We have lost a sense of respect for the wild river, for the complex workings of a wetland, for the intricate web of life that water supports."

(Sandra Postel, 'Last Oasis- Facing Water Scarcity,' 2003)

The competencies required to deliver the sustainability transition outcomes are now discussed in Section 4. Several key competencies must be developed in sustainability education to help academics and students understand the roles and responsibilities inherent in sustainability management. Section 4 reviews a number of these, with a special focus on the UN Sustainable Development Goals (SDGs) learning objectives.

Hadgraft (see Chapter 4.1 in this volume) recommends systems thinking as a guiding principle in sustainability education. Systems thinking is a holistic approach in examining the way in which all systems, including parts of our production and consumption systems, interrelate and over time operate within the context of larger Earth systems. The relevance of systems thinking to sustainability education is particularly pertinent in the relationship between our human consumption and production activities and our creation of waste.

Biswas and John (see Chapter 4.2 in this volume) suggest that life cycle thinking provides students with an opportunity to assess the environmental impacts of various stages of a product or service life cycle, typically from cradle to grave or ideally from cradle to cradle, where end-of-life waste management decisions are included. One of the most utilised approaches is that of life cycle assessment (LCA). LCA presents an assessment framework for quantitatively assessing the environmental and social impacts of our production and consumption decisions and is used in assessing the greenhouse gas (GHG) contributions of products and services. In addition, it can be very useful in the comparative assessment of the environmental performance of different or competing products and services or technologies.

The UN SDGs have become a guiding framework for sustainability assessment in public policy, industry performance, and more broadly defining learning objectives in sustainability education. As noted by Segalas and Tejedor (see Chapter 4.3 in this volume), they have also become a guiding framework in sustainable education development. The 17 SDGs

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released by the United Nations, to continue on from the Millennium Development Goals, cover the period 2015–2030. The SDGs are largely focused on increasing global efforts to end poverty, fighting social inequality, and tackling climate change. The SDGs call for all countries across the world to develop strategies that help a broad range of social goals, including zero hunger, education for all children, reduction in environmental degradation (biodiversity and oceans), increased focus on sustainable consumption and production, and world peace.

Macedo (see Chapter 4.4 in this volume) recommends that integrated problem solving and design thinking are also important pedagogies in helping students to develop both an awareness of the complexity and interconnectivity of sustainability challenges and a realisation that many of the sustainability problems we face are due to poor or inadequate design.

Fukukawa and John (see Chapter 4.5 in this volume) contend that education for sustainable development (ESD) is a capability that can be used as an 'evaluative space' for critical thinking in the teaching of sustainable development as well as in framing the role and value of sustainability thinking.

In addition to the important role played by commercial and natural science-related competencies, Konrad and Freeth (see Chapter 4.6, in this volume) suggest that interpersonal competencies also play an important role in fostering students' understanding and value of sustainability. Interpersonal competencies should include a student's capacity to empathise, lead, and negotiate sustainability problem solving.

4.1
ENGINEERING SYSTEMS THINKING IN EDUCATION

Roger Hadgraft

Key concepts for sustainability education

- Systems thinking in sustainability education enables students and practitioners to understand the connections between environmental, economic, social, and political systems.
- Sustainability involves economic systems, social systems, and environmental and ecological systems. They are all interconnected, and sustainability education needs to explore the inherent dynamics of these interconnected systems.
- Systems are made up of components and interrelationships, defined by a boundary to suit the analysis. A system may be a component in a larger system. Hence, we have systems of systems. For example, the aged care system is part of the health system, which is part of a larger economic system.
- The relationships and interactions between the parts are critical, and an understanding of these relationships is important in sustainability education. These define the system behaviour.
- How we define a system depends on our perspective, our purpose. This will, in turn, determine the system boundary we choose and to what level of detail we set out to understand and model the system.
- Systems modelling is critical to understanding future system behaviour. System dynamics is one model, using stocks and flows, that can quickly be used to model a range of social and environmental systems to provide important sustainability knowledge and understanding of the associated system impacts.

So, what is systems thinking?

We use the word 'systems' a lot. We have computer systems, financial systems, gaming systems, electrical systems, ecosystems, etc. What do they have in common? First, any system is made up of parts, or *components*. For example, a car is made up of a chassis, wheels, a drivetrain, an engine, an electrical system, a battery, doors, a steering wheel, brakes, etc.

Second, these parts work together in reliable ways to produce the overall *behaviour* of the system and to fulfil the *purpose* of the system, in this case, transportation. When one

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essential part fails, we have probably all had the experience that the whole car fails, and we may be left on the side of the road, waiting for assistance.

So, the components *interact* with each other to make the car go. The battery provides energy to get the engine started. The engine provides power to the drivetrain, which turns the wheels. The brakes ensure that the car can safely slow and stop when required. The seats keep us comfortable, and the seatbelts keep us safe.

We could analyse our laptop in a similar way. There are a series of components, both hardware and software, that constantly interact to deliver the computing services that we require – word processing, web browsing, playing a game, reading email, etc. When a key component fails, our computer becomes much less useful, e.g., if our internet connection fails, our file storage fails, or the computer is infected by a computer virus.

Although these examples, the car and the laptop, seem like quite complex devices, they have quite predictable behaviour – well, at least most of time. It is tempting to think that if we understand each of their components and the interactions between them (how matter, energy, and information are transferred between the components) then we have understood the system.

This seems intuitively appealing and seems to match the world around us, which is mostly quite predictable. This process of reductionism (Riel & Gulick, 2019) has been popular for millennia, but particularly since Newton, when the universe as a giant machine became a popular concept (Dolnick, 2011). If we can understand the fine detail of component behaviour, we should be able to predict the system behaviour indefinitely.

Unfortunately, in the 1960s, this idea was completely disproved. We now know that even very simple systems can exhibit surprisingly complex behaviour. For example, see Mitchell (2009). Further, tiny changes to system parameters, including starting conditions, result in drastically different system behaviour. This has become known as the 'butterfly effect' – the beating of a butterfly's wings leads to changes in the weather on the other side of the globe – well, at least in theory. It's a nice image.

In this way, complex behaviour *emerges* from simple systems. We see *emergence* in insect colonies (ants, termites, bees, etc.), where very simple creatures band together to exhibit complex behaviours such as mound or hive building, hive defence, food gathering, food farming, and so on. Emergence in systems is often behaviour that we don't expect. We keep expecting systems to behave like machines and then they surprise us.

Let's consider an example of an ecosystem, where what seemed like a small change led to much bigger changes in the overall ecosystem.

Reintroducing wolves into Yellowstone Park

The alternative title to this section could be "How wolves change rivers" (Farquhar, 2021; Sustainable Human, 2014).

In 1995, grey wolves were reintroduced into Yellowstone National Park in the United States. Wolves had been eliminated from the park in the 1930s, perhaps for safety reasons. What surprised biologists was the *trophic cascade* of effects from this one species.

The *absence* of wolves had originally led to increasing numbers of elk, which overgrazed parts of the park, particularly consuming young saplings in the flat river valleys. Beavers need young willow plants to survive the winter, so as their food source disappeared, so did the beavers. The problem was exacerbated by the fact that the elk did not move much, particularly in winter, so the willows, so important to the beavers, were eaten away all year round.

Once the wolves arrived, the elk were much more mobile, often being chased into the higher forest rather than the valley floor, which allowed the willows and other trees to regenerate, which led to beaver populations growing. However, this was not the end of the changes.

In the absence of the elk, the valley floors regenerated, with plants and trees quickly growing tall. Songbirds arrived. The beavers built dams to create ponds, which created habitat for otters and muskrats, ducks, and other water-loving animals and birds.

The wolves killed coyotes, which meant there were more rabbits and rats and mice, which provided food for ravens and eagles and foxes and weasels and hawks. Bears fed on the carrion left over by the wolves, so their numbers also increased. They also attacked the elk calves, reinforcing the action of the wolves.

What is most interesting is that the rivers also changed. With more heavily wooded valley floors, the riverbanks were more stable. They meandered less; the channels themselves were more stable. Riffles and pools formed, which helped the animals living around and in the rivers. There was less soil erosion because of the heavier vegetation along the rivers.

So, the wolves not only changed the ecosystem, but they also changed the physical geography of Yellowstone National Park – truly remarkable!

Understanding systems

Could these changes have been predicted? The answer is probably yes. Were they a surprise? They certainly were, based on various coverage of these changes. How do we begin to understand systems so that we can be better informed about changes that we make in systems? We need systems thinking and some modelling tools.

When we approach a new problem, it's useful to get a sense of the whole picture. It's a bit like landing in a new city. A map is incredibly useful. It shows the layout of the city, which immediately gives us ideas about how we will move around in the city, where the key attractions, are, and so on.

Mindmaps

A mindmap is a useful first step in systems thinking, leading us towards understanding the parts and the whole of a system. Mindmaps favour a hierarchical subdivision, which is a useful way of getting our heads around the structure of a new system.

If we take the Yellowstone National Park example, the mindmap might look like this (Figure 4.1.1). This mindmap contains many of the relationships discussed in the example. However, it does not show those relationships in a way that helps us understand the system behaviour. We need a different type of map, which links components and relationships. Before we get to that, this is a useful point to formalise how to describe systems.

Some rules for systems

This approach is drawn from a wonderful book called *Systems Thinking Made Simple* by two authors who have spent 30 years researching how to simplify systems thinking to make it easier to apply by everyone (Cabrera & Cabrera, 2015).

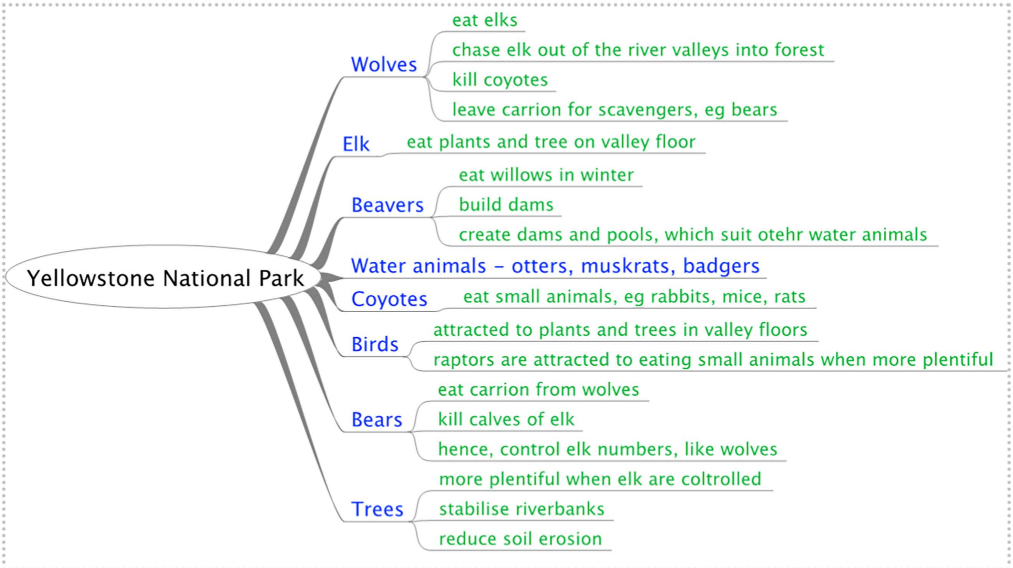

Figure 4.1.1 Mindmap for wolves reintroduced to Yellowstone National Park.

The Cabreras propose four basic concepts that are necessary and sufficient tools for systems thinking:

1. **Distinctions** (D) – We distinguish *parts* of the system from other parts, depending on our purpose. Similarly, we separate the system from its surroundings. This is a process of *boundary* making. How we draw the system boundary and which components we choose will be critical to our analysis and dependent on our purpose (see point 4).
2. **Systems** (S) **–** Every component can be considered a whole and also made up of parts, depending on the purpose. Systems are made up of subsystems. The degree to which we zoom in for more detail or zoom out for less detail depends on what is to be achieved (our purpose).
3. **Relationships** (R) – The parts that make up a system will interact with each other through the relationships between them, e.g., wolves reduce the number of elk, which means more willow trees, which means more beavers in the earlier example.
4. **Perspectives** (P) – We model systems for particular purposes. How we represent that system depends on what we are trying to achieve. A biologist might model Yellowstone Park as discussed previously. A hydrologist would model the same system quite differently, although there will be some common elements given that the wolves ultimately affected the behaviour of the rivers.

These four rules then need a graphical representation, so that we can share our systems thinking with others.

Representing systems

We start with components, the things we *distinguish* in the system. These are represented by rounded boxes. *Relationships* are represented by labelled arrows, as seen in Figure 4.1.2, which is produced by Plectica software (https://www.plectica.com) as described in Cabrera and Cabrera (2015).

This simple model can be extended further (Figure 4.1.3 and Figure 4.1.4) and extended further (Figure 4.1.5).

Similarly, the example of the honeybees, from the introductory chapters of this Handbook, can be represented as shown in Figure 4.1.6. This map represents the simplest version of the honeybee system. As we begin to think about how we might solve this problem, we would need to include components such as farmers, pesticide manufacturers, government regulation, lobbyists, and so on. The system diagram can grow as we better understand the system that we are hoping to change and improve.

Concept maps

What we see in the previous figures is what is known as a concept map. Concept maps are made up of nodes, the concepts or components in our case, and links, the interactions (relationships) between them. Figure 4.1.5 shows a concept map for the reintroduction of the wolves. In this map, the nodes are the various animals and plants that play a part in the ecosystem of interest. The links between them represent the interactions between the species. This map shows very quickly what is happening in the ecosystem. We could, if we wish, continue to add detail by adding further components and relationships.

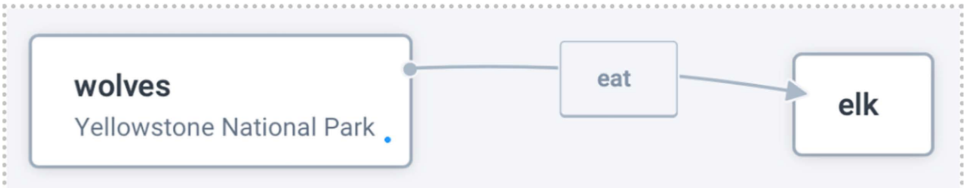

Figure 4.1.2 Two components plus a relationship.

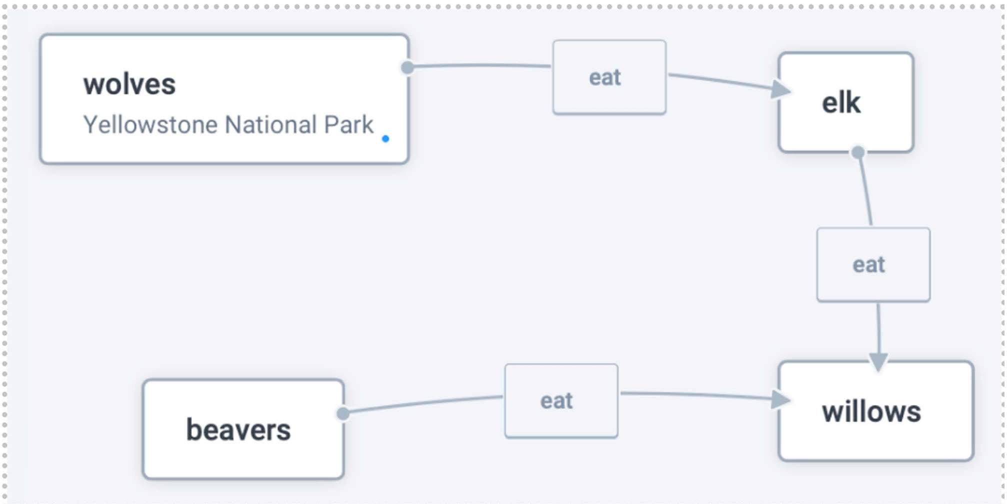

Figure 4.1.3 Some more components and relationships.

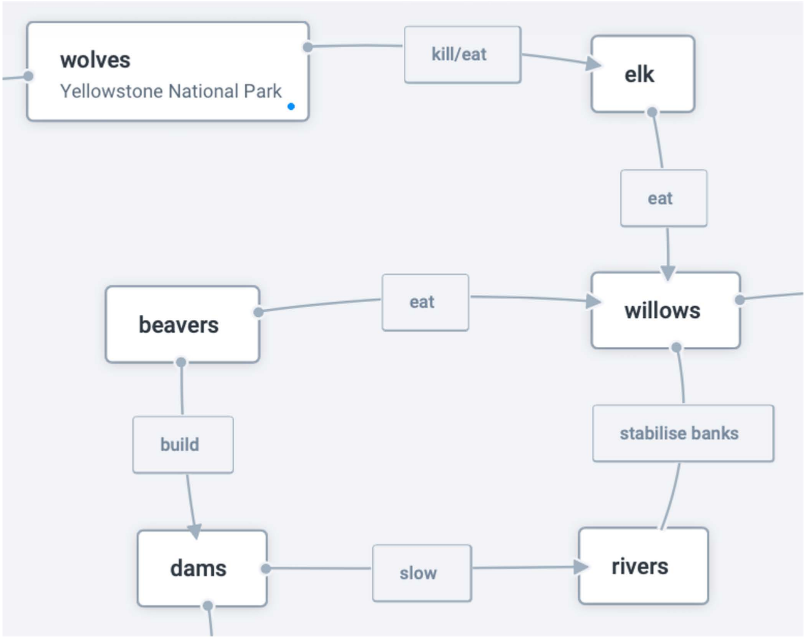

Figure 4.1.4 System map for wolves in Yellowstone Park.

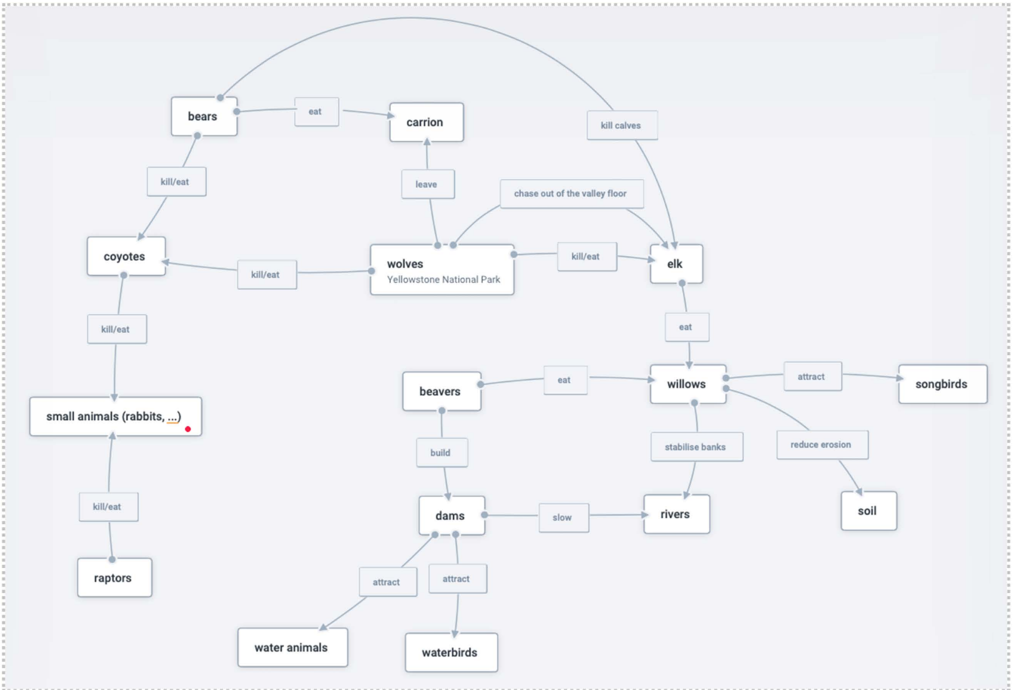

Figure 4.1.5 The complete system diagram (to the level of detail described earlier).

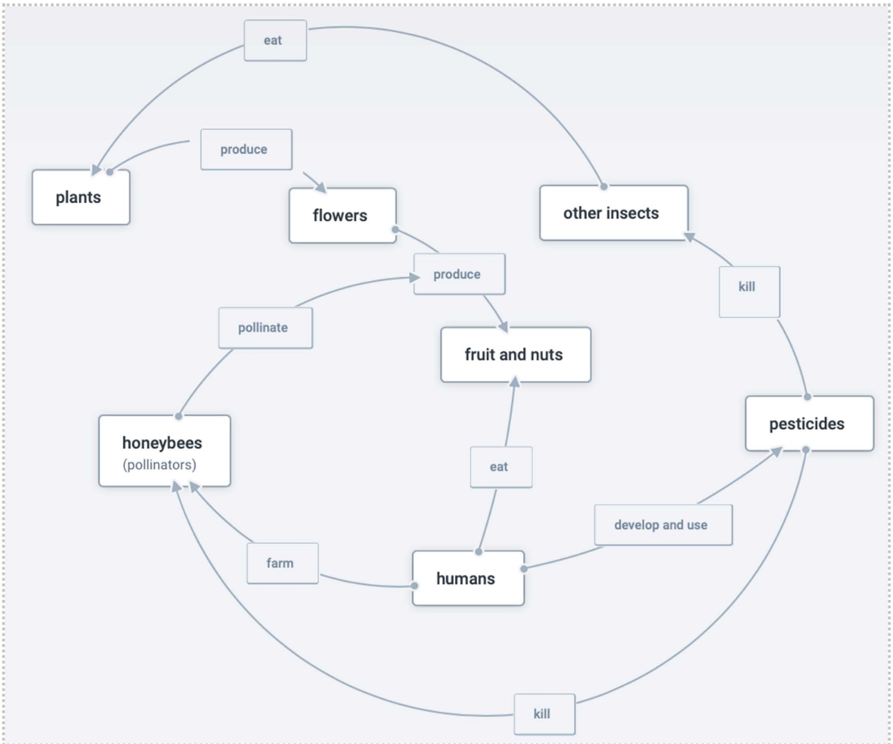

Figure 4.1.6 System diagram for honeybees.

This is also a useful point to talk about the system boundary. For our purposes, we always want to limit our attention to part of a much bigger system. In this case, we are interested in the wolves and their impact. We are not necessarily interested in the whole of Yellowstone Park, and we are not necessarily interested in all the animals and plants in the park as a whole. We just want to analyse a subset of the species.

So, we draw an imaginary boundary around the components that interest us. This could represent a physical boundary; for example, all the action might take place in one river valley, so the system corresponds to just that one river valley. However, even in that valley, we are only interested in some species. We may not be interested in all the tree species, for instance, just the willows and the ones that play an active role in the interactions that interest us.

We also need to recognise that there are interactions happening between the components of interest and other species which may not interest us. These interactions are assumed to not play a large part in how we understand the responses to the wolves.

So, boundary making is, possibly, the most crucial aspect of systems thinking. The boundary is defined by our perspective and our purpose. It tells us what is in and what is out of the current analysis.

There may be conflicts between stakeholders in terms of the boundary definition. In fact, this is almost certain. For example, a new coal mine is sold from the perspective of employment growth by its supporters (who stand to profit enormously from its development). Its opponents view it from an ecological disaster perspective – more CO_2 into the atmosphere, loss of biodiversity, pollution of water resources, and so on. These complex issues can only be addressed through careful systems modelling, which is, unfortunately, only too rare in the planning of large projects such as coal mines.

Open and closed systems

We can divide systems into *open* and *closed* systems. Open systems have exchanges across the boundary – mass, energy, information. Closed systems, obviously, have no such exchanges. All real systems are open systems, but we try to define the boundary so that the exchanges across the boundary will not affect our modelling of the system or are, at least, quantifiable for our purposes.

In our example, our system is clearly open, because there are countless interactions with the species being discussed, which are not represented in our system diagram.

A concept map is a great way of understanding a system qualitatively, but we usually also want to understand a system quantitatively. For this, we need to better understand the nature of the interactions between the components. Causal loop diagrams are a first, useful step on this path.

Causal loop diagrams

In causal loop diagrams, we represent the relationship of one variable to another. For example, as the wolves increase, the number of elk decrease, partly because the wolves kill and eat some of them and partly because the elk are chased into other parts of the park. Similarly, a smaller number of elk support a smaller number of wolves, so each species has a negative impact on the other, as shown in Figure 4.1.7.

This is called a *balancing* loop, because increases or decreases in one tend to be minimised by the other – brought back into balance. This is what we usually see as the natural balance in ecosystems.

The opposite of a balancing loop is a *reinforcing* loop, which tends to cause uncontrolled growth of one variable. This is what happened when the wolves were removed in the 1930s. Elk numbers increased without the natural check that the wolves exerted. This led to the other serious side-effects already discussed.

We can extend this diagram to include the other species we described earlier (Figure 4.1.8). This diagram usefully captures the positive and negative relationships within this ecosystem. What we now need is to be able to quantify these relationships. For this, we can use stocks and flow diagrams, which are the basis of system dynamics modelling (Forrester, 2007; Meadows, 2009).

Stocks and flow diagrams

The causal loop diagram is a useful way to begin to quantify system behaviour. However, if we want to be able to predict future system behaviour, then we need a more mathematical model. The stocks and flow diagram (SFD) is useful here, also known as *system dynamics modelling* (Meadows, 2009). Stocks are the components, e.g., the number of wolves or the number of elk. A flow is a change in a stock, which could be birth, death, and migration, in this case.

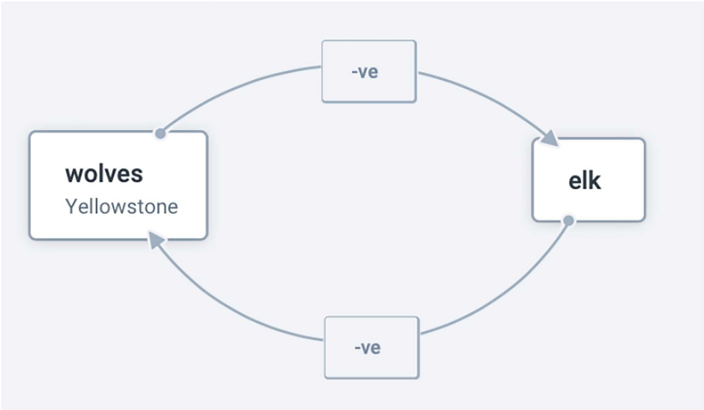

Figure 4.1.7 Causal loops between wolves and elk.

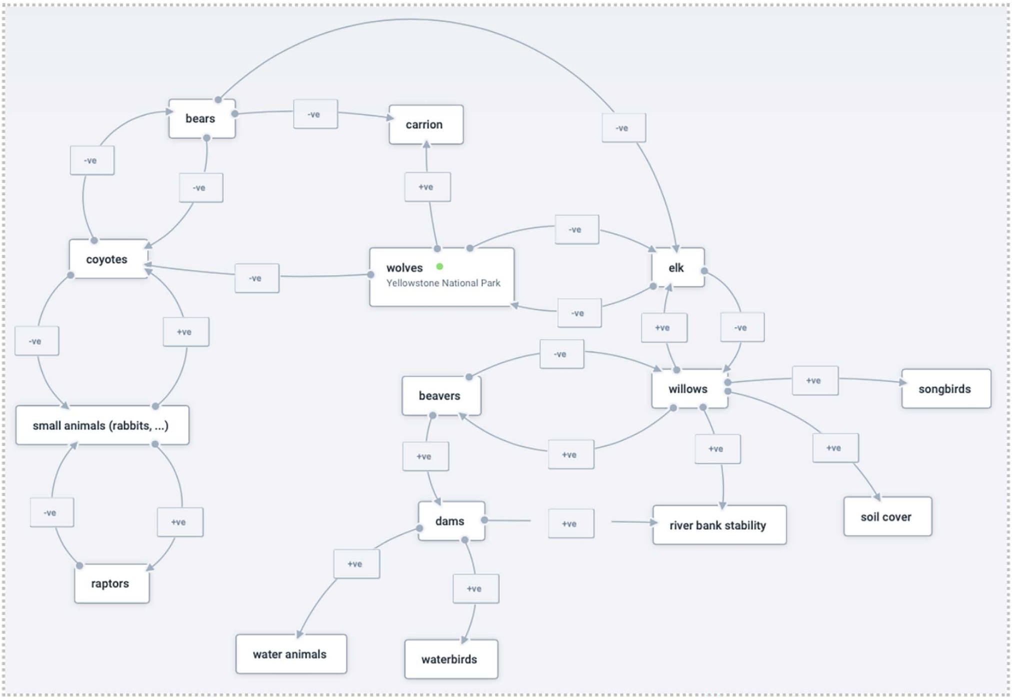

Figure 4.1.8 Causal loop diagram for major species in Yellowstone Park.

Figure 4.1.8 contains *information* links that represent the relationships between the variables. For example, the number of wolves increases the rate at which elk numbers decline, by predation and by chasing them elsewhere.

Figure 4.1.9 shows an SFD for the interaction between the wolves and the elk. The number of wolves and elk are the stocks, of course, and the rates of change of each of these variables are represented by pipelines with valves (the X symbol), which represent the rate of flow. The cloud symbols at each end of each pipeline represent source and sink, which, in this case, is the natural world, the source of all the materials that make up both animals.

Also shown in Figure 4.1.9 are parameter variables, which make the assumptions obvious. For example, the WolfBirthRate = 0.2 means that if the population is 10, 2 new wolves will be born. The DeathRate for each species works similarly. These are assumed values for the purpose of this modelling exercise.

The ElkNormal and WolvesNormal variables were introduced to simulate feast and famine. So, as the number of elk increase above ElkNormal, this increases the birth rate and decreases the death rate for the wolves, because food is plentiful. Similarly, as wolf numbers increase above WolfNormal, elk death rate increases and birth rate decreases.

The overall simulation is shown in Figure 4.1.10, as produced by the AnyLogic software (The AnyLogic Company, 2021). The time period is one year, suggesting a boom-and-bust cycle of 25–30 years for Figure 4.1.10.

Now that the model is working, it is possible to experiment with parameter values. For example, Figure 4.1.11 shows the same simulation where the wolves reproduce at half the rate and die at half the rate as in Figure 4.1.10. Notice that the elk become slightly more plentiful and the wolves slightly less so and the cyclic behaviour has stretched out to about 40 years.

These well-behaved simulations may be due to setting the normal values for the population at 10 wolves and 20 elk. If different starting conditions are used, the results become more dramatic, for example, Figure 4.1.12 and Figure 4.1.13.

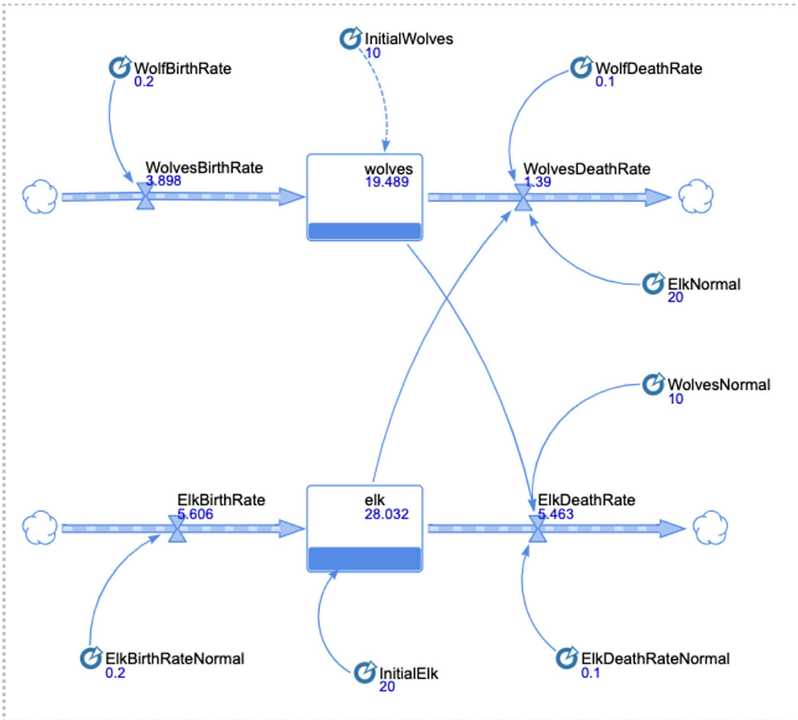

Figure 4.1.9 Stocks and flow diagram for wolves and elk.

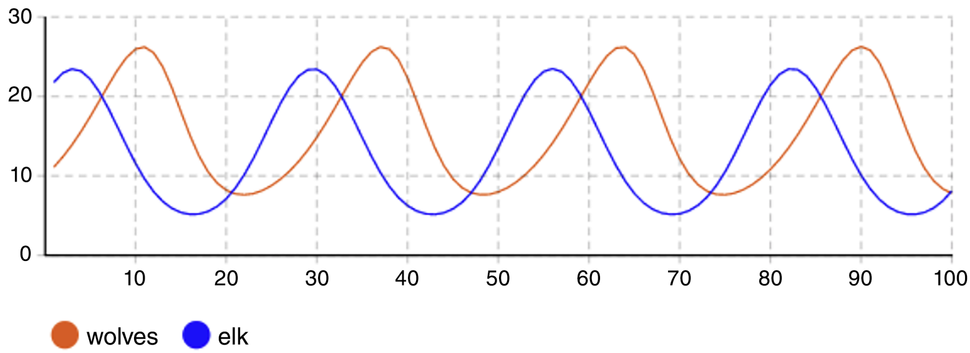

Figure 4.1.10 Simulation of ecosystem balance of wolves versus elk.

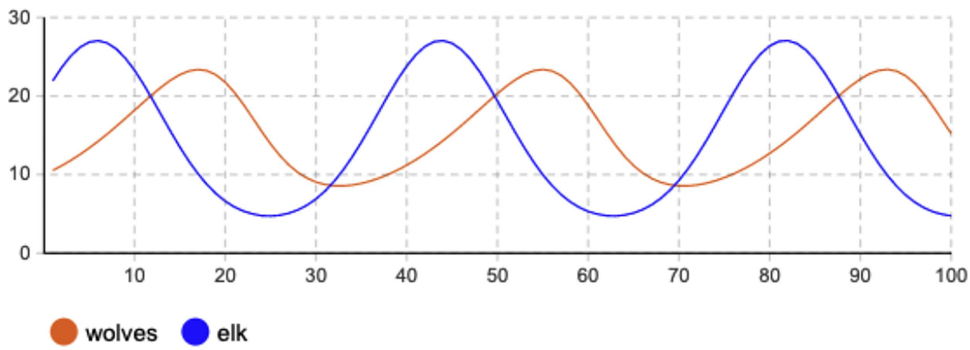

Figure 4.1.11 Simulation for reduced birth and death rates for wolves.

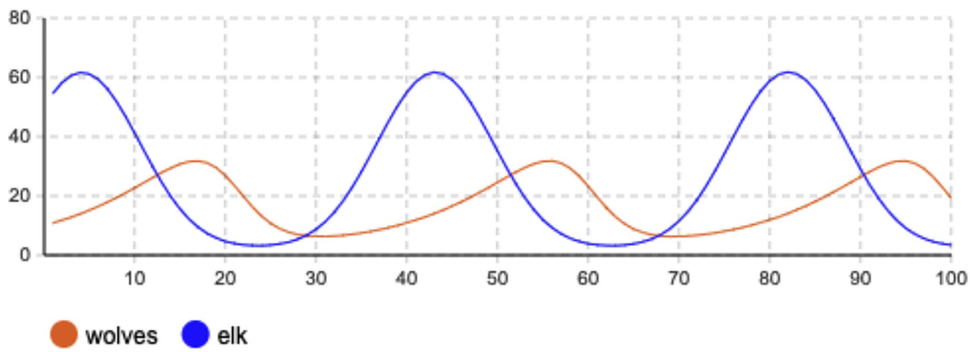

Figure 4.1.12 Simulation with 50 elk and 10 wolves.

You might expect that the starting conditions should not affect the overall system behaviour. The system should converge to a standard solution once the starting conditions have washed through. However, this simulation suggests this is not the case. Each simulation goes through a boom-and-bust cycle but each is different, depending on the starting conditions.

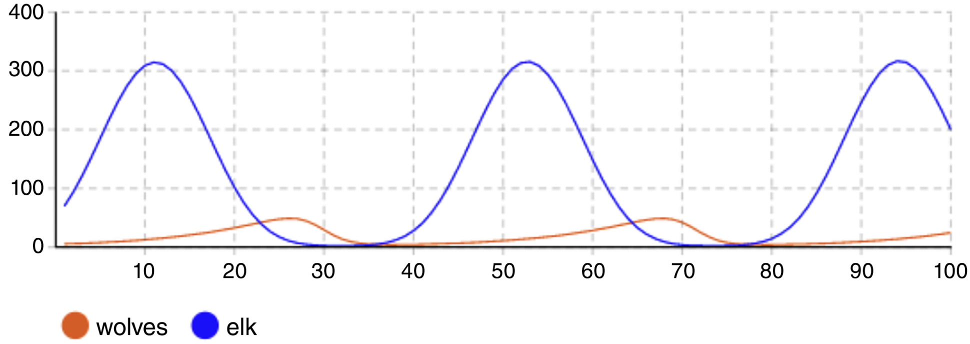

Figure 4.1.13 Simulation with 50 elk and 5 wolves.

Other state variables also play a part. For example, the temperature changes with the seasons. Animal behaviour is also dependent on temperature and the seasons. So, the birth rate might decline during very cold seasons or if food is unavailable.

The other parts of our original model (Figure 4.1.8) could be similarly represented as stocks and flows and then calibrated on actual data collected in the ecosystem. The various parameter values noted earlier have been assumed. Data need to be collected to verify these. With this modelling tool, it should be possible to better quantify the changes occurring within the ecosystem.

Other models for other systems

There are many other systems modelling tools, often built for quite specific purposes. Electrical systems are modelled via Kirchhoff's and Ohm's laws. Mechanical systems use Newton's laws, equilibrium of forces and moments, and compatibility of displacements. Physics relies on traditional mechanics or quantum mechanics, depending on which system is of interest. These systems and disciplines also have their own conventions for graphical representation of the system of interest.

Challenges for systems thinkers

All these modelling tools deal with *facts*. They capture our best understanding of how a system behaves in scientific terms. Where we run into trouble is when we take a too narrow view of the system of interest. We draw the boundary to suit our interests. A broad engagement with stakeholders can alleviate this problem, bringing multiple perspectives into the conversation. This would allow us to expand the system diagram to include not just economic matters, for instance, but also social and environmental effects.

The bigger problem is that once the facts are included, we then must grapple with the *values* that we place on the different aspects of the system. For instance, how do we balance biodiversity loss against employment? Can we predict the effects on groundwater from fracking? Who wears the consequences? For some stakeholders, short-term benefits (e.g., employment) dominate their thinking. For others, long-term consequences (e.g., environmental degradation) matter more.

This problem of facts versus values has a long history in philosophy and was made famous by David Hume in the 18th century (Hume, 1739). Hume described this as the *is-ought* problem and stated that matters of value (what we believe ought to be true) cannot be derived from what is (the facts). This is the major challenge for decision makers in complex sustainability issues. Although we may be able to agree on what is, by building an inclusive systems model, we cannot necessarily agree on what ought to be done.

Waste management example

The systems considered so far have been natural systems – wolves and elks in Yellowstone and bees and their importance to human agriculture. These tools can also be applied to technical systems such as waste management (see Chapter 2.4 in this volume). In Australia, most households have a co-mingled recyclables bin where they can place paper, cardboard, recyclable plastics, aluminium cans, and steel cans.

From a waste management engineer's point of view, the system looks like what is shown in Figure 4.1.14. The engineer is concerned with designing adequate collection and transport processes and a sorting plant that properly sorts the waste for recovery and further processing.

However, there are many other parts of this system. For example, we need households to sort their waste to both maximise the waste going to landfill and to minimise the waste that goes into the co-mingled bins. This requires a level of 'waste awareness', which must be generated through education campaigns (including in schools).

The waste management leader at the local council is more interested in household behaviour to reduce waste through improved purchasing decisions and to increase recycling habits. Their part of the system diagram looks like Figure 4.1.15. The concept called waste

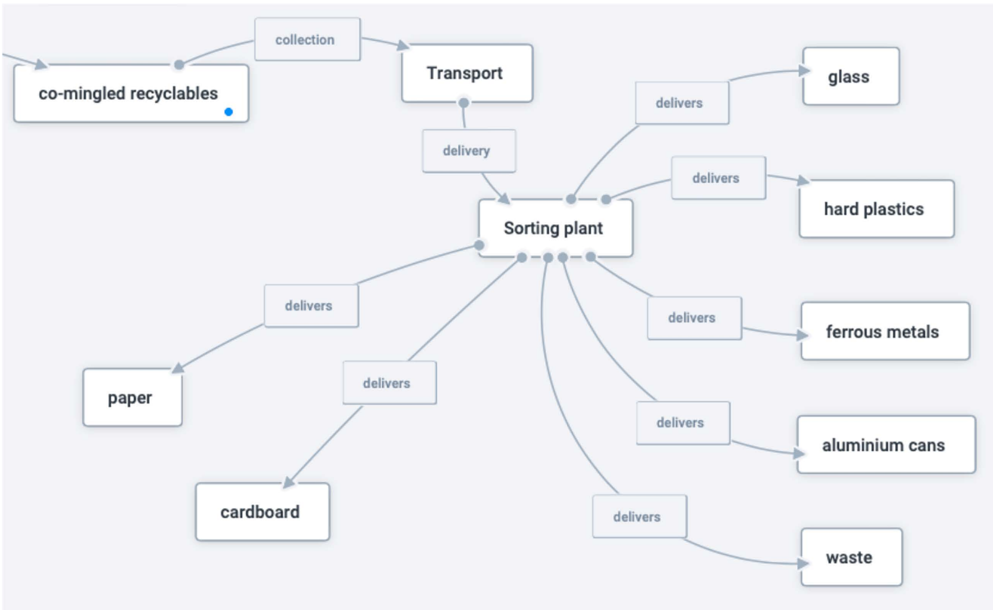

Figure 4.1.14 Co-mingled recyclables processing.

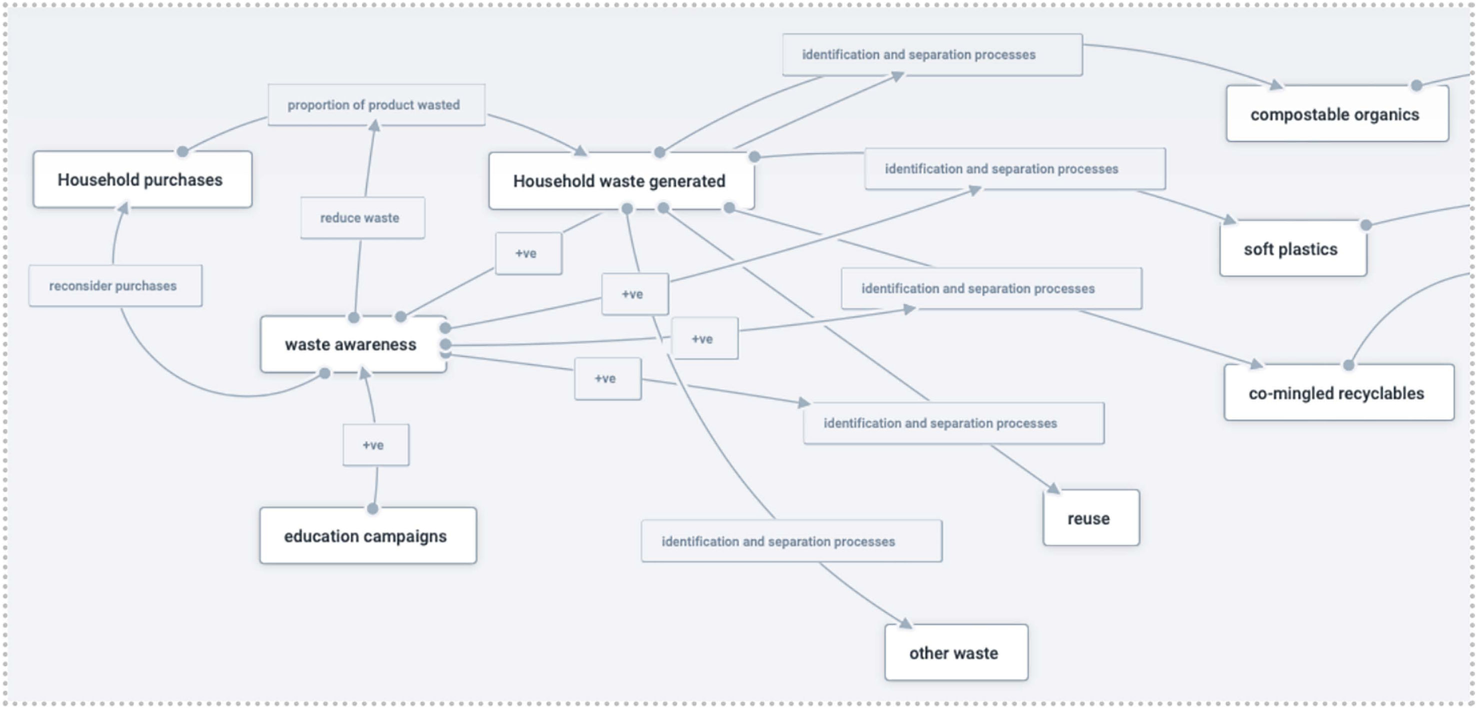

Figure 4.1.15 Household recycling habits.

awareness is quickly shown to have a profound effect on a range of identification and separation processes as well as altering household purchasing decisions, e.g., looking for products with less packaging, using refillable containers, and simply buying less, perhaps growing more food in the backyard.

These two system views meet at the kerbside, where household habits meet the collection system (Figure 4.1.16). This is a rather simplified view, which also highlights how complex such a system can quickly become. It also helps both the engineer and the waste management leader realise that they need to better understand each other's needs if the system is to work well. Smarter recycling as well as reduced quantity of waste ultimately helps the engineer to deliver an effective recycling service.

Further elaboration could consider the 'other waste' category, most of which goes to landfills in Australia, an increasingly fraught solution due to groundwater contamination and the difficulty of finding suitable sites near to major cities. Sweden, and others, have solved this problem by incineration, which then returns energy to the grid. Extending the diagram to include these processes is left as an exercise for the reader.

Having built the system diagram (Figure 4.1.16) the next stages are to work through the other system diagrams described earlier – the causal loop diagram and the SFD – to begin to quantify the effects in the system, such as education campaigns. What evidence might be collected to quantify the value of education campaigns? How does spending on education increase recycling rate and decrease waste in the recycling bins?

Conclusions

Systems thinking is an essential skill to understand and to manage any complex problem in the world, particularly the challenges of climate change, which are global by nature. Systems thinking requires some discipline to spend time identifying the *components* of the system as well as the *boundary* that defines the system of interest. It is also necessary to define the *detail* to which the system will be studied. How many components matter and at what level of detail?

Identifying the *relationships* between the components is the next key step in systems thinking. These relationships define the *interactions* between the components. These interactions define how the system *behaves*. If we can quantify these relationships, we can model the future behaviour of the system to some degree.

Implicit in this approach is the *perspective* from which the system is viewed. It cannot be assumed that my perspective is the same as yours. This explains the difficulties in stakeholder engagement, when multiple perspectives must be carefully elaborated if the system is to be understood from all perspectives.

This approach relies on the four fundamental rules of systems thinking – making distinctions, forming systems, identifying relationships, and defining perspectives. Modelling tools, such as Plectica, can enable system models to be quickly defined, enabling all stakeholders to agree on how the system is represented.

The next stage is to use quantitative modelling tools, such as causal loop diagrams and stocks and flows models, to predict future system behaviour. In sensitive ecological systems, these models can then provide insight into how the system might be managed.

Systems thinking is an essential tool in understanding complex sustainability problems, where economic, social, and environmental needs and constraints inevitably conflict. The difficulty that our politicians seem to be having in responding to climate change highlights

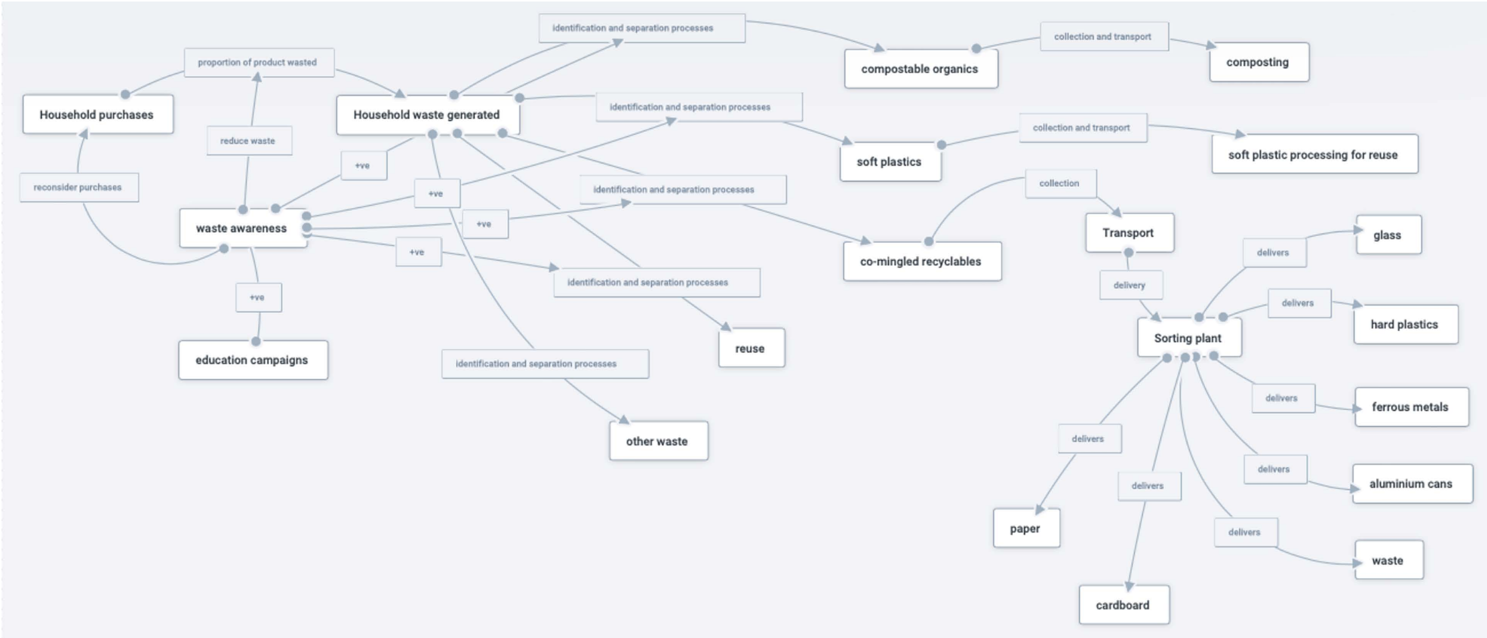

Figure 4.1.16 Household waste recycling.

the fact that we humans struggle to see the world in systems and to understand future consequences. Systems thinking helps us to structure our woolly thinking about the future and gives us tools that we can share with each other to frame important conversations about our shared futures.

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4.2

THE VALUE OF LIFE CYCLE THINKING IN SUSTAINABLE ENGINEERING EDUCATION

Wahidul Biswas and Michele John

Key concepts for sustainability education

- Life cycle thinking (LCT) is a valuable threshold concept in sustainability education highlighting the economic, social and environmental impacts from a product or service over its life cycle.
- LCT helps to explore the opportunities for improving our production and consumption decisions towards sustainable development outcomes.
- Life cycle sustainability assessment (LCSA) is used to demonstrate how LCT can improve sustainability performance of our modern production and consumption decision making.
- LCT also highlights the important role of cleaner production strategies, eco-efficiency, industrial symbiosis, design for the environment, green engineering in engineering curricula and their role in sustainable engineering management solutions.

Introduction

Life cycle thinking (LCT) is a concept that emphasises the need to understand the environmental, social and economic impacts from a product or service over its entire life cycle. LCT can assist with the innovation of products and processes throughout the product/service life cycle to help achieve closed-loop material flow and to decouple emissions and resource use from economic growth (Biswas and John, 2022).

Life cycle thinking is also a threshold concept in the teaching of sustainability (see Chapter 3.3 in this volume). Life cycle thinking (LCT) requires students to recognise the total lifecycle associated with our production and consumption decisions – from product design, to material sourcing, production, use, end of life waste management and disposal. This prompts a significant shift in the students understanding of the full extent of the environmental and social impacts associated with a product or service from product idea conception to the products final waste disposal. (see Chapter 3.7 in this volume).

LCT is focused on a longer term view of the impacts of our production and consumption decisions and requires a very detailed understanding and evaluation of the all processes involved including all inputs/outputs into and out of the production/service process.

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LCT analysis often requires large sets of data in order to fully understand all inputs and outputs involved in the making of the product/service and requires an understanding of system thinking (see Chapters 3.3 and 4.1 in this volume) and triple bottom line concepts in understanding the inherent sustainability performance of the product/service. Furthermore, life cycle thinking is critical in supporting design thinking development as it is fundamental to the students understanding of how the full life cycle of the product/service interfaces with its sustainability performance.

LCT promotes a broader and more complete understanding of the economic, environmental and social impacts from our production and consumption decisions, moving student learning away from the typical single solutions and narrowly defined discipline-specific problem definitions often presented in our engineering thinking (see Chapter 3.3 in this volume).

This chapter also discusses how the Sustainable Engineering Group (SEG) at Curtin University has incorporated the concept of LCT into a multidisciplinary engineering unit for undergraduate students called Engineering for Sustainable Development (ESD). Secondly, it explores how this concept has been utilised to emphasise the value of LCT in forging an increased awareness and responsibility for whole of life cycle design and operation in the minds and skill sets of young graduate engineers.

Life cycle thinking in engineering sustainability

Engineers play a pivotal role in implementing the sustainable development agenda. After the Earth Summit in 1992, a group of engineers identified that approximately 70% of the issues listed in the Agenda 21 Action Plan involved engineering design, and at least 10% of these issues had major engineering applications (The Natural Edge Project, 2007). Universities across the world have been developing approaches to equip engineering graduates with the values, problem-solving skills and knowledge to successfully apply the principles of sustainable development throughout their professional career. Sustainable development is a normative concept because it views the world not in the way it is, but in the way it should be (Wiek et al., 2011). Therefore the skills required by practitioners for sustainable development represent a meta-disciplinary endeavour, combining information and insights across multiple disciplines and perspectives, with a common goal of achieving a desired balance between economic, environmental and societal objectives (Mihelcic et al., 2003). This suggests a need for a range of sustainability metrics and methodologies such as life cycle thinking, system thinking, multicriteria decision-making tools and impact assessment frameworks in engineering education (University of Cambridge, 2016).

According to Boyle (2004), "the engineering context of sustainability involves the design and management of sustainable technology, research into environmental and social impacts and limitations, living within global limitations, and management of resources from cradle to cradle" (Boyle, 2004). Engineers help convert raw materials into products and services. Their decisions influence a number of important production factors including:

<u>Design</u>: Optimised process, structure, mechanical element, chemical reaction.
<u>Operation</u>: Risk management, cleaner production strategies, social consideration.
<u>Maintenance</u>: Risk management, cleaner production, good housekeeping
<u>After use</u>: Recycling, decommissioning strategies

LCT can enhance sustainable engineering curriculum by incorporating economic, environmental and social consequences across the product or service life cycle. It identifies the opportunities to reduce environmental and social impacts during production from the extraction of raw materials to the processing, manufacturing, assembly, distribution, use and ultimate disposal stages.

A key aim of LCT is to avoid 'burden shifting' (European Union, 2010). This means minimising the impacts at one stage of a product life cycle or in a particular geographic region or impact category while avoiding increases in other production stages. Some examples of the potential role and value of LCT include:

- Comparing different versions of the same product offering the same service.
- Identifying the 'hotspots' or processes or inputs or life cycle stages of a product or service which show inefficiencies in the use of materials and energy, consequently allowing economic, energy and material savings.
- Conceiving new products, processes or services in agreement with sustainability principles (i.e. resource conservation, eco-design, waste reduction).
- Providing data for a scientific and objective basis for impact analyses.
- Guiding the development of green procurement policy.
- Providing data for environmental (green) product development
- Development of an environmental management system (EMS) for the sustainable maintenance of assets by ensuring minimal impact on the environment and resource efficiency.

LCT encourages the holistic consideration of the entire product value chain. Designers, planners, manufacturers, engineers, consumers and recyclers should all consider the life cycle of products/services, specifically, to understand the inputs (including resources such as energy and water) and outputs (emissions to the environment) that result from the transformation of resources into a product, from a product to service, and from service to end-of-life (EoL) disposal (cradle to grave).

LCT focuses on assessing the sustainability performance of products and services and can be used by decision makers in the private and public sector in the development of sustainable products, in green procurement (e.g. organic fertiliser, bio-fuels, recycled composites, solvent free paints) and in the provision of environmentally friendly services (e.g. solar electricity, 3D printing) (UNEP, 2016; Klöpffer, 2003).

One of the most well-known applications of LCT is in environmental life cycle assessment (E-LCA), normally referred to as life cycle assessment (LCA) (see Chapter 3.5 in this volume). LCA was developed by industrial ecologists to evaluate the environmental impacts of products and services during all phases of their life cycle (UNEP, 2012). In recent times, significant progress has been made in the development of LCA methodology, allowing engineers to more holistically assess environmental impacts across all stages of production, use and EoL disposal of a product (Mihelcic et al., 2003). LCA enables engineering students to consider the application of the 6Rs (reuse, reduce, remanufacture, redesign, recycle and recover) to reduce environmental impact as well as to reduce raw material input, energy use, processing time and associated costs of production (Meo et al., 2014) (see Chapter 2.4 in this volume).

LCT can also be used in design for environment (DfE) applications including the redesign of a product to meet legislative requirements or design for recycling and disassembly (Jensen and Remmen, 2005). LCT can assist in the conservation of natural resources and a reduction in land use, therein increasing the carrying capacity of the Earth by decreasing the ecological footprint associated with production, consumption and waste disposal.

A reduction in chemicals and energy use in the product life cycle can also provide intragenerational equity benefits.

LCA has been accepted as an engineering impact assessment technique and forms an important component of engineering sustainability courses in the UK and the United States. According to the Royal Academy of Engineering (2005), LCA is considered one of the top four skills for a graduate engineer. Finnegan et al. (2013) reported that as a result of increasing demand from industry, LCA has been included in the built environment curriculum across a number of US and European universities. An Australian study by Shah and North (2010) found that the demand for LCA skills within the Australian workforce was increasing, highlighting the increasing industry application and value seen in LCT.

Europe is considered to be well advanced in LCT research with a group of European universities exchanging resources in developing LCT-related courses ranging from sustainability to product design (Shaw et al., 2007).

The implementation of LCA and carbon foot printing at the School of Chemical Engineering and Analytical Science and the University of Manchester, UK, found that LCA presented an important research opportunity for chemical engineers (Gallego-Schmid et al., 2018). This coursework went beyond the calculation of results and gave students key transferable skills to increase their employability, such as the capacity to negotiate/discuss in groups, software learning and to develop critical thinking ability by taking LCT into account.

Some literature discusses the application of an LCT approach in engineering education (Minguez et al., 2021b). Lin et al. (2012), in their paper on LCT, discussed the application of LCA as a construction management tool, but did not explicitly discuss supply chain management and/or socio-economic implications. In the Clarkson University model (Powers et al., 2011), LCT is taught as a part of an Industrial Ecology unit, which involves students utilising LCA to identify potential environmental solutions. By comparison, RMIT University, Melbourne, offered an entire unit on LCA in their undergraduate engineering course (Crossin et al., 2011).

The Sustainable Engineering Group (SEG) at Curtin University, Western Australia, have been teaching a core engineering unit in 'Engineering for Sustainable Development' to undergraduate students for all most two decades (Rosano and Biswas, 2015). This chapter examines how this undergraduate engineering unit embraced the concept of LCT to enhance the value and importance of sustainability management education in an undergraduate engineering degree.

Teaching LCT to Curtin engineering students

The unit on ESD is typically taken by second- and third-year BEng students. ESD deals with the contribution of engineering technologies and processes to the development and implementation of sustainable solutions using LCT principles. The pedagogical approach for teaching LCT to ESD students involves both passive and active learning techniques. The passive learning provides a conceptual understanding of LCT through well-structured, theory-intensive lectures, case study presentations and topical sustainability-related reading materials and case studies.

The problem-based active learning gives the students an opportunity to solve open-ended and complex real-world problems (wicked problems) in supervised workshops and through assessments. The students are provided with the activities to develop an LCA framework where they learn to work collaboratively in solving the given sustainability problem. This problem-based active learning has been found to improve sustainability knowledge development and helps students develop the skills required in solving complex multidisciplinary engineering problems. Students need to initiate the problem-solving collaboratively and in doing so develop a better understanding of the importance of multiple ways of knowing and perspectives in solving complex sustainability challenges (Greiff et al., 2013) (see Chapter 3.3 in this volume).

Similar pedagogical approaches are found in other engineering-related courses. The University of Washington (UW) has incorporated LCT into their civil and construction engineering coursework (Lin et al., 2012). Following the lectures, students are given a series of assignments that also use an LCA framework. Clarkson University provide LCT education through a unit on industrial ecology, which is followed by exercises utilising an LCA framework to identify potential solutions for supply chain environmental improvement (Powers et al., 2011). Cornejo and Orner (2019) demonstrated the value of LCA and life cycle cost analysis in a semester-long group project in Costa Rica. They noted that LCT helped students to develop engineering competencies that focus on producing solutions and making informed decisions accounting for global, cultural, social, environmental and economic factors.

Roure et al. (2018) proposed a systematic sustainability assessment framework using an LCA approach in the civil engineering department at the Université de Sherbrooke, Canada. They focused on the application of LCA approaches and tools such as E-LCA and life cycle costing (LCC) in civil engineering curricula. At the University of Michigan-Flint in the United States, systems-based LCT and sustainability concepts are incorporated into engineering curricula through two courses on industrial ecology and LCA (Lee, 2015). The Department of Quantitative Sustainability Assessment (QSA) at the Technical University of Denmark also included LCA in the engineering curriculum, with a progression in LCA complexity from bachelor's degrees to master's/PhD level (Olsen et al., 2018).

LCA is considered a valuable sustainability assessment tool for assisting Curtin engineering students in the development of sustainability competencies in both sustainability understanding and sustainability measurement. As noted earlier, many European and American universities are also embracing the concept of LCT in engineering curricula to help provide a sustainability education for their students.

Enhancing LCT through the application of life cycle sustainability assessment (LCSA)

LCSA is an effective approach in the teaching of LCT concepts (UNEP, 2012). LCT requires LCSA to include E-LCA, social life cycle assessment (SLCA) and Life Cycle Costing (LCC) to determine triple bottom line (TBL) indicators for a product/service, given system boundary or life cycle stages, in order to be able to assess the overall sustainability performance of the product or service.

Sustainable product design

Students learn that LCSA is a 'sustainability assessment tool' to help identify hotspots (inputs or processes) causing the most environmental or social impact. E-LCA (or LCA), LCC and SLCA are established LCSA tools specifically designed to assess these impacts during the life cycle of products and services. In addition to LCSA, ESD also covers the following industrial ecology topics that are also taught to further enhance the students' ability to apply mitigation measures across the product life cycle to achieve better sustainable engineering outcomes.

Design for the environment

DfE principles aim to minimise significant environmental impacts and increase resource efficiency at all stages of a product's life cycle – from raw material extraction and processing to manufacturing, packaging and distribution, product use and EoL disposal (see Chapter 3.2 in this volume). Students learn eight eco-design strategies, including new concept development (e.g. delivering services instead of selling products), use of low-impact materials (e.g. vegetable ink), renewable materials (e.g. compostable plastic made of biopolymers derived from corn to replace petrochemical based plastic), reduction of material usage (e.g. aerogel, carbon fibre composite), optimisation of production techniques and optimisation of distribution systems (e.g. designing packaging systems so that more items can be transported in one trip), designing a product cost-effectively with reduced energy and material consumption and designing a product for reduced environmental impact. Importantly, the students also learn that the initial design of the product is very important, as it can make the EoL product more suitable for reuse, recycling and remanufacturing.

Cleaner production and eco-efficiency

Cleaner production strategies (CPS) are selected to reduce overall environmental impact in a cost-effective way. Students are given examples of CPS that not only reduce environmental impacts, e.g. turning waste into resources, but also to achieve economic benefits from higher cost-benefit ratios and shorter payback periods. Students learn that the application of CPS can help restructure environmental supply chains to assist in reducing life cycle impacts.

Students also learn that CPS can help achieve eco-efficiency improvements (i.e. doing more with less). A workshop activity on incandescent lamps versus compact fluorescent lamps (CFLs) focuses on the initial additional cost of the CFL being offset against reduced operational costs and reductions in environmental impact and delinking growth from environmental impact. In practice, cleaner production and eco-efficiency can be regarded as "two sides of the same coin as they are rooted in environmental prevention strategy" (Biswas and John, 2022). They go beyond pollution prevention by explicitly incorporating conservation of materials, energy and other natural resources for future generations.

Industrial symbiosis

Students also learn that they can consider industrial symbiosis (IS) as a mitigation strategy in product life cycle management, where neighbouring production industries can share their waste, by-products and outputs with reduced dependency on the use of virgin materials and waste disposal. This strategy reminds engineering students of their responsibilities in designing 'waste' out of production systems and thinking of 'waste' as a potential resource material.

The concept of 'source and sink' is also taught to enable students to understand that the reduction in sink (or landfill) by converting waste/by-products at the EoL ultimately will reduce the amount of land required for mining and production and other associated upstream activities. Students learn how the application of the concept of industrial symbiosis can conserve energy, material and natural resources, increasing the carrying capacity of the Earth and enhancing intergenerational social equity (i.e. leaving adequate resources for future generations).

Green engineering

Green engineering is integral in the development of sustainable technologies, as it focuses on the systematic evaluation and improvement of the environmental performance of industrial products and the design of new processes and procedures that are resource efficient with less environmental impact (USEPA, 2021). This is achieved through green chemistry (i.e. increased atom efficiency or maximising the amount of product with less waste creation), biotechnology (e.g. use of enzymes as a catalyst to reduce a number of chemical reactions/steps), nano-technology (e.g. photo-catalytically active TiO_2 self-cleaning, anti-graffiti and anti-fingerprint coatings), biomimicry (e.g. mimicking bird flight in designing an efficient aircraft), waste prevention instead of treatment, design for separation and green design (e.g. recycled aggregates replacing virgin crushed rock limestone aggregates in pavement construction). A biomimicry teaching example on technological innovation shows how the behaviour exhibited by birds in flight can provide economic and environmental benefits when mimicked in aircraft aerodynamics, where:

- Reducing the wake results in lower pressure a differential across the aerofoil.
- This lower pressure differential creates lower force (drag) acting against the direction of motion.
- Lower drag (force) = lower power (force × velocity) required to maintain the same velocity.
- Lower power requirement means lower fuel consumption.
- Lower fuel consumption means lower environmental impact and improved economic performance.

Dematerialisation

Students are introduced to the concept of the 6Rs, including reduce, reuse, recycle, redesign, remanufacture and recovery, that can potentially reduce energy and material consumption and associated environmental impacts during upstream activities using virgin resources. As a part of a workshop activity, students conduct an analysis on the carbon footprint of a Fuji Xerox multifunctional device (MFD), which performs the tasks of a fax, printer, photocopy machine and scanner. Students determine whether or not to purchase a standalone photocopier, printer, scanner and/or fax machine or to purchase an MFD (four items in one). Students also work out that the use of electronic communication avoids paper use that then results in a decrease in deforestation, land use change and unnecessary loss of biodiversity.

Decarbonisation

Students are taught to make critical judgements on decarbonisation activities. An LCA approach has been found to be a useful tool for enabling students to assess whether carbon reduction initiatives like biofuel or carbon capture and storage systems (CCS) are actually carbon neutral. Whilst biofuel combustion does not produce greenhouse gas (GHG) emissions, the production of required feedstock does use chemicals and machinery, which also create emissions. Likewise, ‘low-carbon’ biofuel production often requires energy to capture and then sequester the CO_2 produced under ground, resulting in additional energy use. As a result, CCS in itself is not necessarily carbon neutral as a carbon sequestration activity.

Figure 4.2.1 summarises how the previous industrial ecology topics are delivered in the ESD unit to assist students in enhancing their LCT skills in order to design more sustainable products and services.

LCA as a decision-making tool

Students also learn that LCA is a decision-making tool that can be used to compare the environmental performance of products doing the same job. One example used is the comparison between fast-food and dine-in restaurant meals. When students compare the overall life cycle results that take into account the mining, processing, farming, packaging, disposal of pre-restaurant waste and the use and disposal stages of food production, they discover that the dine-in restaurant performs better than the fast-food restaurant. LCT can be an eye opener and 'threshold concept' for young engineering students in fully understanding the link between LCT and sustainable production and consumption and sustainable engineering decision making (see Chapter 3.3 in this volume)

LCT has matured, moving from its academic origins to more powerful approaches that can efficiently support the provision of more sustainable goods and services through efficient use in product development and external communications in support of customer choice and in public debates (Sonnemann et al., 2017). LCT can be applied to policies focusing on design for sustainability, sustainable consumer information, sustainable procurement and zero-waste management as well as sector-specific policies like sustainable energy and resource-efficient material and food production and supply. It is expected that the use of LCA in policies for the TBL sustainability assessment of products will further expand.

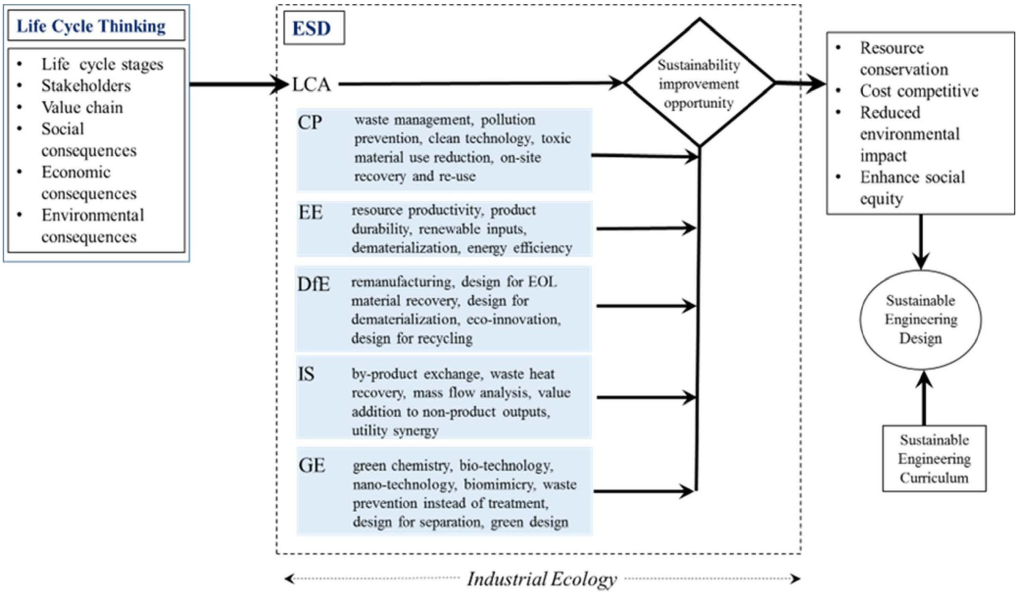


Figure 4.2.1 Relationship between life cycle thinking and sustainable engineering curriculum [CP – Cleaner Production, EE – Eco-efficiency, DfE – Design for the Environment, IS – Industrial Symbiosis, GE – Green Engineering] in the ESD unit at Curtin University.

Critical thinking capability

In this ESD course students are given a number of case studies that show how the use of LCA can improve their critical thinking capability. For example, in a workshop case study, students initially believe that solar photovoltaic (PV) energy and biodiesel energy production are almost carbon neutral as they are considered a renewable energy source. However this perception changes when LCA results show that the manufacturing of solar PV panels and biodiesel crop production systems do produce emissions that also need to be managed and minimised through cleaner production and eco-efficiency strategies.

In another example, on a comparison between a corn-based plastic (polylactic acid or PLA) cup and a polystyrene (PS) cup, students discover that the latter is more environmentally friendly than the former. The students are unable to comprehend this initially, as they consider corn a renewable resource. Corn-based plastic has been found to be environmentally friendlier than PS on weight basis, but not on a volume basis. The students' perception changes when they realize that the function of the cup is to hold liquid, so space and volume matter. Since the PS cup is lighter than the PLA cup, it requires less material to provide the same utility volume, and therefore, the PS cup turns out to be the more environmentally friendly option. Whilst this comparative LCA outcome can change depending on the choice of transportation and method of environmental impact estimation (van der Harst et al., 2014), students are able to understand that something 'natural' is not always the most environmentally friendly option, which in turn suggests a need to investigate sustainability assessment methodologies to more accurately understand full life cycle impacts and support critical thinking in engineering decision making.

Circular economy

The industrial ecology topics in Figure 4.2.1 that are delivered in the ESD unit can help avoid upstream processes by reducing the dependence on virgin material consumption as they keep materials 'circulating' for longer, which is fundamental to the more efficient use of resources and a reduction in environmental impact. These measures (reuse, recycling, remanufacturing, refurbishment, cascading use, etc.), take the form of material and product loops in the chain of consumption. In their tutorial session for a DfE topic, students calculate both CO_2 and cost-saving benefits from the replacement of a virgin or an original equipment manufacturer (OEM) compressor with a remanufactured compressor. They also calculate the amount of land and virgin materials that can be reduced by avoiding upstream processes by converting an EoL compressor with a remanufactured compressor. The students are also made aware of the fact that the consideration of disassembly during the design stage is critically important to enable easier separation of the equipment parts during remanufacturing operations to avoid landfilling and to help achieve circular economy outcomes. Case studies on modular and pre-fabricated buildings are made available to the students as these engineering strategies can potentially avoid the dependence on virgin materials, reduce construction and demolition waste and reduce energy and material consumption during transportation and construction activities. At the University of the Basque Country, Spain, several teaching experiences related to LCT, eco-design, IS and sustainable development have been conducted since 2002 to meet the European Union's goal of promoting a circular economy (Minguez et al., 2021a).

Multidisciplinary LCT teaching examples

SEG has developed a number of multidisciplinary comparative (functionally equivalent product systems) LCSA problems: (diesel vs. hydrogen fuel [Steam Methane Reforming/Alkaline Electrolysis] bus transport; diesel vs. bio-diesel electricity generation; ground water vs. desalinated water production; metal halide lamp vs. light-emitting diode [LED] lamp; front-loading washing machine vs. top-loading washing machine; hydrated lime vs. lime kiln dust) and other stand-alone LCSA service problems (overhead power transmission networks, residential buildings and waste water treatment processes). All these examples have been developed based on real-world material and energy input data including emission factors. These LCT-focused teaching examples help the students to develop systems thinking, anticipatory assessment and interdisciplinarity focus (Wiek et al., 2011; Dentoni et al., 2012). A diesel- vs. hydrogen-powered bus case study highlights the TBL implications of the replacement of diesel with hydrogen fuel from an LCT perspective. The economic, social and environmental implications of pre-manufacturing, manufacturing and use (stages of the fuel cycle) are considered not only to determine the most sustainable fuel but also to identify further improvement opportunities in making the fuel more environmentally friendly and cost-competitive. At the same time, students apply LCA that allows them to determine a framework for comparative product/service sustainability assessment.

Firstly the students apply LCSA to estimate social, economic and environmental impacts of two fuels for comparative purposes. Secondly, they explore the opportunities for TBL improvement by identifying the stages or inputs with the highest impact. Thirdly, they review the literature to determine appropriate CPS and eco-efficiency, IS and green engineering strategies to improve overall sustainability. Finally, they revise the LCSA results by incorporating these mitigation strategies to calculate the overall mitigation/savings potential.

In calculating the sustainability improvements, material, energy, cost, associated social data and emission factors related to diesel-operated and hydrogen-operated buses are provided and students are asked to complete the following tasks:

Task 1 – Calculate the global warming potential (GWP) and acidification from the production and use stage of diesel production for the internal combustion engine of buses for the functional unit and then calculate the GWP and acidification from the production and use stages of hydrogen fuel in the fuel cell of buses to determine the environmental implications of this substitution.

Task 2 – Identify the 'hotspots', or inputs or process creating the most environmental impact.

Task 3 – Calculate the costs associated with the production and operation stages of both options.

Task 4 – Determine the social impacts associated with both options.

Task 5 – Discuss the potential mitigation strategies for treating the GWP and acidification hotspots and clearly mention the sources of information on mitigation strategies.

Task 6 – Discuss, using a TBL matrix, how the engineering improvements like those in the example can assist sustainable development from an economic, environmental and social perspective.

Students in this unit have also been asked to convert the linear production system to a circular system by applying sustainable engineering principles that they have learnt in the course (i.e. resource efficiency and waste reduction). As a part of this task, students needed to identify the weaknesses in the linear system (circular gaps) in order for them to find the right engineering strategies to close or reduce the gap to help attain a circular economy system. The mitigation strategies that were considered in Task 5 assisted students in estimating the amount of materials and energy which could be potentially avoided to reduce both 'source' and 'sink' wastage to help achieve circular economy outcomes.

The value of life cycle thinking to student engineers

To analyse the learning outcomes from the LCT approach taken in this unit, the results from different learning tasks/assessments have been broadly analysed. The number of students enrolled in the ESD unit is typically more than 500 students per year. The assessment criteria for these tasks have been developed based on the Engineers Australia's stage 1 competency standards for professional engineers. These standards cover 16 mandatory elements of competency including knowledge, ability, values and professional attitudes.

Within the workshop format, two separate tasks focused on the development of TBL assessment methodologies and an E-LCA assessment are assessed. The TBL assessment focuses more on a qualitative assessment of potential environmental impacts, whilst the E-LCA assessment gives students the opportunity to quantitatively assess the environmental impacts in terms of GHG emissions.

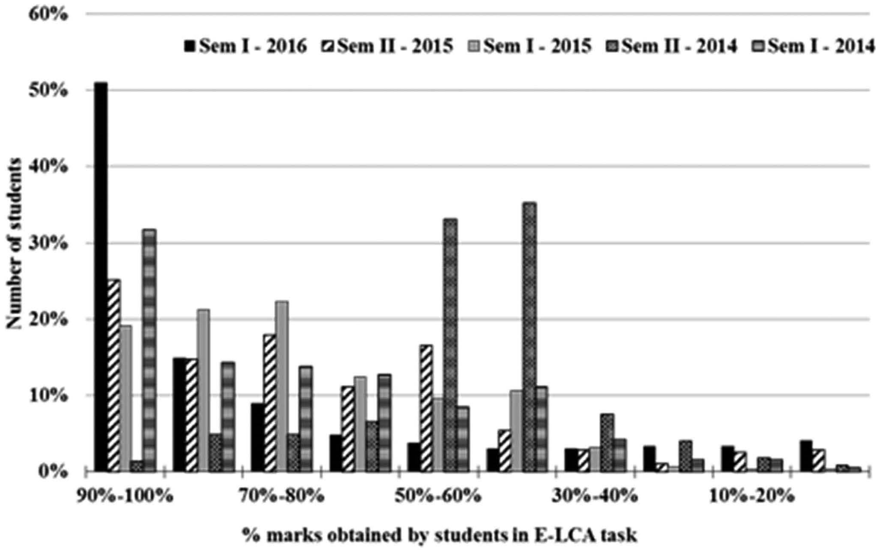
In a quantitative review of E-LCA assessment by SEG in Semester 1 2014 and again in Semester 1 2016, students achieved overall marks between 70% and 100%, highlighting an expected engineering predisposition for numerical assessment and analysis. Students enjoyed the E-LCA task given its quantitative nature and systematic and logical approach in assessment. In this assessment students learned to develop life cycle inventories (LCIs), estimate environmental impacts and identify the production hotspots creating the most environmental impact and then explore and implement mitigation strategies to reduce the environmental impact and finally re-estimate the environmental impacts after application of the mitigation strategies.

The students then present the work in report form, including lessons learnt from the assignment. The detailed feedback helps students to analyse their performance and improve their understanding of environmental impact causation and mitigation. The E-LCA tasks are generally worth 15–20% of total unit assessment.

In the TBL task, students are required to investigate some of the more qualitative perspectives in sustainability assessment. Students are required to develop their own 'sustainable development' indicators including technical, environmental and indigenous cultural indicators. Students then analyse the potential impact of these indicators and discuss their effectiveness in achieving the UN goals of sustainable development. The TBL tasks are generally worth 20–25% of the total unit assessment.

When compared to the E-LCA task, students typically have shown less interest in the development of qualitative indices to represent sustainability performance. ESD lecturers and tutors have reported that it is more challenging to teach TBL methodologies, as the engineering students find it more difficult to understand the relevance of social values and future consequences relative to the more tangible GHG emissions-based assessments from E-LCA and their general expectations around their engineering responsibilities. Whilst assignment questions and unit delivery slightly change from semester to semester, Figure 4.2.2 does demonstrate the difference between students' quantitative and qualitative performance in sustainability assessments for the individual calculation-based E-LCA versus the qualitative more multidisciplinary focused TBL assessments.

After completing these tasks, and with subsequent assessment evaluation feedback, the majority of students achieve a significant improvement in their understanding of the two different but equally valuable sustainability assessment methodologies.



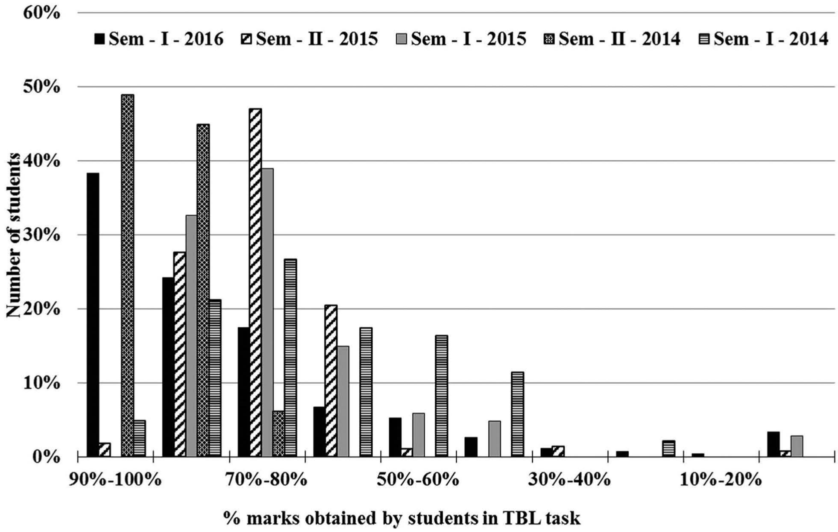


Figure 4.2.2 Student's performance on E-LCA and TBL tasks across S1 2014- S1 2016.

Conclusion

Many universities teach sustainable engineering units that include LCSA as a sustainability assessment tool without explicitly highlighting the need or importance of LCT.

The concept of LCT has been used to help teach future engineers what factors they should consider in engineering decision making to achieve sustainability outcomes. The assignments, relevant theories and workshops based on LCT help to improve their critical thinking and environmental decision-making skills as well as, importantly enhancing their ability to design sustainable products and systems.

LCT is a way of linking design processes and product development from a systems perspective. It helps students to take appropriate design or remedial management actions to help with increasingly important resource conservation measures in converting our current linear economy into a more resource-efficient and zero-waste-focused circular economy.

LCT knowledge in Australia helps engineering graduates to meet the sustainability requirements of the Engineers Australia Code of Ethics and to actively participate in sustainability and environmental reporting in engineering design proposals.

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4.3 THE UN SDGs LEARNING OBJECTIVES IN HIGHER EDUCATION

Jordi Segalas and Gemma Tejedor

Key concepts for sustainability education:

- The UN Agenda 2030 and its 17 Sustainable Development Goals is an essential target in global sustainability and all graduates need to be able to understand their role in its accomplishment.
- Sustainability competencies and learning objectives define what should be learnt in higher education in sustainability.
- Transformative learning approaches (inter-/transdisciplinarity, innovative pedagogics and multiactor involvement) are needed at universities to ensure sustainability learning.
- Universities are essential agents for change in ensuring that modern sustainability education curricula includes focus on the Sustainable Development Goals

Introduction: a bit of history

Education for sustainable development (ESD) has a long history as an international priority (Figure 4.3.1). In 1987 the Brundtland Report by the World Commission on Environment and Development mentioned "sustainability education" for the first time, and in 1992 the concept was taken up and stressed in the Agenda 21 from the Earth Summit of the United Nations Conference on Environment and Development. In 2013, during the 37th session of the UNESCO General Conference, the Global Action Program (GAP) on Sustainable Development Education was approved and, in 2014, the UNESCO published the "Roadmap for Implementing the Global Action Programme on Education for Sustainable Development" to mobilise the community of stakeholders for EDS for urgent action to further strengthen and scale up ESD and in 2020 published Education for Sustainable Development: A Roadmap ESD for 2030 (UNESCO, 2020).

Higher education institutions play a critical role in society's transition towards sustainable development, educating future professionals and decision makers. The United Nations 2030 Agenda (UN General Assembly, 2015) and the Sustainable Development Goals (SDGs) roadmap identifies the university as one of the relevant actors to carry out this

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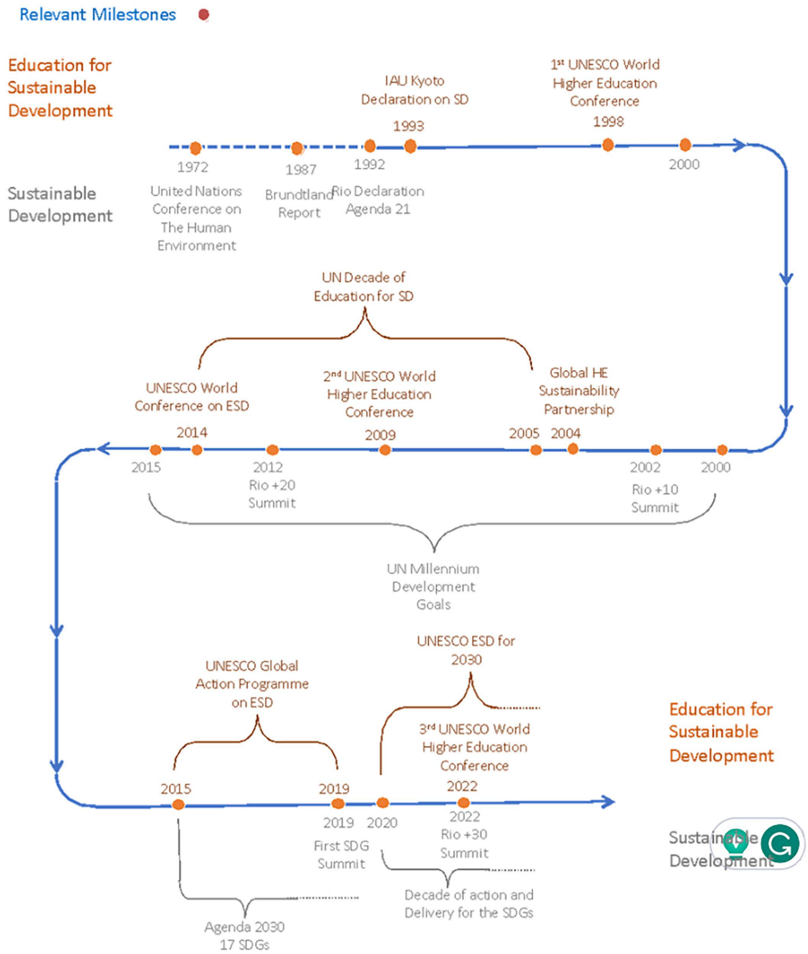

Figure 4.3.1 Timeline of sustainable development and education for sustainable development milestones. (Adapted from SDSN General Assembly, 2017.)

process. This responsibility affects all dimensions of the university's mission (research, education and knowledge transfer), but it also calls on the institutions themselves to include the criteria and values of sustainability in their strategies, plans and management.

The SDGs offer a valuable tool for analysing the world's most pressing problems. In order to solve the challenges of the planet, the next generation needs to know what these challenges are. A good way to make sure this happens is to educate them about the SDGs. Research shows that teaching the SDGs increases academic ability and leads to and motivates the mental and moral growth of learners. It also equips them with the pertinent soft skills critical for securing jobs.

In the last few decades, a number of universities have been devoting major efforts to integrating sustainable development into their curricula. This chapter analyses how Agenda 2030 and its SDG frame learning in sustainable development in higher education.

Agenda 2030 and its 17 SDGs

At the core of the Agenda 2030 are 17 SDGs. The universal, transformational and inclusive SDGs describe major development challenges for humanity. The aim of the 17 SDGs is to secure a sustainable, peaceful, prosperous and equitable life on Earth for everyone now and in the future (Table 4.3.1).

Each SDG has its specific targets and indicators, with a total of 169 targets and 248 indicators. For example, Table 4.3.2 shows the targets and indicators for SDG 4: Quality Education.

Learning objectives and competencies to support the SDGs

Competencies describe the specific attributes individuals need for action and self-organisation in various complex contexts and situations. They include cognitive, affective, volitional

Table 4.3.1 The 17 Sustainable Development Goals

SDG 1. No Poverty: End poverty in all its forms everywhere.
SDG 2. Zero Hunger: End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
SDG 3. Good Health and Well-Being: Ensure healthy lives and promote well-being for all people at all ages.
SDG 4. Quality Education: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
SDG 5. Gender Equality: Achieve gender equality and empower all women and girls.
SDG 6. Clean Water and Sanitation: Ensure availability and sustainable management of water and sanitation for all.
SDG 7. Affordable and Clean Energy: Ensure access to affordable, reliable, sustainable and clean energy for all.
SDG 8. Decent Work and Economic Growth: Promote sustained, inclusive, and sustainable economic growth; full and productive employment; and decent work for all.
SDG 9. Industry, Innovation and Infrastructure: Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.
SDG 10. Reduced Inequalities: Reduce inequality within and among countries.
SDG 11. Sustainable Cities and Communities: Make cities and human settlements inclusive, safe, resilient and sustainable.
SDG 12. Responsible Consumption and Production: Ensure sustainable consumption and production patterns.
SDG 13. Climate Action: Take urgent action to combat climate change and its impacts.
SDG 14. Life below Water: Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
SDG 15. Life on Land: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss.
SDG 16. Peace, Justice and Strong Institutions: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
SDG 17. Partnerships for the Goals: Strengthen the means of implementation and revitalise the global partnership for sustainable development.

Source: UN General Assembly, 2015.

Table 4.3.2 Targets and indicators for SDG 4 – Quality Education

Target	*Indicator*
4.1 By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes.	4.1.1: Proportion of children and young people (a) in Grades 2/3; (b) at the end of primary; and (c) at the end of lower secondary achieving at least a minimum proficiency level in (i) reading and (ii) mathematics, by sex
4.2 By 2030, ensure that all girls and boys have access to quality early childhood development, care and pre-primary education so that they are ready for primary education.	4.2.2: Participation rate in organized learning (one year before the official primary entry age), by sex
4.3 By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university	4.3.1: Participation rate of youth and adults in formal and non-formal education and training in the previous 12 months, by sex
4.4 By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship	4.4.1: Proportion of youth and adults with information and communications technology (ICT) skills, by type of skill
4.5 By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations	4.5.1: Parity indices (female/male, rural/urban, bottom/top wealth quintile and others such as disability status, indigenous peoples and conflict-affected, as data become available) for all education indicators on this list that can be disaggregated
4.6 By 2030, ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy	4.6.1: Proportion of population in a given age group achieving at least a fixed level of proficiency in functional (a) literacy and (b) numeracy skills, by sex
4.7 By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and nonviolence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development	4.7.1: Extent to which (i) global citizenship education and (ii) education for sustainable development, including gender equality and human rights, are mainstreamed at all levels in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment[1]
4.a Build and upgrade education facilities that are child, disability and gender sensitive and provide safe, non-violent, inclusive and effective learning environments for all	4.a.1: Proportion of schools offering basic services, by type of service
4.b By 2020, substantially expand globally the number of scholarships available to developing countries, in particular least developed countries, small island developing States and African countries, for enrolment in higher education, including vocational training and information and communications technology, technical, engineering and scientific programmes, in developed countries and other developing countries	4.b.1: Volume of official development assistance flows for scholarships by sector and type of study

(*Continued)*

Table 4.3.2 (Continued)

Target	*Indicator*
4.c By 2030, substantially increase the supply of qualified teachers, including through international cooperation for teacher training in developing countries, especially least developed countries and small island developing States	4.c.1: Proportion of teachers in: (a) pre-primary; (b) primary; (c) lower secondary; and (d) upper secondary education who have received at least the minimum organized teacher training (e.g. pedagogical training) pre-service or in-service required for teaching at the relevant level in a given country

Source: https://unstats.un.org/wiki/display/SDGeHandbook/Home.

1 The global indicator for target 4.7 was approved in 2020.

and motivational elements; hence they are an interplay of knowledge, capacities and skills, motives and affective dispositions. Competencies cannot be taught, but have to be developed by the learners themselves. They are acquired during action, on the basis of experience and reflection (UNESCO, 2015; Weinert, 2001).

Key competencies represent cross-cutting competencies that are necessary for all learners of all ages worldwide, developed at different age-appropriate levels. Key competencies can be understood as transversal, multifunctional and context independent. They do not replace specific competencies necessary for successful action in certain situations and contexts, but they encompass these and are more broadly focused (Rychen, 2003; Weinert, 2001).

The sustainability key competencies represent what sustainability citizens particularly need to deal with today's complex challenges. They are relevant to all SDGs and also enable individuals to relate the different SDGs to each other – to see "the big picture" of the 2030 Agenda for Sustainable Development. There is a huge literature in sustainability competences. Redman and Wiek (2021) reported that publishing on sustainability learning objectives only began in earnest this millennium and has grown continuously between 1997 and 2020, identifying 272 publications in relevant journals on sustainability competences.

The following key competencies are generally seen as crucial to advance sustainable development (De Haan, 2010; Rieckmann, 2012; Wiek et al., 2011):

- **Systems thinking competency**: The abilities to recognise and understand relationships; to analyse complex systems; to think of how systems are embedded within different domains and different scales; and to deal with uncertainty.
- **Anticipatory competency**: The abilities to understand and evaluate multiple futures – possible, probable and desirable; to create one's own visions for the future; to apply the precautionary principle; to assess the consequences of actions; and to deal with risks and changes.
- **Normative competency:** The abilities to understand and reflect on the norms and values that underlie one's actions and to negotiate sustainability values, principles, goals and targets in a context of conflicts of interests and trade-offs, uncertain knowledge and contradictions.
- **Strategic competency**: The abilities to collectively develop and implement innovative actions that further sustainability at the local level and further afield.
- **Collaboration competency:** The abilities to learn from others; to understand and respect the needs, perspectives and actions of others (empathy); to understand, relate to and be

sensitive to others (empathic leadership); to deal with conflicts in a group; and to facilitate collaborative and participatory problem solving.

- **Critical thinking competency**: The ability to question norms, practices and opinions; to reflect on own one's values, perceptions and actions; and to take a position in the sustainability discourse.
- **Self-awareness competency**: The ability to reflect on one's own role in the local community and global society; to continually evaluate and further motivate one's actions; and to deal with one's feelings and desires.
- **Integrated problem-solving competency:** The overarching ability to apply different problem-solving frameworks to complex sustainability problems and develop viable, inclusive and equitable solution options that promote sustainable development, integrating the previously mentioned competences.

All these competences are interrelated and should be included in higher education, taking into account also the disciplinary competences. Redman and Wiek (2021) defined a framework (Figure 4.3.2) of competencies for advancing sustainability transformations centred on eight key competencies in sustainability, with five established (bold) and three emerging (italic), and complemented by disciplinary, general and other professional competencies.

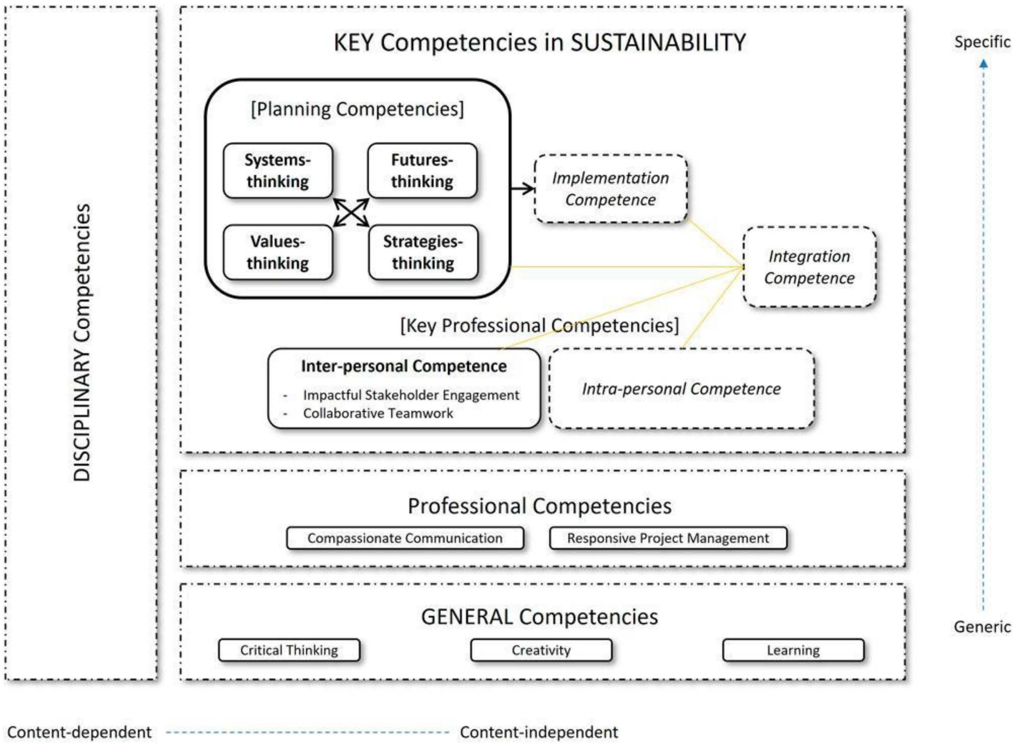

Figure 4.3.2 Framework of sustainability competencies for advancing sustainability transformations. (Source: Redman and Wiek, 2021.)

Rieckmann (2017) defined 255 specific learning objectives for all SDGs, which are to be seen in conjunction with the cross-cutting sustainability competencies. For each SDG, 15 learning objectives are described in the cognitive, socio-emotional and behavioural domains:

- The **cognitive** domain comprises knowledge and thinking skills necessary to better understand the SDG and the challenges in achieving it.
- The **socio-emotional** domain includes social skills that enable learners to collaborate, negotiate and communicate to promote the SDGs, as well as self-reflection skills, values, attitudes and motivations that enable learners to develop themselves.
- The **behavioural** domain describes action competencies.

See, for example, the learning objectives for SDG 13: Climate Action in Table 4.3.3.

Table 4.3.3 Learning objectives for SDG 13: Climate Action

Domain	*Learning objective*
Cognitive	1. The learner understands the greenhouse effect as a natural phenomenon caused by an insulating layer of greenhouse gases. 2. The learner understands the current climate change as an anthropogenic phenomenon resulting from increased greenhouse gas emissions. 3. The learner knows which human activities – on a global, national, local and individual level – contribute most to climate change. 4. The learner knows about the main ecological, social, cultural and economic consequences of climate change locally, nationally and globally and understands how these can themselves become catalysing, reinforcing factors for climate change. 5. The learner knows about prevention, mitigation and adaptation strategies at different levels (global to individual) and for different contexts and their connections with disaster response and disaster risk reduction.
Socio-emotional	1. The learner is able to explain ecosystem dynamics and the environmental, social, economic and ethical impact of climate change. 2. The learner is able to encourage others to protect the climate. 3. The learner is able to collaborate with others and to develop commonly agreed-upon strategies to deal with climate change. 4. The learner is able to understand their personal impact on the world's climate, from a local to a global perspective. 5. The learner is able to recognize that the protection of the global climate is an essential task for everyone and that we need to completely re-evaluate our worldview and everyday behaviours in light of this.
Behavioural	1. The learner is able to evaluate whether their private and job activities are climate friendly and – where not – to revise them. 2. The learner is able to act in favour of people threatened by climate change. 3. The learner is able to anticipate, estimate and assess the impact of personal, local and national decisions or activities on other people and world regions. 4. The learner is able to promote climate-protecting public policies. 5. The learner is able to support climate-friendly economic activities.

All 255 learning objectives are not aimed to be learned in higher education. Some are related to formal primary and secondary education, while others might be learned and practised in non-formal or informal education schemes. Moreover some of the learning objectives officially defined by Rieckmann (2017) involve more than one learning level according to Miller's (1990) pyramid of the learning taxonomy, which may make difficult its operationalisation in university degrees. We think that Rieckmann (2017) work is very valuable, but it cannot be applied directly to higher education, and it needs to be adapted, first, to each field of study and, second, to each degree.

An example of this adaptation is the Sustainability Competency Map developed at UPC Barcelona Tech for engineering education (Sánchez-Carracedo et al., 2021), where each of the 255 SDG learning objectives was assigned to one of the following three categories:

- Learning objectives to be developed in almost all engineering curricula.
- Learning objectives that should be developed in one or more specific engineering curricula but not in all of them.
- Learning objectives that should be developed in other university studies other than engineering, in non-university studies or simply throughout life.

From this analysis, 68 of the 255 learning objectives must be developed in all engineering curricula (26.7%) and 35 objectives in some engineering degrees (13.7%). In total, 103 learning objectives of the SDG (40.4%) must be developed in the engineering curricula. Note that these 103 learning objectives are not specific to engineering. They must be developed in engineering, but it is also possible (and desirable) that they also be developed in other disciplines (at least, a large part of them).

At the European level, the Joint Research Centre and the European Commission's science and knowledge service published the Science for Policy Report (Bianchi et al., 2022) on the European sustainability competence framework: GreenComp. It identifies a set of sustainability competences to feed into education programmes to help learners develop knowledge, skills and attitudes that promote ways to think, plan and act with empathy, responsibility and care for our planet and for public health.

The European sustainability competence framework consists of 12 competences organised into four areas:

- Embodying sustainability values, including the following competences:
- **Valuing sustainability**: To reflect on personal values; identify and explain how values vary among people and over time, while critically evaluating how they align with sustainability values.
- **Supporting fairness**: To support equity and justice for current and future generations and learn from previous generations for sustainability.
- **Promoting nature**: To acknowledge that humans are part of nature and to respect the needs and rights of other species and of nature itself in order to restore and regenerate healthy and resilient ecosystems.
- Embracing complexity in sustainability, including the following competences:
- **Systems thinking**: To approach a sustainability problem from all sides; to consider time, space and context in order to understand how elements interact within and between systems.

- **Critical thinking**: To assess information and arguments, identify assumptions, challenge the status quo and reflect on how personal, social and cultural backgrounds influence thinking and conclusions.
- **Problem framing**: To formulate current or potential challenges as a sustainability problem in terms of difficulty, people involved, time and geographical scope in order to identify suitable approaches to anticipating and preventing problems and to mitigating and adapting to already existing problems.
- Envisioning sustainable futures, including the following competences:
- **Futures literacy**: To envision alternative sustainable futures by imagining and developing alternative scenarios and identifying the steps needed to achieve a preferred sustainable future.
- **Adaptability**: To manage transitions and challenges in complex sustainability situations and make decisions related to the future in the face of uncertainty, ambiguity and risk.
- **Exploratory thinking**: To adopt a relational way of thinking by exploring and linking different disciplines, using creativity and experimentation with novel ideas or methods.
- Acting for sustainability, including the following competences:
- **Political agency**: To navigate the political system, identify political responsibility and accountability for unsustainable behaviour and demand effective policies for sustainability.
- **Collective action**: To act for change in collaboration with others.
- **Individual initiative**: To identify one's own potential for sustainability and to actively contribute to improving prospects for the community and the planet.

Each of these 12 sustainability competences define statements in the domains of knowledge, skills and attitudes. See, for example, in Table 4.3.4 the statements for critical thinking.

Sustainability and SDG education at universities

Learning sustainability competences and SDGs learning objectives can take a wide range of forms within a university. There is no one-size-fits plan all for what delivering education for SDGs (ESDG) at universities looks like, and each institution has to find its own way (Kestin et al., 2020).

The SDG challenges are characterised by complexity, uncertainty, conflicts of values and contradiction. Many of these challenges have so far been proven hard to address, partially because of people's (and institutions') tendencies such as reductionist thinking, working in silos and ignoring uncertainty (UNESCO, 2015). ESDG incorporates a broader agenda of issues, objectives and methodologies than ESD. Examples of these include global citizenship education (Levi and Rothstein, 2018; UNESCO, 2018), jobs for the future (ILO, 2016), innovation and entrepreneurship (Apostolopoulos et al., 2018), indigenising and decolonising the curriculum (Breidlid and Krøvel, 2020) and Theory U (Scharmer, 2018).

Universities cannot approach ESDG as they would any other subject or stream of study. This is because the SDGs cover a very broad range of topics, they are interconnected, their status in the real world is constantly evolving, they are at the frontiers of human knowledge, they are universal but need to be adapted to local contexts, they require a whole range of cross-cutting key competences (Table 4.3.1), they require cross-sectoral collaboration and solutions vary across the world.

Table 4.3.4 Statements for critical thinking competences

Domain	*Statements*
Knowledge	1. Knows that our understanding of sustainability is always evolving. 2. Knows that various biases can influence the discourse on sustainability, including reasoning, communication and political narratives. 3. Knows that predominant narratives can shape the formulation of sustainability problems. 4. Knows sustainability claims without robust evidence are often mere communication strategies, also known as greenwashing. 5. Knows that tackling unsustainable patterns requires challenging the status quo, at individual and collective level, by organisations and in politics.
Skills	1. Can apply personal reasoning to address criticism and arguments on sustainability matters. 2. Can analyse and assess arguments, ideas, actions and scenarios to determine whether they are in line with evidence and values in terms of sustainability. 3. Can scrutinise information sources and communication channels on sustainability to assess the quality of the information they provide. 4. Can reflect on the roots and motives of decisions, action and lifestyles to compare individual benefits and costs with societal benefits and costs. 5. Can look at various sources of evidence and assess their reliability to form opinions about sustainability.
Attitudes	1. Is curious and inquisitive about the links between the environment, human action and sustainability. 2. Trusts science even when lacking some of the knowledge required to fully understand scientific claims. 3. Takes an evidence-based perspective and is ready to revise it when new data emerge. 4. Is willing to accept and discuss sustainability questions, issues and opportunities. 5. Is sceptical about information on sustainability before verifying its source and investigating potential vested interests.

Source: (Bianchi et al., 2022)

To address these aspects of the SDGs, ESDG activities need to employ a number of transformative learning approaches that are not currently standard practice within universities (Cottafava et al., 2019; Redman and Wiek, 2021). These are interdisciplinarity, innovative pedagogies and multiactor involvement.

Interdisciplinarity

Interdisciplinary approaches are crucial for teaching the SDGs because 1) SDGs cover a wide range of topics that span far beyond what is usually covered by a particular discipline or within the expertise of a particular lecturer. Therefore, providing even a basic overview of the SDGs framework requires utilising expertise from other disciplines, which are typically housed in different departments and schools of study; and 2) SDGs are interconnected, so that each of the goals can be influenced by the other goals both positively (synergies) and negatively (trade-offs). This implies that successfully addressing a particular goal requires understanding and simultaneously managing consequences for other goals (Griggs et al., 2017).

Therefore, ESDG activities, even if they focus on just one area of the SDGs, should always attempt to meaningfully draw linkages across different fields of study to explore interconnections with other goals and get a holistic systems view of the issues involved.

Innovative pedagogies

ESDG is about empowering and motivating learners to become active sustainability citizens who are capable of critical thinking and able to participate in shaping a sustainable future. Pedagogical approaches that are adequate to this aim are learner centred, action oriented and transformative

Learner-centred pedagogy sees students as autonomous learners and emphasises the active development of knowledge rather than its mere transfer and/or passive learning experiences. The learners' prior knowledge as well as their experiences in the social context are the starting points for stimulating learning processes in which the learners construct their own knowledge base. Learner-centred approaches require learners to reflect on their own knowledge and learning processes in order to manage and monitor them. Educators should stimulate and support those reflections. Learner-centred approaches change the role of an educator to one of being a facilitator of learning processes, instead of being an expert who only transfers structured knowledge (Barth, 2015).

In **action-oriented learning**, learners engage in action and reflect on their experiences in terms of the intended learning process and personal development. Action learning refers to Kolb's theory of the experiential learning cycle with the following stages: 1) having a concrete experience, 2) observing and reflecting, 3) forming abstract concepts for generalisation and 4) applying them in new situations (Kolb, 1984). Action learning increases knowledge acquisition, competency development and values clarification by linking abstract concepts to personal experience and the learner's life. The role of the educator is to create a learning environment that prompts learners' experiences and reflexive thought processes.

Transformative learning aims at empowering learners to question and change the ways they see and think about the world in order to deepen their understanding of it (Slavich and Zimbardo, 2012; Mezirow, 2000). The educator is a facilitator who empowers and challenges learners to alter their worldviews. The related concept of transgressive learning (Lotz-Sisitka et al., 2015) goes one step further: it underlines that learning in ESD has to overcome the status quo and prepare the learner for disruptive thinking and the co-creation of new knowledge.

Multiactor involvement

Engaging actors who are involved in addressing sustainable development challenges and implementing the SDGs in the "real world" has an important place in ESDG activities. Such actors can provide deep insights into the challenges and strategies of putting knowledge learned in the classroom into complex real-world situations, provide inspiration for and testament to the relevance of ESDG outside the university, bridge knowledge gaps in teaching resources, bring issues to life and make the offerings more current and topical. Engaging these actors can also allow universities to increase their internal and external networks' reach and impact.

Conclusion

SDGs, SDGs competences and their learning objectives are frameworks that can facilitate the understanding and enhancement of ESD in sustainability education.

Universities have been experimenting with a wide range of approaches to implement ESDG (Leal Filho et al., 2019) over the past 20 years, aimed at enhancing the learning of SDG key competences and learning objectives in modern curricula.

The approaches that have been developed extend from embedding SDGs in current curricula (Leal Filho et al., 2021) and raising awareness (Kopnina, 2018), through to the introduction of specific SDG units such as interdisciplinary introductory units, discipline-specific units, massive open online courses (MOOCs), SDG-focused project-based units, etc., and finally to the designing of whole sustainability degrees focused on the SDGs. Co-curricular activities such as challenge contests, hackathons and student-led activities have also been shown to be effective in raising awareness of the importance of the SDGs and their role in supporting the development of a more sustainable future.

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4.4 INTEGRATED PROBLEM SOLVING AND DESIGN THINKING

Joseli Macedo

Key concepts for sustainability education

- The complexity of systems requires that problems be solved in an integrated manner. Sustainability as the integrative discipline brings together most fields of study.
- Design thinking is a solid approach to look for solutions within complex systems and provides a sound basis for sustainability education.
- The complexity of sustainability challenges requires holistic thinking and integrated multidisciplinary approaches to problem-solving.
- The interconnectivity of sustainability needs to be recognized and the current paradigm of solving specific problems with no regard for the systems that contain them replaced.
- Sustainability education based on social training has a better chance to elicit the knowledge and ingrain the necessary values on generations to come.

Introduction

Integrated problem-solving

The need to develop strategies for integrated problem-solving stems from the fact that disciplines have specialized to an extent that it is no longer possible to contemplate solutions within a single realm. After the Renaissance, the liberal arts comprised all that was needed for a holistic knowledge of the world. Early in the nineteenth century, the specialization and separation of existing and new subject matters began, and this compartmentalization of knowledge brought us to where we are today (Buchanan 1992). In the twentieth century, design thinking emerged as a way to integrate knowledge within the arts and sciences both to solve contemporary problems through customization to specific needs. Buchanan (1992, 6) argues that "[w]ithout integrative disciplines of understanding, communication, and action, there is little hope of sensibly extending knowledge beyond the library or laboratory in order to serve the purpose of enriching human life". Sustainability is the integrative discipline that can bring back together the various fields of study, along with their discipline-specific theories and methods, that were separated by specialization in the last 50 years.

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Dialectical inquiry, or what Schön (1983) calls "reflective conversation", is an effective way to develop possibilities for integrated problem-solving. Reflective conversations give new meaning to the values of control, distance, and objectivity and can be used to overcome opposition, conflicts, and contradictions by bringing them within a system or ordered whole. Reflective conversations also allow the reframing of problems, yielding new discoveries and generating an iterative process of appreciation and action, uncertainty and understanding. If a problem is reframed successfully, the reflective conversation continues until a satisfactory solution is devised.

The design process takes us beyond problem-solving, hence the importance of design thinking in sustainability education. Schön (1983, 49) trusted the abilities of practitioners to use "an epistemology of practice implicit in the artistic, intuitive processes which some practitioners do bring to situations of uncertainty, instability, uniqueness, and value conflict" and use the appropriate design process in their reflective practices. This epistemology serves the needs of design thinking towards sustainability well. Sustainability is nothing but uncertain, unstable, unique, and rife with conflicts that stem from personal, social, and cultural values.

Maher et al. (2018) argue that a stronger integration of design approaches and sustainability science is necessary in addition to tools that can help both researchers and practitioners to apply design thinking in the development of sustainable solutions. They define design as

> a process of producing simple and effective responses to complex and vague problems that span across disciplines and stakeholder groups. . . . It takes a holistic perspective, drawing together different perspectives on problems and their context, technology, human needs, empathy with users and stakeholders to create aesthetic artefacts, which can be rich in meaning.
>
> *(Maher et al. 2018, 1568)*

A transdisciplinary approach has become imperative for sustainability science, and having both academics and practitioners work in an integrated way, beyond their disciplinary boundaries, is key. A discipline is defined by a community with a scientific history that shares a common area of research and a common vocabulary or network of communication. Traditions help to define the community and the discipline by establishing a pertinent knowledge base or domain and the mode of inquiry that is most acceptable to the community. Communication, therefore, is important in the transmission of the community's knowledge, beliefs, morals, and rules of conduct.

The attitudes and activities of peers can also be a very powerful influence on decision making. Problem-solving within a single discipline is "a manipulation of available techniques to achieve chosen ends in the face of manageable constraints" (Schön 1983,169). Practitioners in one discipline must understand the nature of the paradigm of that discipline to understand and communicate how it conflicts with or complements the paradigms of other disciplines; there is no common "if-this-do-that" model among disciplines. As Schön (1983, 274) states, "[t]he nature of the reflective conversation varies, from profession to profession and from practitioner to practitioner, depending on the presence or absence, and on the content, of overarching theory". Approaching sustainability as an integrative discipline allows for innovation and formalizes what has historically happened every time opportunities for cross-pollination gave rise to insights and new inventions.

Design thinking

Brown (2009, 14) defines design thinking "as a way of describing a set of principles that can be applied by diverse people to a wide range of problems". The design disciplines tackle design as a problem-solving exercise, and solutions are usually found through a creative, iterative process. This process, commonly used by the family of design professions (architecture, engineering, urban design and planning, landscape architecture, and industrial design, to name but a few), has been adapted to other disciplines and has helped people find answers to vexing questions. The broadening of the concept of design resulted from a cultural evolution generated by "an informal, collective, generational process of design" (Schön 1983, 77). The apparent messiness of design thinking can be attributed to the fact that it is a nonlinear, exploratory process (Brown 2009). Design thinking has been included in several curricula ranging from the design disciplines, to business, to organizational change.

Broad competencies that are subsumed within design thinking include systems thinking, effective communication, and ethical reasoning. When engaged in problem-solving exercises using a design thinking approach, all involved must think and act as a team member; in addition, it is necessary for all members to be familiar with relevant background and technical knowledge that lead to successful design. When we consider design as a way of thinking, we begin to understand how the process used by designers can benefit those in other disciplines. Design thinking is systems thinking: in the process of learning and creating, designers work through complex problems one step at a time and arrive at optimal solutions, sometimes in collaboration with other designers, sometimes with colleagues from other disciplines. Through design thinking we can move from concept to knowledge; the process comprises several transformations.

Design is guided by pluralistic views, and different philosophies have caused rifts between design theory and design practice. Design thinking is useful in understanding and reframing problems, particularly when we are faced with "situations of uncertainty, instability, and uniqueness" (Schön 1983, 268), and looking at issues from a fresh perspective. The dimensions of design thinking are discovered when problems and their respective solutions are reconsidered. Reconsidering the potential solutions to achieve sustainability in different realms and at different scales requires design thinking.

Design thinking can be applied in so many different realms because it is a process of inquiry that relies on both divergent and convergent thinking. The process provides an iterative loop that allows for flexibility and adaptability. It includes systems thinking and systems design with a cyclical focus on the whole at every cycle. A staged approach lends itself to handling uncertainties, which are likely to arise during most problem-solving exercises, and arriving at decisions at every stage. As Cross (1982, 225) puts it:

> designerly ways of knowing rest on the manipulation of non-verbal codes in the material culture; these codes translate 'messages' either way between concrete objects and abstract requirements: they facilitate the constructive, solution-focused thinking of the designer, in the same way that other (e.g. verbal and numerical) codes facilitate analytic, problem-focused thinking; they are probably the most effective means of tackling the characteristically ill-defined problems of planning, designing and inventing new things.

In design thinking, one of the ways to solve the problem is to change the problem to find a solution, which can be the most challenging and difficult part of designing. Schön (1983,

40) argues that "problem setting is a process in which, interactively, we name the things to which we will attend and frame the context in which we will attend to them". Lateral thinking, defined by de Bono (1973) as the capacity to re-conceptualize processes in completely new ways, is constrained when analytical aspects are prioritized. When practitioners cannot turn problematic situations into manageable problems, what Schön (1983, 63) calls a "frame experiment" may be tried. This is reflection-in-action at work; a process in which "action on the situation is integral with deciding, and problem solving is a part of the larger experiment in problem setting" (Schön 1983, 165). Reflection-in-action allows one to observe, criticize, restructure, and test intuitive understandings of situations.

The complexity of sustainability challenges

Situations of complexity and uncertainty demand "the imposition of an order" (Schön 1983, 103). Sustainability challenges always require both specialized and integrated knowledge. Complex problems lend themselves well to design thinking methods because design problems are usually ill-defined and ill-structured. Archer (1979, 17) argues that "an ill-defined problem is one in which the requirements, as given, do not contain sufficient information to enable the designer to arrive at a means of meeting those requirements simply by transforming, reducing, optimizing or super imposing the given information alone". Cross (1982, 224) argues that "to cope with ill-defined problems, the designer has to learn to have the self-confidence to define, redefine and change the problem-as-given in the light of the solution that emerges from his mind and hand".

Sustainability challenges are usually very different from the "puzzles" (Kuhn 1996) that scientists and scholars try to solve. First, the necessary information to solve the problem may not be available. Second, exhaustive analysis may not lead to the correct solution. Thus, when it comes to sustainability challenges, solution-focused strategies are preferable to problem-focused ones. And the complexity need not rest on the process; simple processes may generate complex solutions (or products/objects).

Most challenges related to sustainability are complex because they hinge on values. Eco-centric and anthropocentric perspectives are often at odds, and the choices we make, particularly those related to the finite reality of most natural resources, reflect those perspectives. Our moral compass comes into play, and design thinking can help reconcile dilemmas that arise from the complexity of issues.

Integrating design thinking with sustainability science could help us overcome the challenges that we as a global society face in changing our relationship with the natural environment. As Maher et al. (2018, 1566) put it: "our traditional approach for building knowledge and solving problems is poorly suited to the unique nature of sustainability challenges." To meet the challenges imposed by the need to embrace sustainability, we will have to change a great deal, particularly the way we think about our responsibilities as citizens.

The interconnectivity of sustainability

Complex and sometimes contentious problems, such as those generated by the need to prioritize sustainability, require holistic and synergetic thinking; they also require imagination and vision. Thus, the need to shift the current paradigm of focusing on isolated issues and to assume a holistic stance when dealing with sustainability. Innovation requires a continuous process that is "best thought of as a system of overlapping spaces rather than a sequence of orderly steps" (Brown 2009, 21). A comprehensive approach that transcends disciplinary, institutional, and national boundaries grounded on design and systems thinking can give us the structure needed to address the interconnectivity of sustainability.

Many of the sustainability problems we face are due to poor or inadequate design, and solving them will require shedding our notions of time and space, energy and materials, knowledge and behaviour. Sustainable design can benefit from incorporating social, economic, and ecological local knowledge into processes leading to the sustainability of a place. Practice grounded by design logic can be used to highlight the social and physical realities of a place by defining the ideas and concepts behind them. In addition to place-specific processes, which are more appropriately addressed by local networks and actions, practitioners who recognize and act as members of an integrated global society are better equipped to deal with interconnected sustainability issues.

The progress made so far in sustainability has been dominated by science; the methods and logic of design thinking differ from those used in science; thus, there needs to be a concerted effort to embed design thinking into sustainability education. This should not be difficult given the compatibility that exists between design and sustainability science. Integration between the two could spur effective and transformational initiatives, integrated into their particular contexts. There is great value in design principles and methods, and they can support sustainability researchers and practitioners alike.

Nadler (1980) discusses design and planning together when developing a timeline theory for design as a discipline. Because the discipline of planning is closely related to sustainability and most sustainable initiatives are embedded in plans of various kinds (urban, environmental, short-term, long-term, etc.), it is pertinent to consider his viewpoints to explain the interconnectivity of sustainability. He calls for a multidimensional and prescriptive framework and argues that "[a]rriving at effective, implemented solutions is ultimately dependent on people, their understanding and their willingness to take actions leading to success" (Nadler 1980, 305).

The interconnectivity of sustainability requires collaboration and interdisciplinarity, and collaboration across disciplines is paramount for sustainability education.

Education as social training

In the 1970s, a movement to recognize design as a third area in education, in addition to science and the humanities, was launched. It emerged from a general concern with scientific design process in the 1960s, a period heralded as the "design science decade" by Buckminster Fuller (Cross 2001). He "called for a 'design science revolution' based on science, technology, and rationalism to overcome the human and environmental problems that he believed could not be solved by politics and economics" (Cross 2001, 50). In addition, H. A. Simon, in his 1969 book *The Sciences of the Artificial* published by MIT Press, called for the development of "a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process", which he dubbed "a science of design". Schön (1983) criticized Simon based on the fact that in professional practice we have to deal with situations that do not fit moulds and problems that do not easily fit into a scientific formula. There were other detractors of the design science movement, such as Christopher Alexander and J. Christopher Jones, who thought design methods did not have anything to offer; they disagreed with the machinist idea of fitting everything into a logical and fixed framework.

The reactions observed in the design camp match the zeitgeist of this period. Design practitioners had difficulty applying scientific methods as such; this impediment combined with the emergence of a new environmental consciousness in the late 1960s (refer to Chapter 2 in this volume) and the radicalization of political movements created a context within which design problems were characterized as "wicked problems" (Rittel and Webber 1973). The search for techniques and methods amenable to dealing with these problems, not only in design but also in disciplines such as planning and engineering, spurred the emergence of journals dedicated to design research, theory, and methodology.

The journal *Design Studies* published a series entitled Design as Discipline, which intended to "establish the theoretical bases for treating design as a coherent discipline of study". Most issues contained articles dedicated to identifying design "as a subject in its own right", as stated in the Introduction to issue 1 of volume 1. Several academics and practitioners contributed to this discussion, particularly regarding the ways in which design as a discipline would become part of basic education and how design methodology should be used both in design research and in the training of students from any and all disciplines. Design was understood as a way to express ideas through doing and making, different from sciences, which is expressed through notation, and the humanities, expressed in natural language, especially written language. Design is less about analysis and more about creation and construction. The essential language of design is modelling; ideas about how things ought to be are conveyed through a variety of media, including drawings, diagrams, physical representations, and gestures. (See Cross (2001) for more on the design-science conflict and three different interpretations of the relationship between the two: scientific design, design science, and a science of design.)

Archer (1979) proposed that design be a "third area" of education. In considering the criteria that this third area would have to satisfy – along with science and the humanities – to be included in general education, Cross (1982) contrasts the three areas and outlines their individual characteristics. He justifies the inclusion of design in general education stating that "Design develops innate abilities in solving real-world, ill-defined problems. Design sustains cognitive development in the concrete/iconic modes of cognition. Design offers opportunities for development of a wide range of abilities in nonverbal thought and communication" (Cross 1982, 226).

From a social training perspective, there is a fundamental difference between scientific and design epistemology. In scientific disciplines we are trained to use methods that are standardized and replicable; validation is achieved through repetition and confirmation. In design, there is no need for replicability, in fact, repetition (plagiarism) is undesirable. Although Kuhn (1996) did not discuss design in his seminal work *The Structure of Scientific Revolutions*, his contentions about incommensurability would fit the logic needed in innovative and inventive design endeavours. Nonetheless, as Grant (1979, 46) wrote: "Most opinion among design methodologists and among designers holds that the act of designing itself is not and will not ever be a scientific activity; that is, that design is itself a nonscientific or ascientific activity".

Design education has been traditionally delivered by design practitioners; most disciplines that comprise design, such as architecture, landscape architecture, and urban design, adopt an apprenticeship model, and practitioners impart their knowledge, skills, experience, and values by tutoring students and working alongside them. The socialization of this model is very different from the traditional "sage on the stage" model, where academics impart their formal and for the most part theoretical knowledge through lectures rather than on their practice-based experience.

Academics have a responsibility for the vacuum and the gaps, for the absence of sustainability, ecology, and other topics in education. Sustainability education that stresses the need for students to be not only aware of what they are learning and why but also self-aware provides the social training necessary for them to internalize and normalize sustainable practices. This relates education to cognitive perspective. Cross (1982, 224) argues that "[p]eople who seek the certainty of externally structured, well-defined problems will never appreciate the delight of being a designer". What design thinking does is give us the capacity for integrative thinking (Brown 2009).

In addition to design thinking competencies, educational institutions need to provide students with other competencies to face the sustainability challenges that they will undoubtedly face in their future professions and practices. A series of competencies is suggested by UNESCO (2017, 10) as part of education for sustainable development (ESD): systems thinking, anticipatory, normative, strategic, collaboration, critical thinking, self-awareness, and integrated problem-solving. UNECE (2012) suggests a series of competencies for educators.

Conclusion

Creativity and choice are indispensable ingredients in our attempt to make this world more sustainable, and they are both encouraged by design thinking. Design develops one's abilities to tackle a particular kind of problem; it develops the cognitive skills and abilities to solve real-world problems. Buchanan (1992, 16) argues that "design is potentially *universal* in scope, because design thinking may be applied to any area of human experience".

The tradition of design disciplines devising well-integrated solutions to wicked problems is the reason that design thinking should be used in solving complex sustainability challenges. Design thinking as a new liberal art "points toward the impossibility of relying on any one of the sciences (natural, social, or humanistic) for adequate solutions to what are the inherently *wicked problems* of design thinking" (Buchanan 1992, 20).

The complexity of sustainability challenges, most notably those involving the interaction between human beings and environmental systems, needs to underlie academic programs so that students are prepared not only to be good stewards of the natural environment but also to engage in actions that improve the quality of life for humans in that environment.

Ultimately, design thinking requires consilience (Wilson 1998). Consilience brings together knowledge across disciplines by linking the facts and fact-based theories and reconciling their differences. The complexity of problems we are facing today requires the integration of knowledge from multiple disciplines. We need to access the creative problem-solving abilities that we all possess, emphasize interconnections, and reframe problems by looking at them from different perspectives. This is what design thinking is all about.

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4.5

(RE)THINKING EDUCATION FOR SUSTAINABLE DEVELOPMENT

A capability approach

Kyoko Fukukawa and Michele John

Key concepts for sustainability education

- Education for sustainable development (ESD) should be taken as a ‘capability’ for facilitating and enhancing further learning rather than simply utilised as a topic of learning.
- Sen’s capability approach (Sen, 1999) suggests that ESD is in itself a capability that can be used by educators in the development of sustainability education.
- Developing the capacity for ESD is a crucial component of sustainability learning that must address the relational complexity that is inherent in sustainability decision making and the trade-offs often encountered.
- Wider frames of reference and perspectives are important in sustainability thinking in managing public debate and democratic engagement and acceptance.
- Sustainability education needs to create an ‘evaluative space’ in order to consider how one set of actions in a particular domain impacts upon other domains in order to generate greater consensus in the solving of complex sustainability problems, which can play an important role in influencing and recalibrating these spaces.
- An ‘evaluative space’ provides an important forum for critical thinking development and helps develop the competencies required for independent, creative and critical thinking in sustainability education in both business schools and across other disciplines.

Introduction

This chapter focuses on education for sustainable development (ESD), in particular in relation to business studies, expanding beyond the typical purview of business, questions the relationship between educational and business settings, and questions what it means to deliver ESD more fundamentally across all disciplines.

The emergence of ESD is taken in this chapter to be a ‘new disruptor’ within education. This can be understood twofold: it represents a specific ethical agenda to assert over existing business education, but equally it requires a level of re-thinking about the nature of business and questions anew how we define business education in the first place.

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It is worth noting, reference to the term 'development' in ESD is not taken here to refer to development issues or studies per se in relation to emerging economies, but rather as a business and educational development that is pertinent to all economies. As outlined later with respect to United Nations Educational, Scientific and Cultural Organization's (UNESCO's) definition of ESD, the critical issues are wide ranging and interconnected globally and pertaining to all business education contexts. As will become apparent, the framing of this chapter bears relation to debates between ethics and economics, with specific reference to Amartya Sen, who has done much to reinvigorate mainstream economics through the contributions of moral philosophy and welfare economics (Sen, 1987).

The significant prevalence of ESD teaching at business schools dates to the early 2000s, following the introduction of UNESCO's definition of ESD. UNESCO (2021) notes that:

> Education for Sustainable Development (ESD) empowers learners of all ages with the knowledge, skills, values and attitudes to address the interconnected global challenges we are facing, including climate change, environmental degradation, loss of biodiversity, poverty and inequality. Learning must prepare students and learners of all ages to find solutions for the challenges of today and the future. Education should be transformative and allow us to make informed decisions and take individual and collective action to change our societies and care for the planet.

This presents an agenda for educators and students to look at how they can make positive changes to support sustainability through their own actions and behaviour (Ghoshal, 2005; Rands and Starik, 2009; Starik et al., 2010). Of particular interest for this chapter is the emphasis on an evaluative approach and the competencies required for independent, critical thinking. This then raises questions about the 'means' to this education, rather than simply the 'ends' of education and which, in turn, poses further questions as to how we define the parameters and intentions of business and how best to implement and maintain an appropriate means for sustainable development thinking in future leaders.

Many business schools can be seen adopting the main tenets of ESD. Yet an underlying challenge remains as to whether business education models, and education models in general, are in fact merely reproducing conventional business-as-usual practices despite the ongoing discussions on sustainable development (Burchell et al., 2015; Rasche and Gilbert, 2015; Painter-Morland et al., 2016).

This chapter draws on the philosophical pragmatism of Amartya Sen's capability approach (1999). Sen's work enables us to ask more operative questions about how education can offer an appropriate alignment or articulation of means and ends towards sustainable development.

This chapter adopts Sen's (1999) underlying argument for 'development as freedom', where Sen suggested that 'freedom' is the primary objective of development and the principal means of achieving development. In this case, we need to consider how 'sustainability' (outlined in more detail in the next section) is to be taken as the underlying capability *of* ESD, not simply its outcome or goal. This argument also relates to debates around 'welfare economics' (propounded by Sen and others since the 1970s). This suggests we need to work towards more comprehensive goals and perspectives, which gives rise to the need for what Sen refers to as 'evaluative spaces', i.e. where understanding on how actions within one domain, or pertaining to specific needs, has impact on other domains and factors. If we can extend the evaluative 'space' (or the array of factors and outcomes we take into account), we can then seek to reach greater consensus with businesses and wider society on sustainable development challenges and issues.

Situating education within sustainable development

Kurucz et al. (2014, 454) position sustainability as a 'provocation' to traditional business management education, which they argue is limited in its 'capacity to address complex global issues', despite such issues being increasingly important and visible in the business world.

Sustainability offers a mode of critique and renewal, 'to build a new vision for management education that moves business schools beyond functioning as management training and diploma-granting facilities' Kurucz et al. (2014, 454), and instead to move towards their becoming 'public spheres of conscientization' (Freire, 1998 cited in Kurucz et al., 2014, 439). It is not so much that within a curriculum that sustainability represents a defined set of learning elements within a syllabus, but that it is a *way of approaching* the subject area as a whole. Analogy can be made in learning a foreign language. The syllabus sets out a finite set of vocabulary to learn, but it also requires certain principles of grammar to be understood, which in turn enables the words to be used in a variety of ways and contexts. Ethics and sustainability can be understood more as the 'grammar' of learning. It is a way of formulating the subject and a way of maintaining and underpinning learning.

As will be outlined, ESD should be considered a 'capability' for facilitating and enhancing further learning rather than simply a topic of learning. Beyond the classroom, this raises searching questions about the practical and epistemological relationship between business practices, education and research, as well as more broadly the status and positioning of business practices within wider social and economic discourse.

Cullen's (2017) bibliometric review shows that since the mid-1990s the fields of business and management studies have shown a substantial growth in interest in sustainability as a general topic, and from around the mid-2000s 'the emphasis of books published in this area began to change from one which advocated "sustainable development" to one which viewed sustainability as a management practice which could help businesses and society simultaneously' (429). The specific literature within business education has been more limited, but has shown similar growth rates. Cullen notes how the rapid increase in interest, over a relatively short period of time, has led to confusions (and arguably dilutions), with a wide range of different understandings and definitions of sustainability (Marshall and Toffel, 2005; Ferdif, 2007; Parr, 2009). Equally, it can be argued interest in sustainability in mainstream business and management studies has come late, and as a result significant attention 'has yet to be integrated at any level into most business school courses and programs' (Starik et al. 2010, 377). By the mid-2000s, for example, while the topic was seen to have had significant take-up, sustainability was nonetheless seen 'as a relative "newcomer" to the MBA curriculum' (Christensen et al., 2007, 352). For the purposes of this chapter, sustainability is to be understood within the broad terms set out by UNESCO (outlined earlier), which allows for an understanding across economic, social and environmental issues.

As Cullen notes, 'sustainability has been a central concern in fields such as geography, sociology and development studies for decades, [while] the relatively recent interest from management studies can be seen to stem from the various social, environmental and economic crises facing the world' (2017, 430). As a part of which, sustainability concerns both intergenerational and collaborative thinking. There is a need to understand different generational temporalities, which, in terms of short-term political cycles are not always easy to 'sustain' and make workable. Similarly, establishing and then sustaining collaboration across different domains and disciplines can prove difficult. These, then, are as much sustainability issues as are the headline concerns of finance, resources and the environment.

As will be discussed in the next section, the work of Amartya Sen (1999) is concerned with an underlying interest in the expansion of real freedoms that people can enjoy – to advance, for example, the kind of 'well-being' that Baden and Higgs (2015) suggest is the goal of education. Importantly, Sen argues for freedom as an end in itself; a 'constitutive role' of freedom, which 'relates to the importance of substantive freedom to enriching human life. The substantive freedoms include elementary capabilities like being able to avoid such deprivations as starvation, undernourishment, escapable morbidity and premature mortality', as well as freedoms of education, literacy, political participation and freedom of speech, etc. (1999, 36). However, he also accounts for 'instrumental' freedoms and rights that 'may *also* be very effective in contributing to economic progress'. These are operative in development, though still substantive freedoms remain fundamental. As Sen notes, 'the significance of the instrumental freedom of political freedom as a *means* to development does not in any way reduce the evaluative importance of freedom as an *end* of development' (37).

An underlying tension of this chapter is the degree to which sustainability issues can be read in terms of substantive freedoms (on a par with the aforementioned elementary capabilities) or whether as more an instrumental means towards change. The position taken here is that in order for ESD to be instrumental within a changing landscape in business studies that impacts positively on society at large, there is an important need to consider sustainability more substantively – as something constitutive of how we live or intend to live.

In discussing ESD, it is pertinent to draw attention to the 'principles for responsible management education' (PRME), since both are linked initiatives of the UN Global Compact. (for further information on PRME see Chapter 6.1 in this volume) At its core, PRME is directed at the next generation of business professionals. As Parkes et al. (2017) outline:

> the underlying goal [in establishing PRME] was to develop the capabilities of our students to be generators of sustainable value for a more inclusive global economy through our teaching, research, and campus practices. Then UN Secretary-General Ban Ki-Moon, pointing to the potential of the PRME initiative, noted that, "The Principles for Responsible Management Education have the capacity to take the case for universal values and business into classrooms on every continent"
>
> *(61)*

The secretary-general's words undoubtedly suggest a more inclusive, interconnected set of relationships. It is interesting how we might read the phrase 'universal values and business', whether we take the 'and' as an operator between two entities or as a means to intrinsically link the two. Parkes et al.'s (2017) reference to students as 'generators' and in having 'capabilities' in the first instance would seem to suggest a working *out from* business, so to impact upon the wider world. Yet, over time, this may lead to a different conception of where the boundaries lie, if indeed they need to exist at all between business and society.

Currently, if we look at the '2020 Guiding Principles and Standard for Business Accreditation' of the well-known Association to Advance Collegiate Schools of Business (AACSB), it is evident that while the overall vision is for business and business schools to be 'a force for good, contributing to the world's economy and to society', the thrust of the language emphasises business as somehow separate to (even if 'serving') society or communities. It uses phrases such as 'society is increasingly demanding that companies become more accountable', 'the same factors impacting business also are changing higher education' and 'business schools must respond to the business world's changing needs by providing relevant knowledge and skills to the communities they serve'. Of course, the purpose of such a body is to set accreditation standards, which inevitably leads it to narrow its focus, in this case, business education (and so the site of business practices more generally). Yet the accreditation bodies are arguably themselves looking to innovate and to be more responsive to the colleges they interact with. As AACSB (2020) puts it:

> Accreditation standards and associated processes should foster quality and consistency, but not at the expense of the creativity and experimentation necessary for innovation. Also, accreditation standards and processes should not impede experimentation or entrepreneurial pursuits; the standards must recognize that innovation involves both the potential for success and the risk of failure.
>
> *(AACB 2010, 10)*

There is a need to look beyond prescriptions and instead consider underlying capabilities and how these can align with aspirations.

Various stakeholders are all looking in the same direction, towards a more progressive business landscape. What is missing is a cohesive space for engagement and capability development in facilitating and enhancing further learning. It is in this respect that Sen's perspective on a 'capability approach' can be useful to redefine problems as questions around the appropriate capabilities required to achieve certain outcomes or functions. As a long-time advocate of welfare economics, involving the co-consideration of ethics and economics (Sen, 1987; Putnam, 2004, 46–64), Sen suggested a need to re-evaluate the way we relate to debates concerning the market, i.e. how we position ourselves vis-à-vis business *and* society. The most prominent argument in favour of the market mechanism is that left unrestricted, it typically allows income and wealth to flow (and 'trickle down'), which broadly Sen agrees to, with some caveats.

However, his argument for the market is fundamentally different in relation to its inclusion of an inalienable right to undertake exchange and transactions. 'Even if such rights are not accepted as being inviolable,' he writes, 'it can still be argued that there is some social loss involved in denying people the right to interact economically with each other' (1999, 26). He notes, '[t]he discipline of economics has tended to move away from focusing on the value of freedom to that of utilities, incomes and wealth. The narrowing of this focus leads to an underappreciation of the full role of the market mechanism' (27).

In Sen's view, there is a need to rebalance the 'engineered' or highly mathematical approach to twentieth-century economics through the reintroduction of ethics (Putnam, 2004, 47–48). It is worth noting, in Sen's case, 'the reintroduction of ethical concerns and concepts into economic discourse must not be thought of as an *abandonment* of "classical economics"; but rather the *reintroduction* of something that was included in the writings of Adam Smith' (Putnam, 2004, 48). Sen aligns strongly with the work of Adam Smith. He notes wryly how commentators often rarely get beyond the famous quote of 'the benevolence of the butcher, the brewer, or the baker' and suggests, even if they do not read further, 'this passage would indicate that what Smith is doing here is specifying why and how normal transactions in the market are carried out'. Sen reminds us of the underlying *social* principle of economics, that we always trade with others. It is a freedom we seek to secure, which can only be secured *through* relations with others, rather than despite or without them. In effect, exchange comes *before* business; it is one of the fundamental constructs in social society. Within this we can begin to view any rigid distinction between business *and* society as problematic.

Sen's focus on capabilities and 'freedoms' *as* development (not the result of development) sets out a more pragmatic and interconnected understanding of the market, wealth and society, which we can adopt to make better sense of how ESD needs to be conceptualised and articulated within the context of business school or other disciplinary curricula. Sen's capability approach is a moral framework that suggests that social arrangements should be largely evaluated according to the extent of freedom people have to choose, promote or achieve the 'functionings' they personally value. While Sen certainly does not dismiss classical economics, his reading, as suggested earlier, is nuanced and reintroduces philosophical and ethical considerations relevant to contemporary debates.

ESD therefore represents an opportunity to rethink how we define the curriculum for a new generation. What needs to take effect is not only a framework (and set of accreditation standards) for articulating new values but also a *means* to allow 'the next generation of managers, leaders, and business professionals, committed to developing their capabilities to be generators of sustainable values for a more inclusive global economy' (Parkes et al., 2017, 62). It is in this direction that Sen's 'capability approach' offers valuable insights.

Comprehensive outcomes

The agenda of ESD in itself puts forward a need for change in education – to change the curriculum, to change behaviours, to change business practices. Institutionally, this gives educators and administrators a 'case for change', but as already intimated, implementation of new approaches can end up being superficial, or at least bolted on rather than built in. As a result, what is required is a wider range of capabilities for a transformative understanding of business.

Underlying Sen's work is the need for an integrated picture. He notes, for example, how various economic indicators in isolation can be used to show disparities in wealth between countries, but when combined with other factors such as health statistics produce quite striking and unexpected disparities. For example, male survival rates in the United States are higher than that of the state of Kerala, India, by over a decade. The obvious explanation is that the United States is vastly more affluent and so people live longer. Yet the same statistics show that black males living in United States have a *lower* survival rate than in Kerala. What Sen argues with in these statistics is the importance of *combined* factors, or 'substantive freedoms', as he calls them. These include aspects of social and health care, community relations, education, law and order, security and political factors (notably the level of democracy). In order to attend to issues such as poverty and health, it is not enough to simply spend more money. Businesses, for example, can often be criticised for the ineffectiveness of philanthropic activity; for only donating to, not actually *contributing* to society. Development is not merely a return on investment and it is not a luxury: 'enhancement of human freedom is both the main object and the primary means of development. The objective of development relates to the valuation of the actual freedoms enjoyed by the people involved. Individual capabilities crucially depend on, among other things, economic, social, and political arrangements' (Sen, 1999, 53).

Sen's account of 'development as freedom' might be described best as the *freedom to* do things (to live according to your own capabilities), rather than suggestive of the more negative *freedom from* something. In other words, development is not applied to free us from a problem; instead, it is the articulation of our freedom. According to Sen's data, males living in Kerala will on average earn substantially less than black males living in the United States but potentially possess more *substantive* freedoms in terms of education, social networks, literacy, etc. And it is these substantive freedoms that he argues *combine* to lead to longer life expectancy. Crucially, a combined ethics and economic perspective looks to the bigger picture, asking different questions of and across datasets. Similarly, ESD requires a broader canvas to be taken into account, which itself is challenging the field of business studies.

The factors involved in ESD are of course much broader than just those pertaining specifically to poverty, well-being and life expectancy, but similar principles are at stake (and there are interrelated debates). Firstly, ESD should not be viewed as development on from traditional business, or indeed as an imposition upon, or even policing of, existing business practices. This would be to suggest ESD is somehow seeking *freedom from* business (forever characterised as bad). Alternatively, the view might be taken that business and commerce have matured to a point at which it is now possible to apply ESD. Again, this would be the wrong way to frame things, as if ESD is a luxury we can now afford. The point is to consider ESD as the *freedom to* pursue business in a particular way, one which offers a more integrated picture and so is both led by and leads to greater capability. As Sen writes: 'Capability is a kind of freedom: the substantive freedom to achieve alternative functioning combinations (or, less formally put, the freedom to achieve various lifestyles)' (1999, 75). The use of the term 'functioning' varies across Sen's work, but as Hart (2013, 37–38) notes, the term generally gravitates to 'achieved functionings', made possible through an individual's 'capability set'. As Sen writes: 'The capability set would consist of the alternative functioning vectors. . . . While the combination of a person's functionings reflects her actual *achievements*, the capability set reflects the *freedom* to achieve: the alternative functioning combinations from which this person can choose' (1999, 75). Sen gives the example of how an affluent person choosing to fast has a very different 'capability set' (or set of choices) than the destitute person unable to feed themselves.

Given the various (and even competing) demands and perspectives encapsulated by ESD, we can think of it as an attempt to bring together a variety of 'lifestyles' or choices, which represents a complex 'capability set', all of which needs elucidation and evaluation. Following this logic, it is necessary to consider what substantive freedoms are required of business within the frame of ESD.

Education itself is one key freedom or capability. We need the ability to think critically and creatively in order to re-evaluate and transform business. Thus, the capabilities of a teacher to deliver the kind of education they value is important in itself, but equally this is part of the greater freedom to understand sustainable development and for education to provide support for business thinking, to allow for a wider set of viewpoints. In this sense, education is not simply about feeding business with appropriately skilled labour to enable the status quo. Education is to be taken as a substantive freedom of business itself. It is part of an infrastructure that gives individuals and individual businesses the means to pursue the values they deem to be important.

From Sen's perspective, intervention is not what makes changes, but only what supports it. What we require are the grounds for change, which form the freedom to assert change. It can be argued that economic development can better support and resource education, yet Sen (1999, 41) sees this the other way round, arguing education is a freedom supportive of economic development. Education is, for example, capability towards the function of greater productivity. He cites, for example, the East Asian economic 'miracle' as being strongly predicated on 'human resource development' and higher levels of literacy, underlying which – in this particular context and circumstance – is a common cultural and social investment in the primacy of education.

With respect to ESD, education is not simply a driver towards greater productivity, but towards *better* (and sustainable) business practices.

The capability approach pays attention not only to opportunities but also processes or procedures 'that allow freedom of actions and decisions' (Sen, 1999, 17). The idea of understanding 'development as freedom' leads us to pose different kinds of questions about what we think development means and how it correlates to ideas of freedom. In effect, Sen turns our frames of reference around, to understand freedom not as the 'goal' (whether development or education), and so not as an *end*, but equally as *means*. This is given further definition through his distinction between 'culmination outcomes' and 'comprehensive outcomes'. Taking a hypothetical idea that a competitive market mechanism could be matched by a centralised, even dictatorial system, Sen asks – if both yield the same economic result, is there any real difference if we concern ourselves only with end results? Intuitively, he writes, 'something would be missing in such a scenario . . . the freedom of people to act as they like in deciding on where to work, what to produce, what to consume and so on' (Sen, 1999, 27). Despite being able to produce the same end results, the argument is that we would still prefer the scenario offering free choice. The difference is between whether or not we focus on just the end or equally upon the means and such that means are constitutive of the ends, i.e. it is how we define ourselves through the process as much as the end.

Sen's explicit interest in capabilities is of more specific importance in providing a pragmatic way of analysing a situation and of defining development or change *through capabilities*. It can be viewed as a form of idealism, as Sen refers to 'outcomes' (and is context specific). His approach, in looking at the processes and procedures that allow for opportunities, as a *combined reading*, and which vary enormously between different situations, is concerned with development as a *form* of action and doing, not simply a value or belief (which arguably can remain merely an ideological pronouncement).

Therefore, for Sen, there is a distinction 'between "culmination outcomes" (that is, only final outcomes without taking any note of the process of getting there, including the exercise of freedom) and "comprehensive outcomes" (taking note of the processes through which the culmination outcomes come about)' (Sen 1999, 27). The relative merits of a market system, he argues, is not based solely on the 'capacity to generate more efficient culmination outcomes' (1999, 27). In the context of ESD, there are numerous different ways to implement it within the education setting, which in turn can be reflected in simple measures and accreditations. However, if we look to how implementation *culminates*, i.e. how ESD is 'actually existing' and how it progresses beyond the educational context, we might come to quite different views about how best to pursue it. In an ever increasingly regulated society, with numerous systems of accreditation and auditing, universities and companies have become skilful in appropriately positioning their activities (and without necessarily making fundamental changes to their practices). In this sense the implementing and integrating of ESD (as a culmination outcome) is not necessarily the same as its embedding (Rasche and Gilbert, 2015). For that, we need to understand – as active forces – the integrated context of education, business and society. ESD provides a prompt to redraft how we define these terms, and indeed how these sites of practice interrelate, and for a broader 'evaluative space' (to adopt Sen's term, explored further later), whereby a wider range of options and interactions can be taken into critical consideration.

Evaluative space: ESD as capability

If we review the various issues that UNESCO list in their definition of ESD, such as climate change, biodiversity, poverty and sustainable consumption, each in turn are laudable concerns. However, difficulties may arise if we start to consider them in relation to one another. For example, is there a hierarchy of low to high priority, and in attending to one issue can we remain true to others? Overcoming issues of poverty could in some circumstances lead to increased production or a decrease in biodiversity (where perhaps greenbelt land is used to overcome housing shortages etc.). Wilkinson and Pickett (2010) argue that improvements to quality of life and equality can be met without further economic growth. Indeed, their thesis is that equality and sustainability are intrinsically linked. Sen's capability approach is attuned to these kinds of interrelated concerns. In discussing equality, for example, he is critical of a utilitarian perspective which puts 'equal weight on everyone's utility gains' (1992, 13), when in fact, he argues, we cannot assume all individuals can achieve the same utility gain from the same resources or circumstances. Therefore, despite general agreement that equality is a good thing, it is not something we can necessarily uniformly agree upon in practice. As much as we may need to debate the importance of equality, for Sen, the question is also always 'equality of what?' (Sen, 1992). Being egalitarian, he argues 'is not a "uniting" feature'. He writes, 'it is precisely because there are such substantive differences between the endorsement of different spaces in which equality is recommended . . . that the basic similarity between them (in the form of wanting equality is *some* space that is seen as important) can be far from transparent' (1992, 14). Similarly, the question of 'why sustainability?' can appear to dominate, whereas, Sen would ask, 'sustainability of what?'. The answer to this will vary depending on numerous factors. And like equality, there are some 'spaces' in sustainability (as Sen terms it) that are more readily associated than others. So, for example, the environment can quickly be evoked, yet, as noted in this chapter, the potential conflicts and issues range much more broadly. The protest movement #BlackLivesMatter, for example, has sought to show how environmental concerns such as air pollution are also deeply entwined with matters of class and race (Kelbert, 2016). What Sen has to say of equality can be transposed to matters of sustainability: 'it is important to recognize equality in one space – no matter how hallowed by tradition – can lead one to be anti-egalitarian in some other space, the comparative importance of which in the overall assessment has to be critically assessed' (1992, 16).

The frequent reference to 'space' needs some clarification. The capability approach is concerned with what Sen refers to as 'evaluative space', which is never definitively defined, certainly not as a specific site or domain. Nonetheless, looking across his writings, we can relate 'space' to a form of operation that varies according to different domains, discourses and disciplines. Different professional, conceptual and discursive domains or spaces will emphasise different 'objects of value':

> The identification of the objects of value specifies what may be called an *evaluative space*. In standard utilitarian analysis, for example, the evaluative space consists of the individual utilities (defined in the usual terms of pleasures, happiness, or desire

> fulfilment). [. . .] The capability approach is concerned primarily with your identification of value-objects, and sees the evaluative space in terms of functioning and capabilities to function.
>
> *(Sen, 1993, 32)*

As already discussed, capability sets provide possibility of different choices or functions. All of which, however, sit within 'spaces' (meaning domains or discourses), which are inevitably important in driving the terms of debate. Different evaluative spaces or agendas will have a strong impact on how we come to view capabilities and functionings in the first place. Sen says:

> The selection of the evaluative space has a good deal of cutting power on its own, both because of what it *includes* as potentially valuable and because of what it *excludes*. For example, because of the nature of the evaluative space, the capability approach differs from utilitarian evaluation . . . in making room for a variety of human acts and states as important in themselves (not just *because* they may produce utility, nor just to the *extent* that they yield utility). It also makes room for valuing various freedoms – in the form of capabilities. On the other side, the approach does not attach direct – as opposed to derivative – importance to the *means* of living or *means* of freedom (e.g. real income, wealth, opulence, primary goods, or resources), as some other approaches do. These variables are not part of the evaluative space, though they can indirectly influence the evaluation through their effects on variables included in that space.
>
> *(Sen, 1993, 33)*

Education provides an obvious context in which not only can we engage with an evaluative space but also potentially construct one. ESD in particular presents specific means to pursue the relational complexity that is suggestive of Sen's account. However, as discussed earlier, the implementation of ESD and the pressures of various drivers can inhibit how we frame or engage in the issues. Baden and Higgs (2015), as shown, are critical of the dominant approaches, suggesting that 'ethical issues tend to be presented as instrumental rather than the infusion of wisdom into the curriculum' (545). Nonetheless, they outline a number of areas where a wider frame of reference and perspective can be adopted to broaden the purview of business studies. So, for example, they suggest accounting modules can work upon the concept of the triple bottom line (Elkington, 1997) to include social and environmental performance not just economic performance.

Financial management, while potentially more difficult, can look at financing that contributes positively to social needs. Human resource management can turn to 'quality of life' indices to offer justifications for improved working conditions not just on the basis of improved productivity but also on the human value benefits gained. Marketing is another difficult area, as arguably it is predicated on consumption, which can be in tension with sustainability issues. Nonetheless, it is possible to promote decreases in production and focus on shifts to services. Entrepreneurialism can be centred around inspirational pro-social role models, corporate governance modules can look to alternative legal models and structures and strategy modules can emphasize stakeholders over shareholders (Baden and Higgs, 2015, 546–548).

Each of these examples suggest changes to what might be *included* or *excluded* in the 'space' of the curriculum and teaching environment. Of course, a key concern is the *extent* to which such changes are made. They can be presented as mere alternative functionings, becoming just one choice out of a range of choices. As such, a compartmentalised approach is still followed. We might even relate this to a more utilitarian mode, as a means to *maximise* sustainability in a given area, without necessarily broaching its deeper significance. Certainly, it is the case, through modularisation, that the different subject areas may not necessarily interact. Samuelson notes, for example, 'a course with "sustainability" in the title might consider the risks for both the business and its fence-line neighbors. . . . But in finance and other classes, these same students are taught to externalize costs and discount the future' (2013, 67). However, if we are to see ESD as genuinely broadening a capability set and evoking a different kind of evaluative space, it is important to maintain a critical dialogue between differing perspectives and needs. As noted by Cebrián et al. (2013, 286) 'ESD can foster a sustainable social transformation, through the clarification and reassessment of values'; indeed 'sustainability can be defined as a learning process that encourages transformative learning, the capacity to challenge existing patterns and worldviews, to construct new knowledge collectively, to rethink current practice, and to critique and examine sustainability issues' (287), an argument that is also echoed by Kurucz et al. (2014).

The evaluative space determines key considerations or the terms of debate, even the degree to which sustainability might be viewed as significant in the first place. Education can clearly play a role in influencing and even re-calibrating such spaces, but it also concerns how we relate to the necessary capabilities that are also important. 'The freedom to lead different types of life,' writes Sen, 'is reflected in the person's capability set' (1993, 33). This is by no means an unproblematic notion. We might not always be aware of our capabilities, nor have the impetus to make the right choices despite them being available to us. Furthermore compounding issues, such as those mentioned earlier in relation to environment and race, are either not easily visible or can become so entrenched that a limited capability or mindset can be normalised. To give an example specific to sustainability and the business context, we might consider the differing capability sets of a large, nationwide car dealership and a small, local mechanics firm. With the former, narratives pertinent to sustainability can often be made quite explicit. Perhaps the company promotes a new line in hybrid or electric cars and/or a waste scrappage scheme framed explicitly as a 'green' service. A problem, of course, is that the business is also predicated on increasing sales, so adding to the number of cars on the road. It is focused on providing new cars, rather than new components. Down the road, the local mechanic does not necessarily see themselves as being particularly focused on sustainability issues, as their business focus is on repairing cars and keeping them on the road. The actual sustainability issue is about re-using resources. These businesses engage differently with the evaluative space concerning sustainability. One is overt about such evaluations. Indeed, the car dealership is likely to have a dedicated corporate social responsibility (CSR) report and provide lots of sustainability-related signage on its premises to impress its customers. Such displays of 'consciousness' on the part of the business could be said to further influence future capabilities. However, what is significant about Sen's work is the need to *relate between* different circumstances and indicators – to understand relational differences and that change occurs *through* circumstances. In this case, while the mechanic is perhaps not so consciously engaged in the evaluative space of sustainability issues, it does not mean the business is not already in possession of the requisite capabilities and is indeed already functioning in a sustainable way. The question over 'sustainability of what?' is again pertinent. As Sen argues, capability is not a resource of fixed value, but something that must be examined in terms of its scaling according to specific circumstances. The difficulty, of course, is in bringing legitimacy and/or consciousness to such capabilities. At this level, as Putnam (2004, 60) suggested, census around matters of capability requires public debate and democratic engagement and acceptance. In looking to a new generation of business practitioners, a wider, relational field of vision allows us to look more across different capabilities, to make finer judgements about what is valuable. It is arguably the educational 'space' that has a vital role to play.

Conclusion

This chapter has examined the emergence of ESD within the field of business and management studies. It notes that the current literature focuses on the development and teaching of ethics and sustainability in a compartmentalised way, with less attention to how business can engage dynamically with the new sustainable development agenda (i.e. the wider ramifications it inscribes).

To support the *change* in agenda, consideration has been made of Sen's capability approach, which suggests that ESD itself can be understood as a capability. In terms of sustainability education, what is required is an evaluative space that provides the means for significant change in how we approach the subject of business and in turn how businesses might view themselves from a sustainability management perspective. What is needed is more relational understanding of the broad and at times competing factors and agents at stake in sustainable development.

Current practices in implementing and accrediting ESD can lead to a de-coupling from actual mainstream educational practices, including in business schools. Such decoupling may occur when ESD is seen as an end point of strategic renewal, rather than as a means of educating, expanding on and practising ethical practices and sustainability. Sen might argue, not for *sustainability as ESD* (i.e. that ESD can lead to sustainability), but rather *ESD as sustainability*, and that sustainability thinking and actions, or capability, are *required* for ESD to take root. The point is not for ESD to be some form of 'necessary' outcome, but as a genuine practice based on an expanded 'evaluative space', allowing for *comprehensive* outcomes that merge into sustainability outcomes.

ESD in all disciplines requires radical critical thinking that will challenge current management knowledge and norms. Evaluative spaces provide an opportunity to extend student capabilities through maintaining critical dialogues between differing perspectives and needs and in facilitating and extending further learning. This is, after all, the main challenge of ESD, regardless of the teaching discipline.

Footnotes

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4.6
BEARING FRUIT
Interpersonal competency development in sustainability education

Theres Konrad and Rebecca Freeth

Key concepts for sustainability education

- Interpersonal challenges of collaboration reveal our learning edges as sustainability students and professionals, providing impetus to strengthen interpersonal competency.
- Sustainability education can deliberately create opportunities to foster interpersonal competency for better collaboration.
- Instructors can support the development of interpersonal competency as role models, facilitators and co-learners.
- Interpersonal competency can be developed in project-based sustainability settings.
- "Learning to collaborate while collaborating" focuses on using interpersonal experiences as a basis for inquiry, reflection, conversation, learning and integration in practice.
- A combination of learning processes through different interactions can lead to specific interpersonal learning outcomes (knowledge, skills and attitudes).

Introduction

Interpersonal competency is a key competency in sustainability (Brundiers et al. 2020; Wiek, Withycombe, and Redman 2011) and is the focus of this chapter. As key competencies in sustainability reveal themselves in practice (Barth 2015), and as learning starts with *experiencing* (Kolb and Kolb 2012; Konrad 2021) and *modelling* (Collins, Brown, and Newman 1987), this chapter not only presents but is further guided by interpersonal competency learning processes. The chapter's structure of WHY – WHAT – HOW – NOW – WOW is intended to create an informative and reflection-triggering *experience* which invites the reader to engage in further *experimenting*. The reader will find answers to the following questions: *Why* do we talk about interpersonal competency at all? *What* do we know about this key competency in sustainability? *How* can it be developed, and what can we do with these insights *now*? *Wow* points towards future areas of interest. A formal conclusion further encourages the reader to move to practice.

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WHY: why do we talk about interpersonal competency at all?

A student of a project-based sustainability graduate course stated:

> You can obviously always learn something when you take a class, but the [sustainability] project itself has been the most useful part. Even to **learn how to deal with people**. I mean it's so **complicated**. I don't know why [. . .] we're **always having conflicts**. We're always having issues during the meeting or at least having like drama. Right now, I'm dealing with this close situation with another person of the team that I don't think I can work with, and I need to find out: how am I going to solve that? So that's very useful too, like just **what happens when I ever encounter a person like that in real life?**
>
> *(S1_005, student interview, 13.07.17)*

Does this experience resonate with you? Have you either found yourself, your students or colleagues in situations of conflict, where there were interpersonal issues that slowed down project progress in terms of milestones to be reached?

From climate change and biodiversity loss to pandemics, we humans are facing issues that are overwhelming in their complexity. One way that sustainability scientists and practitioners can tackle this degree of complexity is to work alongside others who bring alternative data, methods, perspectives, and personalities to complement our own efforts. In short, collaboration is needed for the problems we created and the challenges we face (Fam et al. 2019; Freeth 2019; Gulikers and Oonk 2019; Schneider et al. 2019).

However, collaborative work is not easy (Corbacho et al. 2021). While collaboration is needed and often highly rewarding, Klein (1996, 61) reminds us of the many challenges of collaborating, such as "territoriality and turf battles, disciplinary pecking orders and status dynamics, the differing status of quantitative and qualitative inputs, resistance to innovation, insecurity and mistrust, and lack of integrative skills". Hence, addressing sustainability problems collaboratively means being able to navigate such interpersonal issues. Freeth and Caniglia (2020) showed, based on a literature review and an empirical study of an interdisciplinary sustainability research project, that sustainability researchers are generally not equipped with the skills to confidently address the interpersonal challenges of collaboration.

To better prepare students, many sustainability programs at higher education institutions have started to apply project-based approaches to learning (Birdman, Wiek, and Lang 2021; Brundiers, Wiek, and Redman 2010; Brundiers and Wiek 2013). Next to other key competencies in sustainability (Brundiers et al. 2020; Wiek, Withycombe, and Redman 2011), these foster interpersonal competency development (Caniglia et al. 2016; Oxenswärdh and Persson-Fischier 2020; Roy et al. 2020; Savage et al. 2015; Soini, Korhonen-Kurki, and Asikainen 2019). As the student's statement at the beginning demonstrates, collaboration is key for sustainability professionals. Specifically, they will need to know how to collaborate (*knowledge* domain) and be able to collaborate (*skill* domain). On top of this, a collaborative orientation (*attitudinal domain)* enables working through the inevitable difficulties of teamwork. Difficulties and discomforts that arise due to diverging temperaments, viewpoints, working styles, etc., can be seen as *learning edges* (Schneider et al. 2019). If this opportunity is seized, a learning edge can also lead beyond learning, to searching for better solutions in collaborative processes towards sustainability (Caniglia et al. 2020).

Overlooking the interpersonal dimension of projects might come at the expense of strong final project outputs and a fruitful working environment, leading to more profound outcomes (Wiek et al. 2014).

Thus far, we have argued that students in the field of sustainability need interpersonal competency for conducting their work collaboratively. However, the connection between sustainability and interpersonal competency is deeper than this. We believe that sustainability requires "finding, establishing, and maintaining the 'right balance' " because extracting more (from the environment or from ourselves) than can be regenerated will ultimately lead to depletion (Konrad 2021, 7). A commitment to sustainability is thus a commitment to nurturing the "sources of renewal" (Gallopín 2003, 19), which allows ecological systems to flourish even as they adapt and evolve to changing conditions. This is true too for the human systems in which we work, such as inter- and transdisciplinary teams collaborating in the field of sustainability. Interpersonal competency can enable paying attention to the team's sources of renewal.

The community-supported-economy (CSX) network association represents a practice example of connecting a commitment towards sustainability with interpersonal competency development. ('CSX' derives from 'CSA' which stands for community-supported agriculture. The 'X' implies that CSA principles are applied to a different context 'X'.) The CSX network association used the process of finding and developing a shared vision to enable people to leave their comfort zones and engage with different viewpoints. This vision calls for a solidary, diverse, inclusive world, in which people take joint responsibility for ecologically, socially and fair basic supply as well as further satisfaction of needs. To turn this vision into reality, the CSX network association has formulated and continues to follow their own internal vision, namely, being a vibrant organization that enables its members and interested parties to learn and be(come) effective together. Members from different strands of life are not only committed to the CSX vision but also to growing together as a team and experimenting with different ways of collaboration. Understanding themselves as learners, walking on grounds to be still explored, requires a conflict-embracing attitude. Their collaborative practices include a weekly one-hour get-together with rotating roles of moderator and note-taker, prepared agendas and check-in and check-out rounds. This fosters a trustful environment that also allows people to air feelings and diverging opinions which are linked to people's different needs (Rosenberg 2015), experiences and expectations. It also requires interpersonal skills such as facilitation and communication for addressing such situations. The CSX network association invited inputs from external experts (e.g. on sociocracy and teal organizations) on how to facilitate moments of divergence and how to take joint decisions. They then embedded these practices through cycles of experimentation and shared reflection.

WHAT: what do we know about interpersonal competency as one of the key competencies in sustainability?

Interpersonal competency, like other key competencies in sustainability, is a functionally linked complex of "knowledge, skills, and attitudes" (Wiek, Withycombe, and Redman 2011, 204). Hence, it combines head, hands and heart (Sipos, Battisti, and Grimm 2008), allowing for "successful task performance and problem solving with respect to real-world sustainability problems, challenges, and opportunities" (Wiek, Withycombe, and Redman 2011, 204).

Systems thinking competency is key to understand a problem, while *futures thinking* competency is key to anticipate future states with and without interventions. *Normative thinking* competency allows us to craft and evaluate desirable sustainable future visions, guiding our endeavours, while *strategic thinking* competency allows for the planning of actions to make them real (Brundiers et al. 2020; Gardiner and Rieckmann 2015; John et al. 2017; Wiek et al. 2015). Brundiers et al. (2020) recently added *implementation competency* to stress the importance of action. Further, Brundiers et al. (2020) discussed the inclusion of *intrapersonal competency* into the framework, which we will come back to at the end of this chapter. Here, the attitudinal, inner dimension is in focus (Woiwode et al. 2021).

Interpersonal or *collaborative competency* ties these key competencies together (Wiek, Withycombe, and Redman 2011). In other words, interpersonal competency creates opportunities for sustainability projects to 'bear fruit' through skillful interactions between different people who are investing different competencies in shared problem-solving. Interpersonal competency is described as the ability to "apply the concepts and methods of each competency not merely as 'technical skills', but in ways that truly engage and motivate diverse stakeholders" and to empathically work with others (Brundiers et al. 2020, see specific learning objectives).

According to empirical research, students most often highlight interpersonal competency as a learning outcome of project-based sustainability courses (Corbacho et al. 2021; Heiskanen, Thidell, and Rodhe 2016; Konrad, Wiek, and Barth 2020, 2021b; Molderez and Fonseca 2018; Soini, Korhonen-Kurki, and Asikainen 2019). Interpersonal competency was originally defined as "the ability to motivate, enable, and facilitate collaborative and participatory sustainability research and problem solving", including the "capacity to understand, embrace, and facilitate diversity across cultures, social groups, communities, and individuals" (Wiek, Withycombe, and Redman 2011, 211). This key competency in sustainability has been further specified into collaborative teamwork and impactful stakeholder engagement (Brundiers and Wiek 2017). **Collaborative teamwork** can be described as "the process when people engage in utilising different and complementary types of expertise, skills, and attitudes to complete a task", which results in "high-quality task delivery (task effectiveness) by co-creating a stimulating and healthy work environment (social process effectiveness)" (Brundiers and Wiek 2017, 5).

Possessing collaborative teamwork **knowledge** means that one has an understanding, or a *mental model* (Collins, Brown, and Newman 1987), of what meaningfully working together on a project requires. First, it requires organization, i.e., clarifying or determining roles and responsibilities. Second, it requires facilitation of processes. This ranges from team-building activities to actual task performance, drawing on appropriate teamwork tools and methods, such as codes of conduct, agendas, protocols, and making sure everybody is on the same page. Collaborative teamwork **skills** encompass facilitation, linked to communication, and conflict mediation – and require having knowledge to apply such teamwork tools. Self-reflection has also been identified as a collaborative teamwork skill (Konrad, Wiek, and Barth 2021b), because empathetic interactions may be activated by reflecting upon and questioning one's subjective perspectives. This links to collaborative teamwork **attitude**, which implies being conflict-embracing (e.g. conflicts occurring due to divergent perspectives), being solution-oriented, self-confident and embodying a can-do spirit.

Beyond the academic setting, interpersonal competency is critical for enabling impactful stakeholder engagement. **Impactful stakeholder engagement** entails the engagement of "diverse stakeholders from government, businesses, and civil society", pursuing the aim of yielding "task outcomes like quality project deliverables that have been informed by a plurality of views and are broadly accepted, as well as social outcomes including new perspectives, relationships and built capacity" (Brundiers and Wiek 2017, 6). The plurality of views suggests that such settings can come with divergent ideas, opinions, expectations and interests – what requires the ability to deal with tension, or a conflict-embracing attitude (Konrad, Wiek, and Barth 2020).

Impactful stakeholder engagement **knowledge** means that one has an understanding (or a mental model) of what meaningfully interacting with different people around a sustainability challenge requires. First, it requires preparatory activities. These include the familiarization with stakeholders' interests, concerns, expertise and expectations, as well as the preparation of materials and the identification of facilitation methods supportive for specific process facilitation. Second, it requires accounting for and integrating a variety of perspectives, so all participants feel heard and seen. Impactful stakeholder engagement **skills** draw upon this knowledge and manifest in facilitation and communication, both linked to the preparation of stakeholder events. Impactful stakeholder engagement **attitude** refers to the self-confidence one needs to have to engage with stakeholders on sustainability issues.

Empirical research on interpersonal competency development, based on a grounded theory-inspired comparative multicase study of three international project-based sustainability courses (Konrad, Wiek, and Barth 2021a, 2021b), enabled nuancing these interpersonal competency facets and domains (Table 4.6.1).

This research with graduate sustainability students showed that interpersonal competency – in particular, its attitudinal domain – not only fosters further interpersonal competency development but key competency development overall (Konrad, Wiek, and Barth 2021b). Key competencies reveal themselves in practice (Barth 2015). When a student dares to test certain interpersonal skills with others, this creates opportunities to turn knowledge into practice, promoting further learning and development. *What does this imply?*

For project-based sustainability courses shown to be conducive for key competency development (Molderez and Fonseca 2018; Roy et al. 2020; Savage et al. 2015; Soini, Korhonen-Kurki, and Asikainen 2019), learning processes and environments can be designed and facilitated in ways supportive of interpersonal competency development. Next we consider *HOW* to support the development of interpersonal competency facets and domains in sustainability education so that future sustainability professionals feel prepared to face challenges together.

HOW: how can interpersonal competency be developed?

The previously mentioned comparative, multicase study identified four different but complementary learning processes for interpersonal competency development (Konrad, Wiek, and Barth 2021b). These are *receiving input, experiencing, reflecting* and *experimenting*. In theory, all participants of a project-based sustainability course (students, instructors, stakeholders and mentors) can provide for all learning processes. Four interaction types have been identified that trigger the specific learning processes for interpersonal competency development (Konrad, Wiek, and Barth 2021a) (Table 4.6.2).

Table 4.6.1 Interpersonal competency constituencies: facets and domains

Interpersonal competency facets and domains		
Collaborative teamwork	Attitudes	Conflict-embracing, self-confident, solution-oriented, can-do
	Knowledge	Mental model, i.e., knowing that collaborative teamwork entails sound team organization (clarity on roles and responsibilities; facilitated team processes, starting with team-building activities, regular team meetings; the application of teamwork tools and methods, e.g. code of conduct/team agreement, meeting agenda and protocol template)
	Skills	Facilitation, communication, conflict mediation, self-reflection
Impactful stakeholder engagement	Attitudes	Self-confidence in engaging stakeholders on sustainability issues
	Knowledge	Mental model, i.e., knowing that and how impactful stakeholder engagement entails preparatory activities, including familiarization with stakeholder interests, expertise and expectations; the preparation of supportive materials and activities prior to engagement events; accounting for and integrating diverse perspectives of all stakeholders
	Skills	Preparing stakeholder events; facilitation at such events; general communication

Source: Based upon Konrad, Wiek, and Barth 2021b.

Table 4.6.2 Interaction types and the typical learning processes these trigger in support of interpersonal competency development

Interaction	*Typical processes*
Peer (student-student)	Experiencing, reflecting, experimenting
Deliberate (student-instructor)	Receiving input, experiencing, reflecting, experimenting
Professional (student-stakeholder)	Receiving input, experiencing, experimenting
Supportive (student-mentor)	Reflecting, experimenting

Source: Based upon Konrad, Wiek, and Barth 2021a

As can be seen in Table 4.6.2, professional interactions tend to focus on the doing (experiencing and experimenting). While skills are trained, they are not ‘named’ unless the doing is followed by reflection. It is in supportive interactions with mentors, for instance, where students are typically offered more informal opportunities to share about their experiences and thus reflect on their learning. Thus, it is important for the course designer/instructor to deliberately make space for such supportive interactions in order to foster students’ interpersonal competency development. It is the conscious combination of learning processes, through interactions, which fosters interpersonal attitude, knowledge

Table 4.6.3 Interpersonal competency facets and domains and their connected processes and interactions

Interpersonal competency facets and domains		*Combination of learning processes allowing specific development*	*Typical interaction types as triggers*
Collaborative teamwork	Attitudes	Experiencing, reflecting, experimenting	Peer, deliberate
	Knowledge	Receiving input, experiencing, and reflecting	Deliberate, peer, supportive
	Skills	Receiving input, experiencing, reflecting, experimenting	Deliberate, peer, supportive
Impactful stakeholder engagement	Attitudes	Experiencing, reflecting, experimenting	Professional, deliberate
	Knowledge	Receiving input, experiencing, and reflecting	Deliberate, professional, supportive
	Skills	Receiving input, experiencing, reflecting, experimenting	Deliberate, professional, supportive

and/or skill development. Table 4.6.3 gives more nuanced insights which interpersonal competency facets and domains can be fostered by the combination of specific interaction types.

Following are some examples to ground these conceptual findings from the presented study, shown in Table 4.6.3.

The collaborative teamwork **attitude** of being conflict-embracing, for instance, can be developed by the experience of exchanging divergent perspectives with a willingness to explore one's own perspectives, be curious about the perspectives of others and, if necessary, agree to disagree (Freeth et al. 2019). While this disagreement might produce discomfort, it can lead to learning if there are opportunities to reflect on how to deal with the situation in a solution-oriented way. A solution-oriented attitude has further been found to be a component of a collaborative attitude (Konrad, Wiek, and Barth 2021b) and therefore suggests that interpersonal competency further fosters learning. A student stated:

> Understand their perspectives, so meetings are more effective. So, if you get someone's perspective and you know that this is something that was bothering them, maybe they do not feel comfortable saying it. You can say it and you can say, 'Let's try to reassess this', and [. . .] I tried to do that a lot.
>
> *(S1_011, focus group, November 30, 2017, line 267)*

Following the experience of discomfort and reflection upon this in peer interactions, it was the openness to trying to find alternatives that further developed students' conflict-embracing attitude. The learning process of experimenting complemented this attitude development.

For the development of the **knowledge** domain, the learning process of receiving input is supportive of both collaborative teamwork and impactful stakeholder engagement. After having received input on stakeholder engagement, including facilitation training, students got to experience a stakeholder engagement event. This allowed students to better understand what impactful stakeholder engagement means and entails. A mental model was developed:

> I got a feel of what [. . .] workshop engagement with people [. . .] feels like and where you need to be very careful to spend the time smartly [. . .], where you need to give them leeway to take longer [. . .], of course, they do not behave the way you set it out to be. [. . .] The question is how you can then spontaneously react to that? How can you still maintain a friendly atmosphere even though things are not going by your plan? The entire idea of pre-testing a lot and that it needs so many 'hands on deck' is something that I think for me is beneficial from the [. . .] project.
>
> *(S1_002, student interview, October 30, 2017, line 12)*

This experience was brought to the meta-level by inquiry and reflection on these interactions and their implications for impactful stakeholder engagement. This supported the student to further develop this interpersonal competency domain. While input was received through deliberate interactions and the experience was provided through professional interactions, room for reflection was given in supportive interactions.

An example illustrating collaborative teamwork **skill** development equally shows how this domain is linked to the other two:

> I always feel like their sessions are really helpful, when they gave us the chance to write down [. . .] two situations where a conflict occurred and then in class we acted through [. . .] hypothetical scenarios. [. . .] They gave us the chance to talk about it, and it was a roleplay, so we had different roles and [. . .] while we were playing, [. . .] you could understand the other person.
>
> *(S1_004, student interview, July 12, 2017, line 55)*

The student statement shows that skill development builds on prior received input (in this case, on team dynamics through student-instructor interaction) and experiences (of team conflicts in student-student interactions). Experiences do not need to be positively connotated to learn from or through them. Experimenting, e.g. with hypothetical scenarios, allowed one to broaden one's skill repertoire in a safe space, equipping students with the means to face conflicts ahead to feel better prepared. Both input and provided experience of conflict resolution stemmed from deliberate interactions, while peers came into play for experimenting.

According to learning theories, such as experiential learning theory (Kolb and Kolb 2012) and cognitive apprenticeship (Collins, Brown, and Newman 1987), receiving input to create a mental model is a starting point for learning as it gives the learner an orientation to help navigate their 'learning journey'. Grasping an experience through concrete experiences and abstract conceptualizations should be followed by transforming an experience through reflective observations and active experimentations (Kolb and Kolb 2012), as this supports and likewise demonstrates that meaning is derived from the prior experience. Consequently, a person is better equipped to apply derived attitudes, knowledge and skills in different contexts.

Freeth and Caniglia (2020) came to similar insights based on research within an interdisciplinary sustainability research project. Recognizing that not all researchers have had formal educational opportunities to develop interpersonal competency, they propose "learning to collaborate while collaborating". However, in the output-driven, busy environment of sustainability research, learning to collaborate while collaborating does not happen automatically. Instead, there is value in making explicit the opportunities to develop interpersonal competency during the course of inter- and transdisciplinary projects and creating the conditions to do so. These conditions, which can also be created in student projects, are best established early, at the point of designing and planning collaborative research. For example:

- Creating a team culture, from the first times of meeting together, that encourages researchers to learn from mistakes in their collaborative work, rather than to hide these (Edmondson 1999). Researchers are learners and students are researchers.
- Treating differences among team members as a source of strength, including disciplinary and methodology differences, cultural differences or differences in temperament. Otherwise, such differences can be confusing and even threatening and become a basis for misunderstanding and conflict. Changing these negative patterns requires a curiosity about others and an appreciation that their ways of working can complement ours in collaborative research (van den Bossche et al. 2011; Hackett and Rhoten 2010). Hence, a collaborative attitude further fosters interpersonal competency development.
- Ensuring that there is sufficient time for reflection and conversation about these experiences of collaborating so that the learning, from moments of success as well as moments of frustration and failure, can be integrated into the ongoing work of the team (Baker, Jensen, and Kolb 2002). This includes allowing for difficult experiences, such as navigating power in a team, to become "discussable" (Donovan 2014; MacMynowski 2007). While instructors can deliberately design and are usually in charge of such opportunities of learning, all involved – the researcher, learner, student and stakeholders – can support collaboration and the development of interpersonal competency by asking for space for reflection.

To sum up, whether individuals have developed key competencies in sustainability, in particular interpersonal competency, becomes apparent when they apply them in various contexts. To not only derive outputs in the shape of project deliverables at the end of the semester but have students enter the professional field aware of what they are capable of in terms of interpersonal attitudes, knowledge and skills requires reflecting upon the interactions they have been engaging in. Thus, in a nutshell, for interpersonal competency development, doing and the reflecting about the doing are two sides of the same coin. Practices of reflection (for example, about received inputs or through discussing experiences and articulating one's observations in a shared reflection) can generate practical knowledge (for example, how to collaborate or how to engage stakeholders). Interpersonal competency is developed through making interactions the subject of inquiry (Konrad, Wiek, and Barth 2021a).

NOW: what can we do with these insights?

We have stressed the importance of interpersonal competency and its development in sustainability education. For sustainability professionals it is key to being able to collaborate and co-create a worthwhile future for all Earth's inhabitants, embracing uncertainty, conflicts and challenges as opportunities to show what we are collaboratively capable of.

We have also provided some insights into the attitudes, knowledge and skills that constitute interpersonal competency. Moreover, we illustrated how these domains can be developed in project-based learning settings, through the combination of typically occurring interactions and the respective processes they trigger. We have included several examples of what interpersonal competency development can look like in practice.

How does this translate into your classroom context now?

Make interpersonal interactions the subject of inquiry and (self) reflection. Research showed which learning processes each student interaction is prone to trigger (Table 4.6.2). Professional interactions, for instance, mainly offer opportunities for experiencing and experimenting, e.g. with facilitation skills. If such an opportunity is provided for students, debrief this experience with them. Alternatively, provide for peer interactions in which students reflect together. Some questions supporting the process of reflecting can be:

- How was the experience?
- What happened?
- Was there anything surprising?
- Why was it surprising?
- Were there any awkward moments when you did not know how to react?
- What did you do – and what could have been helpful?
- What went well?
- What would you do again or differently next time and why?

Asking questions is powerful. As learning facilitators and process designers, it is also our task to provide opportunities to answer these, allowing for reflection. As hooks (1994, 11) states:

> Teaching is a performative act. [. . .] To embrace the performative aspect of teaching we are compelled to engage 'audiences,' [. . .]. Teachers are not performers in the traditional sense of the word in that our work is not meant to be a spectacle. Yet it is meant to serve as a catalyst that calls everyone to become more and more engaged, to become active participants in learning.

Reflections can be triggered. Thus, a self-reflective attitude – or self-reflection as a skill – can be fostered, e.g. by asking questions and modelling self-reflection and letting this practice bear fruit in interpersonal interactions. For interpersonally competent future change agents, interpersonally competent role models are needed.

Instructors are role models and need a certain level of interpersonal competency to engage with their stakeholders in an impactful manner: the students. So, our elaboration on interpersonal competency can serve as an orientation for one's own further learning objectives.

Luckily, competency development is a lifelong process and not a destination. Therefore, both students and instructors alike can further develop their interpersonal attitudes, knowledge and skills through making the interactions they engage in active subjects of inquiry.

Instructors can use the typically occurring interactions deliberately to trigger specific learning processes in students. Unless "reflective processes that allow teachers to understand and transform their research and practice" (Callejas Restrepo et al. 2017, 658) are institutionalized, one has to make the active effort oneself to create space for "refl-action", the active combination of action and reflection for one's own learning (Konrad 2021). Professional development, particularly interpersonal competency development, requires ongoing critical reflection (Callejas Restrepo et al. 2017).

As Ettling (2012, 546) writes about educators as change agents: "Setting the stage for dialogue among learners and with us, as educators, creates the environment for change to occur, both in ourselves and in the learners". Instructors are gatekeepers and enablers, or in Bürgener and Barth's (2018, 822) words, "the single most important factor when it comes to success in students' learning and it is the teacher's competencies that create learning opportunities with the greatest potential learning outcomes".

Critical instructors' traits that support the learning and facilitation of interpersonal competency development include thorough preparation of the course and the projects; clearly communicating course objectives, milestones and boundaries; instigating and facilitating a variety of learning processes; and willingness to open up and learn themselves, according to an interviewed instructor (T_701, ARW instructor interview, 10.04.2018). One can see that this aligns with the knowledge domain of impactful stakeholder engagement presented earlier.

As Freeth (2019, 33) states, people who lead collaborations (which includes instructors in sustainability education who foster student collaboration) are "primarily responsible for creating conditions conducive to collaboration"; however, "all members of a collaborative team are responsible for how they engage in the team." This implies that a certain level of interpersonal competency, including self-reflection and awareness, is key for course designers and instructors.

WOW: future areas of interest and insight

Brundiers et al. (2020) recently added *intra*personal competency as an integral part of interpersonal competency, therefore also underlying all the other key competencies in sustainability. Whereas interpersonal competency can be seen in interactions with other people, intrapersonal competency can be seen as a "self awareness competency" (UNESCO 2017). It can be defined as "the ability to reflect on one's own role in the local community and (global) society; to continually evaluate and further motivate one's actions; and to deal with one's feelings and desires." (UNESCO 2017, 10). This includes recognizing one's own emotions, thoughts, desires and habits and further the ability to regulate oneself in terms of mood (Brundiers et al. 2020). As Senge, Scharmer, and Winslow (2013, 51) stated: "How can you possibly be of any real use as a leader on a larger scale if you can't lead yourself through the thicket of your own emotions and thoughts?" Because we have yet to conduct thorough research on this part of interpersonal competency, we want to emphasize in our final personal reflections on intrapersonal competency that future research in this area could benefit interpersonal competency development and, ultimately, sustainability problem-solving (Wamsler 2020).

*

Rebecca: My “wow” contribution is in the form of a provocation. Low self-awareness and self-regulation can be burdensome to those we collaborate with. This includes, for example, having blind spots about the impact of our racial, gendered or economic privilege when collaborating in diverse groups. Or allowing a fear of conflict to inhibit healthy conversations about diverse experiences and expectations. Conversely, self-awareness is a gift to those we work with. Intrapersonal competency creates the interior conditions for being able to express empathy, clarity, honesty, integrity and accountability. These five qualities constitute “social sensitivity” found in high-performing research teams (Cheruvelil et al. 2014, 33).

*

Theres: My “wow” contribution is in the form of a personal experience and reflection on it. A while ago, I realized that a sustainable future and regeneration can only be achieved through people working together. But it wasn’t until recently that I figured out how ‘inner sustainability’ is key for what I want to see in the world (strengthened by scholars such as Woiwode et al. 2021). And I have come to see that sustainability and economy, in the strict meaning of the term (*oikos nomos*), in my eyes, are actually about the same thing: Taking care of the household; keeping a healthy balance. That is, for me, what sustainability is about – on a global scale. Taking care of planet earth so all life can thrive. Inner sustainability, for me, then translates into taking care of myself, of my own internal household. *What are my needs? What do I need to thrive, be and feel alive?* Pausing, reflecting, becoming aware of myself, and taking care of my own well-being. I came to realize that this is a healthy basis for collaboration. *How have I realized that?* Not least through dancing tango – and reflecting (!) on this experience.

Imagine two individuals dancing tango together. They are leaning slightly towards each other, yet each person is in charge of their own balance. If I lean too much onto the other person, I’ll get too heavy for my partner. If I am hanging too loosely in the other person’s arms, then I equally demand the other person’s strength to support me. For a moment, this might work out. The dance will not last, though, or at least will not be that enjoyable. *How does this relate to collaboration?*

Have you ever found yourself in a group in which not all were on the same page? Because one or two members of the group, maybe even you, might have been out-of-balance, absent-minded, maybe because personal needs were not being met? Maybe these needs weren’t in your conscious awareness and were therefore hard to communicate and satisfy?

If your answer is yes then potentially other people needed to look out for you, to keep ‘dancing’, to keep working together. However, the embodied experience of collaboration through tango does not translate to teamwork of only two people. Imagine a dance floor full of couples dancing together. If one couple stumbles, due to a lack of care of their own household, the entire ballroom might be affected.

This is my personal experience and reflection on intrapersonal competency and its importance for collaborative future co-creation. To be further explored – and nurtured.

*

With this chapter, we sought to share our perspectives on interpersonal competency and its development in and for sustainability education. We close this chapter with a question that we ourselves were gifted with by Gogo Dineo Ndlanzi from South Africa during the Leverage Points Conference at Leuphana University of Lüneburg in 2019: *"How can we bear fruit if we are not rooted?"*

What does this mean for you on a personal level?

And how does this translate into your collaborative practices, in and outside the classroom?

Conclusion

We have argued for the role of interpersonal competency development in sustainability education. If students are to become future change agents, they need to know how to empathetically and constructively engage with others, embracing their differences and respective strengths to face present and future challenges. While it is always possible to *learn to collaborate while collaborating*, it is preferable for professionals to join collaborations having already had the benefit of developing interpersonal competency in a safe classroom space. Through the combination of *receiving input* (e.g. on good teamwork practices), *experiencing* (e.g. having both successes and tough times as a team), *reflecting* about the way we interact with each other and (re)act in different situations and *experimenting* with teamwork tools or facilitation practices, students are supported to enter their professional life with a collaborative mindset as a baseline for collective action.

Sustainability professionals invariably engage with a wide diversity of people. If students are to be ready to face the sustainability challenges ahead, we cannot prepare them in theory only. Providing opportunities to experience, experiment, reflect and integrate insights in practice will produce graduates better prepared for the collaboration challenges they will face.

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SECTION 5

Educating the educators

"*Until man duplicates a blade of grass, nature can laugh at his so-called scientific knowledge.*"

(Thomas Edison, 1847–1931)

The first four Sections of the book have discussed a number of significant sustainability concepts and contexts that need to be understood to both develop and deliver sustainability education. In this Section we examine the critical role of 'educating the educators' through important teacher training and development in sustainability education.

Section 5 discusses the important task of providing teachers with both development in, and support with, education for sustainable development (ESD) to ensure effective teaching of sustainability.

Teacher education is understandably a critical element in modern sustainability education development. This challenge includes the development of both (pre-) teacher sustainability knowledge and understanding as well as the development of pedagogy and strategies for teaching sustainability education. There are many approaches that can be taken in helping educators to understand the role and value of education for sustainable development.

For teachers to be well prepared to facilitate sustainability education, we must determine what needs to be included in teacher education programs. Gough (see Chapter 5.1 in this volume) argues that this should include an understanding of ecosystem health, social inclusion and public-good development and protection, within a framework of education for sustainable development.

Segalas and Tejedor (see chapter 5.2, in this volume) discuss the important role of Faculty empowerment in the sustainability education transition. The role of the faculty in supporting sustainability education development is crucial. Faculty empowerment is needed for programs of action in universities to help catalyse more sustainability education development and to prioritise sustainability curricula. For example, incentives could be offered to teachers to motivate their commitment to the development of sustainability education curricula. As a mode of teacher education, Sanchez-Carracedo et al. (see Chapter 5.3 in this volume) contend that online teacher education is an important methodology in 'educating

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the educators' given the geographic dispersion of tertiary educators and the recent challenges of pandemic enforced (Covid) isolation. On-line teacher education also provides an effective mechanism for the delivery of extended outreach teacher professional development (i.e., teachers currently employed in non-urban teaching positions) within a reasonable time frame.

The role of teachers in university sustainability education development is discussed by Gomera et al. (see Chapter 5.5 in this volume). Teacher-education programs need to be supported to specifically develop a sustainability mindset in teachers that then enables them to effectively teach sustainability and encourage students' sustainability knowledge development. Teachers are key agents of change in the sustainability education transition.

Fricker et al. (see Chapter 5.6 in this volume) discuss the importance of promoting First Nations perspectives in sustainability education teacher education, which can provide cultural and indigenous perspectives and values, important in both framing and understanding First Nations peoples thinking, heritage and wisdom. First Nations perspectives are also important in providing a wider cultural view on what should be included in sustainability education.

5.1

TEACHER EDUCATION FOR SUSTAINABILITY

Impetus and obstacles

Annette Gough

Key concepts for sustainability teacher education

- Teachers at all levels of formal education (primary, secondary and tertiary) have a key role in sustainability education.
- Teacher education institutions have been slow to respond to sustainability education.
- There are many obstacles to implementing sustainability in teacher education.
- Teacher education programs need to include sustainability content knowledge, attitudes and behaviours as well as transformative pedagogies.
- Mainstreaming sustainability in teacher education programs remains a challenge.

Introduction

Teachers have a key role in environmental education

The notion that environmental education should become an essential part of the education of all citizens emerged in the mid-1960s (Wheeler 1975). At the same time, it was recognised that teachers play an important role in promoting environmentally responsible citizenship and that there was a need to involve teachers in research "to determine more exactly the content of environmental education and methods of teaching best suited to modern needs" (Goodson 1983, 118). Involving teachers in planning content and methods for environmental education meant that they needed to be environmentally educated first.

Teachers were identified as a major target audience for environmental education in the Belgrade Charter (UNESCO 1975) and recommendations 17 and 18 from the 1977 Tbilisi Intergovernmental Conference on Environmental Education (UNESCO 1978). The recommendations from the latter specifically refer to pre-service teacher education and in-service teacher education and call for teacher education to include environmental education as a "priority activity" (UNESCO 1978, 20). These recommendations were framed around the belief that all teachers need "to understand the importance of environmental emphasis in their teaching" and so "environmental sciences and environmental education [need to] be included in curricula for pre-service teacher education" and that "the necessary steps [are taken] to make in-service training of teachers in environmental education available

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for all who need it" (UNESCO 1978, 35–36). By 1990, UNESCO-UNEP were arguing that the preparation of environmentally educated teachers was "the priority of priorities" (UNESCO-UNEP 1990, 1).

There is no doubt that teacher education is essential to achieving sustainability. The recent *Berlin Declaration on Education for Sustainable Development* (UNESCO 2021b, 3) stated the need to "recognize the crucial role of teachers to promote ESD and invest in the capacity development of teachers and other education personnel at all levels and to ensure a whole-of-sector approach to the necessary transformation of education". As the World Bank (2021, n.p.) states, "Teachers are the single most important factor affecting how much students learn. More than just conduits of information, they equip children with the tools to analyze, problem solve, and effectively use information". With around 85 million teachers worldwide (9.4 million in pre-primary, 30.3 million in primary, 18.1 in lower secondary, 14.0 in upper secondary and 12.5 in tertiary education) (World Bank 2021) and an annual turnover rate of around 10%, teachers are an obvious significant, and ongoing, target group. The issue is, however, how to reach them and what to teach them about sustainability so that they can then teach about sustainability to their students.

The UN Decade of Education for Sustainable Development implementation scheme (UNESCO 2005) recognised that educators and trainers needed to be assisted with the relevant knowledge and information to address education for sustainable development (ESD), consistent with Charles Hopkins and Rosalyn McKeown's (2005) *Guidelines and Recommendations for Reorienting Teacher Education to Address Sustainability*. However, the *Review of Contexts and Structures for Education for Sustainable Development 2009* (Wals 2009, 50–51) noted that

> The extent to which ESD has been integrated into teacher education programmes is unclear as: 1) limited knowledge of ESD at all levels is still a fundamental challenge and, in many cases, ESD has yet to move beyond a focus on the environment in many training programmes; 2) ESD is still often carried out by a limited number of teacher training institutions at the national level and needs to be further mainstreamed; and 3) more policy support is needed to guide ESD in teacher education and professional development.

The follow-up report on the decade (Wals and Nolan 2012) did not include teacher education as part of its monitoring and evaluation brief, but it still noted the importance of teacher education to primary and secondary education. The final report on the decade (Buckler and Creech 2014, 31) did, however, note that "More work still needs to be done to reorient teacher education to approach ESD in content and learning methods".

Teacher education, and curriculum, continued to be a focus in the *Future We Want,* the outcomes document from the 2012 Rio+20 United Nations Conference on Sustainable Development: "We therefore resolve to improve the capacity of our education systems to prepare people to pursue sustainable development, including through enhanced teacher training, [and] the development of sustainability curricula" (United Nations 2012, 60).

Teacher educators who were conscious of and engaged with the environmental education movement responded to these calls for environmental education in teacher education through a range of individual and group projects for both pre-service and in-service teacher education (see, for example, Evans et al. 2017; Fien 1995, 1998; McKeown and Hopkins 2002; Kyburz-Graber et al 2006; Ferreira et al. 2006; Ferreira et al. 2009; McKeown and Nolet 2013; McKeown 2014). Many of these initiatives had a curriculum focus on increasing teachers' awareness of environmental issues and environmental content knowledge, but a few were concerned with pedagogy and recognising the need for changing worldviews.

More recent research has still concluded that "teachers need better training to be agents of change, as part of a whole sector approach to Education for Sustainable Development (ESD)" (Giannini in UNESCO 2021a, 2):

> while there is evidence that the integration of environmental issues in education policy and curricula has increased significantly over past decades, reports on teacher education indicate that most teachers are ill-prepared to implement the environment-related education they are being asked to teach by national policy-makers.
>
> *(UNESCO 2021a, 19)*

It is therefore not surprising that the current UNESCO roadmap for ESD towards 2030 identifies leaders and staff of teacher colleges at all education levels as main actors in the implementing plan:

> Leaders and staff of teacher colleges should include systematic and comprehensive ESD capacity development in pre-service and in-service training and assessment of teachers in pre-primary, primary, secondary and tertiary education including adult education. This will include learning content specific to each SDG as well as transformative pedagogies that help to bring about action.
>
> *(UNESCO 2020, 30)*

Thus, there is much action still needed to implement sustainability into teacher education.

A major and continuing issue in achieving this goal is that teacher education institutions are generally autonomous in what they teach, although within the confines of the accreditation requirements of their context, and they often play games with the rules. In Scotland, for example, there were guidelines that teachers are required to be "knowledgeable about sustainable development and competent to contribute to ESD" (Higgins and Kirk 2002, 9), but it is an *option* for teacher education institutions to teach ESD and to determine how much emphasis is given to it. If teachers, and ultimately their students, are to understand sustainability, then there is a need for more stringent policies and guidance to ensure that teacher education programs everywhere include sustainability in their core content. Similarly, in Australia, sustainability is a cross-curriculum priority in the curriculum for schools (ACARA 2021), but there is no mention of sustainability in *Australian Professional Standards for Teachers* which "articulate what teachers are expected to know and be able to do at four career stages: Graduate, Proficient, Highly Accomplished and Lead" (AITSL 2018, 2).

This chapter reviews a range of international and local initiatives and strategies for re-orienting teacher education to address ESD through curriculum, pedagogy and whole-school system approaches, from the 1970s through to future directions.

Early initiatives

At an international level, following the 1977 Tbilisi Conference (UNESCO 1978), the UNESCO-UNEP International Environmental Education Programme (IEEP) commissioned and published 30 volumes of its Environmental Education Series (the "Green Books") to support various aspects of teacher education. These include pre-service or in-service teacher training modules and programs (11 of the 30 volumes), education modules for classroom use (7), guides and approaches to various aspects of environmental education (9) and trend paper or surveys (3). These volumes were intended to support the implementation of environmental education in member countries.

The Environment and Schools Initiative (ENSI) Project started in 1986, initially funded by the Organisation for Economic Co-operation and Development (OECD), was an in-service-like teacher education project. However, this project was different from the usual series of workshops for classroom teachers that comprise in-service teacher education in that it was action research based where teachers and schools worked with researchers in developing their practice. The initial ENSI Project has gone on to be a decentralised international network that brings together school initiatives, educators and other stakeholders in several countries to promote and understand activities promoting sustainable development in schools and their communities. It has sponsored a number of projects, including *Quality Criteria for ESD-Schools: Guidelines to Enhance the Quality of Education for Sustainable Development* (Breiting et al. 2005), which are useful in both pre-service and in-service teacher education settings. For example, the Breiting et al. (2005) document presents a non-exhaustive list of 'quality criteria' to be used as a starting point for reflections, debates and further development regarding future work on ESD among educational officials, teachers, headmasters, parents and students, and it has been translated into numerous European languages. The ongoing ENSI activities, which generally draw on experiences from across a range of countries, are mentioned here as they provide resources for both pre-service teacher education and in-service teacher education (see, for example, Kyburz-Graber et al. 2006).

National projects for incorporating environmental education into teacher education have been developed and implemented in a number of countries at both pre-service and in-service education levels over many years. The Australian *Teaching for a Sustainable World*, subtitled "A New Agenda in Teacher Education" (Fien 1995), and subsequently disseminated internationally by UNESCO (2002) as *Teaching and Learning for a Sustainable Future*, was designed as a pre-service teacher education project, but the modules could also be used in in-service teacher education contexts. Interestingly, this project was funded by the Australian development assistance agency, AIDAB, and the modules attempted to integrate environment and development issues, which makes them an early example of materials consistent with an ESD agenda. Also in the early 1990s, there was a European Union initiative on environmental education within pre-service teacher education programs which addressed pedagogical, assessment, implementation, curriculum and school aspects of what makes an "environmentally educated teacher" (Brinkman and Scott 1996). There was no national approach in the United States, and a survey conducted by Rosalyn McKeown (2000) found that the environmental education component of preservice teacher education programs varied, where they existed at all. Little had changed in the United States when Victor Nolet (2013) noted that only some teacher education programs had begun addressing sustainability in both pre-service and advanced professional development of teachers.

Indeed, across many countries, at the individual teachers' college or university level, there were numerous initiatives to incorporate environmental education into teacher education programs. However, these usually took the form of an elective program rather than being part of the core teacher education program (Gough 1998; Ferreira et al. 2006).

Although the possible breadth of reorienting teacher education for sustainability could (and should) include both pre-service and in-service teacher education, for the remainder of this chapter, I only focus on pre-service teacher education because in-service teacher education is so diverse and ephemeral, and it is generally provided outside higher education contexts. Pre-service teacher education programs have parameters and controls generally associated with the accreditation requirements for these programs; however, this does not mean that reorienting them for ESD is simple, and the remainder of this chapter focuses on strategies and barriers for reorienting teacher education programs for ESD.

Effectiveness of early initiatives to incorporate environmental sustainability education into teacher education

The environmental education (EE) research literature of the 1990s provides a recurring testimony to the lack of success in introducing coherent or consistent programs of environmental education into teacher education courses, despite many efforts (Gough 1998). Reviews of environmental education in teacher education from around this time tended to find that

- All universities offered some form of EE at some stage in their pre-service teacher education programs.
- Not all programs are implemented in a manner consistent with the EE literature.
- EE is often offered as an elective and is frequently only included in a course because of a lecturer's individual efforts.
- EE is sometimes not offered until the final year of a teacher education program.
- There is a substantial number of teachers who enter the teaching profession without any formal training in EE.
- Where EE is taught as an integrated subject, it is most likely associated with science or social studies subjects.

With respect to interventions such as the UNESCO-UNEP IEEP, while produced with the very best of intentions, the exact audience for these volumes was not always clear. The volumes raised particular concerns because of the universalised nature of the statements made in them which do not recognise the diversity of cultures, environments, languages, religions, stages of 'development' and politics within the world, as well as differing stages of colonisation and post-colonisation. In addition, the volumes also overlooked or negated the social context and expertise of the teacher educator through statements such as, "When implemented as intended, these guidelines will, in fact, result in teachers who are sufficiently competent and skilled to offer instruction in environmental education that will clearly contribute to the development of environmentally literate students" (Marcinkowski et al. 1990, 1). Statements like this raise questions about what makes such prototype programs for an EE curriculum appropriate for places other than where they have been developed and whether the major components and guidelines they have identified are also appropriate. This could well explain the low level of usage of these volumes by teacher educators, as more recent research in non-Western countries such as Malawi (Glasson et al. 2006) and the Pacific region (Thaman 2010) indicates. The findings from these studies suggest that teacher education programs that are grounded in local culture and environment are more relevant and effective.

However, there are other aspects of teacher educators and teacher education institutions that require elaboration at this point to better clarify their responses to the calls for the incorporation of EE into teacher education.

Understanding the response of teacher educators and teacher education institutions

The calls for teacher education to include EE were heeded by those who were engaged with the area, but for others, the calls fell on deaf ears because EE was seen as a political priority rather than an educational one. The calls for its inclusion came from government-level meetings and from activists outside of education – often environment groups and government environmental agencies – rather than from within education bureaucracies. As such, it was seen as yet another pressure for inclusion of an area into an already overcrowded curriculum – along with such things as driver education, sex education, multicultural education and so on.

With a few exceptions – such as Oman (Mulà and Tilbury 2011), South Africa (Lotz-Sisitka 2012) and Vietnam (UNESCO 2013) – within governments, the policy pushes and statements in favour of EE were forthcoming from environment agencies and were thus distanced from the education authorities – and as such did not carry any requirement to comply.

Another significant issue in some countries is exactly what constitutes pre-service teacher education. This can vary from being one year of training after a high school certificate for primary teachers in Bangladesh to a two-year master of education program following an undergraduate degree for secondary teachers in Finland and Australia – and in some countries there are many unqualified teachers.

Apart from different lengths in qualifying courses there are also differences between primary teacher education and secondary teacher education in terms of the content and focus of the programs. Primary teachers are educated to be generalists and are often expected to be experts in everything. Their programs often specifically focus on literacy and numeracy as the basics of education because, in some countries, many students do not even reach these basic levels before they stop coming to school. Secondary teachers are trained to be specialised subject teachers rather than generalists, and this too can militate against them being able to take on board EE because of their own preferences and the pressures of content for their specialisations.

Thus, the range of options for the inclusion of sustainability in teacher education programs that can be found in practice include:

- Struggling to be recognised as a core curriculum alongside literacy and numeracy in early childhood and primary teacher education programs,
- Being offered as an elective, which results in a few teachers specialising in ESD,
- Being mainstreamed across the teacher education program so that a genuine 'whole-of-system' approach to ESD can be developed, or
- A combination of the above (adapted from Ferreira et al. 2006, 13).

The extent to which any teacher education institution takes up one or all of these options is usually within the control of the institution. As Peter Higgins and Gordon Kirk (2002, 9) note with respect to Scotland,

> While the structure of programmes is determined by regulatory bodies, teacher education institutions can be as innovative and flexible as they wish, so long as their programmes are fully compatible with the national guidelines . . . it is left to individual teacher education institutions to determine how much emphasis is to be given to ESD.

Hopkins and McKeown (2005, 30–32) identified challenges to reorienting teacher education for ESD, which build on this comment from Higgins and Kirk. Within the teacher education institutions these include:

- Official national and provincial curriculum rarely mandates sustainability.
- Teacher certification guidelines do not mention sustainability.
- Lack of or inadequately trained professionals who are knowledgeable about ESD.
- Lack of or inadequate funding and material resources.
- Lack of or inadequate national, provincial and local policy to support ESD.
- Lack of or inadequate institutional climate that supports the creativity, innovation and risk-taking necessary to support transformative efforts to reorient education to address sustainability.
- Lack of or inadequate reward for institutions or faculty members who undertake ESD programs.

Others have identified additional barriers and challenges. For example, Ferreira et al. (2019) identified engaging various levels of the system (national and/or state education departments, universities, curriculum authorities), the crowded curriculum within teacher education programs, the siloed nature of systemic structures within institutions, the volatility of the university sector, limited awareness of expertise in staff/institutions and limited institutional commitment. Barnes et al. (2021) highlighted similar impediments, homing in on individuals' lack of conceptual understanding of sustainability, individuals' lack of capacity and confidence, lack of resources, lack of knowledge as to how to infuse sustainability education in teaching, challenges with overcrowded and standardised curricula and institutional and ideological challenges.

Approaching sustainability teacher education from the perspective of the pre-service teachers highlights other barriers, as recent Spanish studies discuss. For example, Esteve-Guirao et al. (2019) found promoting changes in everyday activities to favour environmental conservation was a challenge, as the pre-service teachers had difficulties with building relationships between sustainability and their lifestyle. Álvarez-García et al. (2019) found a link between personal and educational characteristics (like gender, the students' habitual place of residence, the type of leisure activities they undertook and some educational factors) had a significant impact on the pre-service teachers' acquisition of three components of environmental competence (environmental knowledge, attitudes and behaviours).

These challenges are discussed in the next section, together with some new visions and initiatives to support them, and then possible strategies for achieving a reorientation of teacher education in the following sections.

Initiatives to overcome obstacles

In 2005, after much international consultation, UNESCO published *Guidelines and Recommendations for Reorienting Teacher Education to Address Sustainability* (Hopkins and McKeown 2005). Unlike the earlier UNESCO-UNEP IEEP series, these *Guidelines* recognised the importance of teacher education institutions developing "their own thematic guidelines based on descriptions and ideals of sustainability" (Hopkins and McKeown 2005, 15). To provide some guidance, nine criteria (seven positive and two negative) for creating and evaluating new ESD projects were proposed (Hopkins and McKeown 2005, 16):

- ESD is locally relevant and culturally appropriate.
- ESD is based on local needs, perceptions and conditions but recognises fulfilling local needs often has global effects and consequences.
- ESD engages formal, non-formal and informal education.
- ESD is a lifelong endeavour.
- ESD accommodates the evolving nature of the concept of sustainability.
- ESD addresses content, context, pedagogy, global issues and local priorities.
- ESD deals with the wellbeing of all three realms of sustainability – environment, society and economy.
- ESD is not imported from another cultural, economic or geographic region.
- ESD is not 'one size fits all', but must be created to account for regional differences.

The *Guidelines* document also recognised that "addressing ESD will require student teachers to think about their profession differently and learn skills that perhaps, teachers in previous eras did not learn or use" as well as understanding the interrelatedness of the environment, society, and economy and having this interrelatedness "evident in their teaching and their lives as community members" (UNESCO 2005, 43). However, by having the guidelines so broad, there is the risk that teacher educators, and those who determine the content of teacher education programs, could well continue to overlook ESD because the agenda has become much more complicated and they do not know what to do, so they continue to operate in ignorance until required to act.

Nevertheless, several initiatives took up the challenge posed by the UNESCO *Guidelines* – including in Australia (Barnes et al. 2021; Ferreira et al. 2009, 2019; Gooch et al. 2008), Canada (Beckford 2008; Dippo 2013; Karrow and Di Giuseppe 2019; McKeown and Nolet 2013), Jamaica (Down 2006), Madagascar (Stephens 2012), South Africa (Lotz-Sisitka 2012), the United States (McKeown and Nolet 2013; Nolet 2013) and Vietnam (UNESCO 2013).

The Australian government, through its Department of the Environment, Water, Heritage and the Arts, initially funded the "Mainstreaming Education for Sustainability within Teacher Education in Australia" research project (Ferreira et al. 2009), with subsequent funding coming from a range of sources (Ferreira et al. 2019, vii). This project piloted a model for whole-of-system change in teacher education as recommended in Ferreira et al. (2006), which adopted a participatory action research approach to mainstream education for sustainability (EfS) within and across a whole pre-service teacher education system. Findings from the pilot study indicate that ESD can be mainstreamed within teacher education by:

- Capacity building within the teacher education community by:
- Developing competencies in education for sustainability;
- Establishing more effective interactions between decision-makers and other stakeholders;
- Establishing a community of inquiry for participants; and
- Developing an appreciation of whole-school approaches to sustainability
- Engaging with policy developers to:
- Enable a realignment of current policies; and
- Make changes to accreditation processes within education departments, teacher registration authorities and curriculum bodies;

- Thinking broadly about the teacher education, so that all stakeholders are engaged in the change process; and
- Improving networks across the teacher educator systems by identifying and supporting key agents of change within the sector and by developing new, and utilising existing, partnerships between schools, teacher education institutions and government agencies in the area of education for sustainability and whole-school approaches.

Between 2009 and 2019 the project team worked with institutions around Australia to refine the model, which came to be called the embedding change model (Ferreira et al. 2019). This model has six steps:

> (1) Scoping and structuring the process; (2) Considering project participants, their roles and their leadership capacities; (3) System mapping; (4) Engaging and developing the network; (5) Providing, sharing and developing new knowledge and information; and (6) Action research/reflection in/on action.
>
> *(Ferreira 2019, 47)*

Similar conclusions emerge from the other studies across different countries, thus providing some guidance on how to address obstacles to the successful implementation of sustainability teacher education.

For example, in the Jamaican study, Lorna Down (2006) describes how issues of sustainability were integrated into two different subjects (a basic computer course in the primary program and a specialist course on Caribbean literature in the secondary program) for the teacher education programs. Down concluded that challenges to the mainstreaming of sustainability in teacher education programs are related to staff, students, syllabuses, policy and support. She noted the need for capacity building of stakeholders; for institutional policy to support such initiatives; for the development of local, regional and international networks to support teacher educators in reorienting their practices for sustainability; and the need for sustainability to be conceptualised as locally relevant.

Achieving the goals of education for sustainability requires a very different approach to learning and teaching from that currently practiced in most schools and teacher education institutions. This is not a new observation – it has been signalled since the UNESCO meetings on EE of the 1970s. However, after the United Nations Decade of Education for Sustainable Development (2005–2014) brought together the Millennium Development Goal (MDG) process, the Education for All (EFA) movement and the United Nations Literacy Decade (UNLD) with sustainability, there was a stronger connection with socially transformative education and the importance of universal literacy and social equity. Changing the content of and pedagogical approaches in teacher education is a challenge, but it is one that teacher education institutions can no longer ignore, as several researchers have described through case studies (including Barnes et al. 2021; Dippo 2013; Ferreira et al. 2009, 2019; Lotz-Sisitka 2012; McKeown and Hopkins 2002; McKeown 2014; and Stephens 2012). Victor Nolet (2013, 4), for example, suggests four strategies for reorienting teacher education programs in the United States:

- Focus on improving outcomes for all students.
- Embed ESD in the process of learning to be a teacher.
- Use existing structure, processes and local resources.
- Provide professional development for faculty and administrators.

Other guidance for teacher education institutions is contained in the example given in the document *Asia-Pacific Guidelines for the Development of National ESD Indicators* for monitoring and assessing progress during the United Nations Decade of ESD in the Asia-Pacific Region (UNESCO Bangkok 2007, 4). In particular, these guidelines recommend that each country has a national education policy that requires pre-service teacher education courses to provide training in ESD and that all pre-service teacher education courses provide training on ESD-related content and pedagogy.

According to Gooch et al. (2008, 185), more guidance needs to be given to the pre-service teachers about "how to teach critical thinking skills and how to formulate plans to address issues such as comparing alternatives, rating suggestions for costs and effectiveness, and anticipating long and short-term consequences of each alternative". They also note the need for the development of networks between pre-service teachers and local communities, for developing exemplars of unit plans as models to guide the pre-service teachers and for reorienting "the ways in which teachers think about, and actively plan to teach for sustainability" (Gooch et al. 2008, 184). Varela-Losada et al. (2019) had similar findings that participatory and experiential learning, fostering ethical considerations and the training of people who are more critical and discerning should be the basis of new models of sustainability teacher education.

In addition, teacher education institutions, as higher education institutions, need to be a catalyst for sustainability progress in academic and practical innovation because "The strategic implications of sustainability reach far beyond individual curriculum changes, isolated environmental practices and signatures on international declarations, and require adjustments to academic priorities, organizational structures, financial and audit systems" as well as requiring "considerable innovation for HE institutions to evolve as 'learning organizations'; advancing strategic integration, staff development, collaborative partnerships, and effective stakeholder dialogue" (Ryan et al. 2010, 113).

Conclusion

Over the past 40 or so years there have been many efforts at many levels to incorporate environmental sustainability education into teacher education – so the fact that there are still no consistent or coherent programs in many institutions is not for want of trying. The approach being taken in recent times is a more comprehensive one, attempting whole-system (institution) approaches. The results from some recent initiatives are encouraging. For example, according to McKeown (2014), the situation is improving and sustainability is being woven into teacher education programs in many ways. For example,

- ESD is being infused into existing coursework – also called embedding or mainstreaming – and is a common strategy for beginning to reorient teacher education to address sustainability.
- New courses and certificate and degree programs are being created.
- Teacher educators are weaving themes of sustainability and ESD pedagogies into the existing courses.

However, it is likely that there will still be a struggle to implement this in many places until sustainability becomes an educational priority rather than a political one and it is wholeheartedly embraced by ministries of education and teacher education institutions.

Thus, it is heartening to see that the current UNESCO roadmap for ESD towards 2030 recommends that

> Ministries of education should **review the purpose of their education systems in light of the ambitions of the SDGs** and define learning objectives fully aligned with those goals. Education policy-makers at local, national, regional and global levels should **integrate ESD into education policies**, including those that concern learning environments, curricula, teacher education as well as student assessment, and always with a gender perspective in mind.
>
> *(UNESCO 2020, 26, emphasis in original)*

Until this recommendation is widely adopted, many initiatives will continue to rely on single enthusiastic individuals and small teams within teacher education institutions. As the previous quote from UNESCO (2020) recommends, teacher education institutions need to work with their ministries of education and accept sustainability as an educational priority within their teacher education programs, thereby increasing the percentage of new teachers who understand and can implement sustainability-related content and transformational pedagogies. This content needs to be a mandatory component of teacher accreditation, not an option, as teachers have a pivotal role in the education of future generations.

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5.2
FACULTY EMPOWERMENT IN THE SUSTAINABILITY EDUCATION TRANSITION

Jordi Segalas and Gemma Tejedor

Key concepts for sustainability education

- Identifying barriers and drivers for education for sustainable development (ESD) in a university helps to identify the best approaches to enhance sustainability education.
- There is no one-size-fits-all approach in the development of faculty-led sustainability education transitions, but any approach needs to facilitate and incentivise ESD in a way that supports university culture and strategy.
- Faculty attitude, engagement, empowerment processes and capability development and training are critical to the successful introduction and development of sustainability education.
- Institutional commitment through a proper action plan (defining responsibilities, time-lines and providing resources) is crucial to ensure the involvement and empowerment of faculty in the sustainability education transition.

Introduction

Talking to me? Faculty engagement in sustainability education

We embrace the UNESCO (2022) definition of education for sustainable development (ESD), which is the one that gives learners the knowledge, skills, values and agency to address interconnected global challenges including climate change, loss of biodiversity, unsustainable use of resources and inequality. It empowers learners to make informed decisions and take individual and collective action to change society and care for the planet. ESD is a lifelong learning process and an integral part of quality education. It enhances the cognitive, socio-emotional and behavioural dimensions of learning and encompasses learning content and outcomes, pedagogy and the learning environment itself.

The first condition to be empowered in anything is the will to be empowered; motivation is crucial in any empowering process. When it comes to faculty motivation in sustainability education in higher education institutions (HEIs), we can broadly apply the Pareto principle (Pareto, 1964) or 80/20 rule (Koch, 2000). After 20 years of research on sustainability

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education in HEI, we classify faculty as four types according to their motivation towards ESD (at least based on European experience) (see Figure 5.2.1):

- 80% – The interested
- 80% – The followers: eager to introduce sustainability in their course but do know not how and need training and facilitating tools to do so
- 20% – The champions: leaders of the ESD processes in the institutions/degrees/courses
- 20% – The non-interested (20%)
- 80% – The sceptics: never will give a shot: will never get on board
- 20% – The may be interested: need strong incentives to make the "effort" to introduce sustainability in their teaching practice.

If you are reading this Handbook you might sit in the champions or followers category. Why is this classification relevant? Because each type requires different incentives, direction and support.

This chapter starts by analysing the education context. Depending on the context, the profile of the teacher may be very relevant. We start by considering whether the contextual factors encourage ESD (policy, recruitment requirements, accreditation bodies, academic recognition, etc.) or discourage (no ESD policy, no requirements from accreditation bodies, no easy possibility to change syllabus, etc.). As described earlier, the existence of ESD champions or sceptics will certainly influence the overall support for ESD whatever the overall education context. This ESD context, however, is crucial for the followers and their understanding of the importance of ESD (Figure 5.2.2).

The strategies to change behaviour through empowerment (Wals, 2011; Fogg, 2009) are mostly connected to the relationship between two dimensions: 1) ESD faculty attitude (how relevant is ESD for them, and what is their willingness to include/enhance ESD in their teaching) and 2) ESD faculty ability in ESD (their teaching competencies in both ESD content and pedagogy) (Figure 5.2.3).

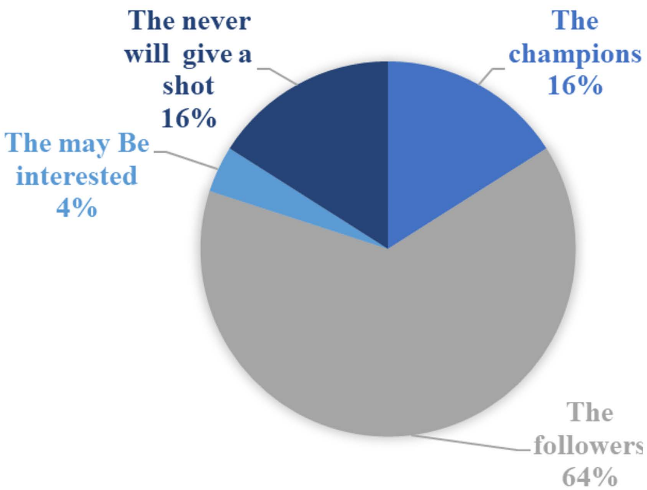

Figure 5.2.1 Faculty classification according to their motivation in ESD.

Figure 5.2.3 shows the relationship between the faculty attitude towards ESD – notice that we are not considering the champions (they are going to do it anyway) and the sceptic (no strategy is likely to be effective, so don't waste energy or time convincing them) – and

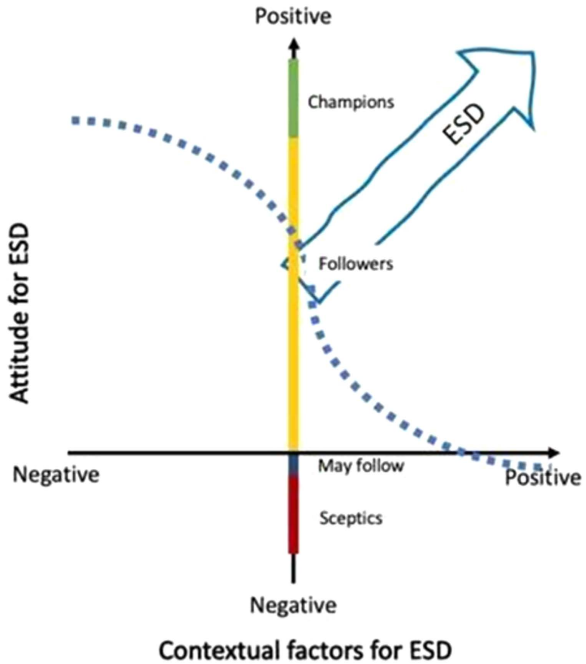

Figure 5.2.2 Relation between attitude-behaviour-context applied to ESD. (Based on the ABC theory of Stern (2000).)

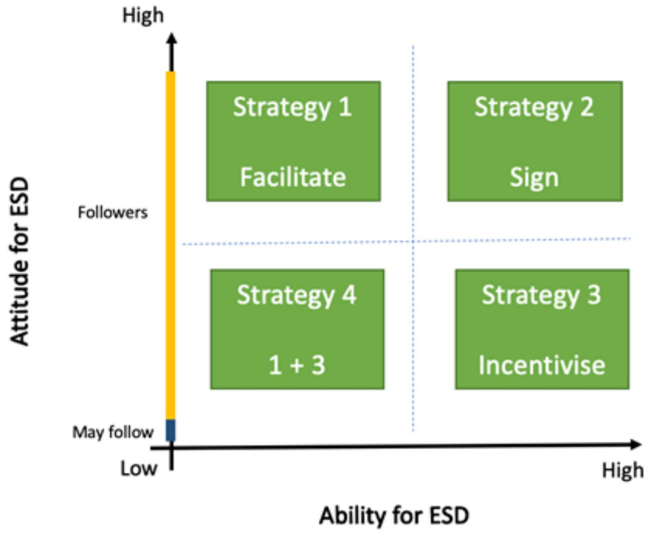

Figure 5.2.3 Relation between faculty attitude-ability for ESD and the strategies needed.

the ability (know how to) to help deliver ESD. In this graph four scenarios are possible that all ask for different but complementary strategies:

- High attitude and high ability (Strategy 2 – Sign)
- High attitude and low ability (Strategy 1 – Facilitate)
- Low attitude and high ability (Strategy 3 – Incentivise)
- Low attitude and low ability (Strategy 4 – Facilitate and incentivise)

The next section introduces the main barriers and drivers for ESD and their relationship to the strategies needed to empower faculty.

Faculty barriers and drivers for ESD

Many studies (McCunn et al., 2020; Pompeii et al., 2019; Akins et al., 2019; Verhulst and Lambrechts, 2015; Lambrechts et al., 2013; Lozano et al., 2013; Velazquez et al., 2006) have investigated the main challenges and barriers for ESD in higher education.

Barriers can be classified in three clusters (Akins et al., 2019; Verhulst and Lambrechts, 2015): those related to lack of awareness, those related to the structure of higher education and those related to a lack of resources. These clusters can be associated with the two dimensions of ESD faculty practice. Table 5.2.1 shows how the main barriers are linked to the attitude and ability dimensions of faculty ESD capability, which then allows us to determine the strategies necessary to overcome the barriers.

The literature (Pompeii et al., 2019; Blanco-Portela et al., 2018; Burke et al., 2018; Aleixo et al., 2018; Hugé et al., 2018; Blanco-Portela et al., 2017; Busquets et al., 2021; Pérez-Foguet and Lazzarini, 2019; Budihardjo et al., 2021) highlights the main drivers that have shown to be effective to enhance ESD. Table 5.2.2 categorises these drivers for each cluster and the strategies that are needed to enhance ESD.

Strategies to empower faculty in ESD

A university that seeks change to include ESD must initiate a holistic strategy to incorporate sustainability into its core values at an institutional level, from where individual awareness and commitment can be better promoted.

A major limitation for ESD can be attributed to academic culture. Faculty autonomy can be a barrier to comprehensive commitment to sustainable development (SD) education. Academic staff are not used to having to engage in open dialogue with regard to teaching or research content or pedagogy. This autonomy may prevent adequate discussion and debate on the importance of new societal challenges like SD and how they might impact on the discipline being taught. Integrating SD into a course can be difficult if the lecturer feels insecure regarding their power position in the department or their knowledge or full understanding of the SD content being discussed. Such a discussion may trigger discussions regarding the credit points of the course, which could be potentially a threat to their academic credibility, i.e. their position and/or course control. Overcoming this resistance is a key point in embedding SD in the curriculum. To help overcome this resistance, the following approaches are proposed:

- Make it known that SD content and pedagogy are not a threat. Instead, it should be explicitly shown that there are inherent linkages with SD which are implicit in each

Table 5.2.1 Barriers for ESD and its relation to faculty practice dimensions

Barriers		*Faculty*	
Cluster	*Description*	*Low attitude*	*Low ability*
Structural	Lack of interest and involvement of the majority of the students and staff members	x	
	Lack of support by management and policy makers	x	
	Lack of professionalisation and training of teachers		x
	Lack of policy making in order to promote sustainability	x	
	Lack of standard definitions and concepts of SD in HE		x
	Lack of recognition, change agents for SD are often not taken seriously	x	
	SD seen as a threat to academic freedom and credibility	x	
	SD is not seen as relevant to a certain course or discipline	x	
Resource	Conservative disciplinary structure of HEI, barely open to new paradigm)	x	
	Inefficient communication and shared information both top-down and bottom-up	x	x
	Resistance to change by education and research	x	
	Focus on short-term profit as a result of managerial thinking and policy making in HE	x	
	Lack of interdisciplinary research as a result of insufficient coordination and cooperation		x
	Overcrowded curriculum	x	
	Focus on content-based learning	x	
Awareness	Lack of incentive	x	
	High work pressure and lack of time	x	
	Lack of access to information due to absence of measuring instruments or by unwillingness of staff		x
	Lack of consistent legislation	x	x
	Lack of qualitative and quantitative performance indicators	x	

discipline by illustrating that there is something to be gained and that there are opportunities emerging from SD for the faculty and for their disciplinary fields.

- Involve non-ESD faculty in SD application projects with other departments. This helps the faculty to better comprehend the important role of sustainability, since it is specifically applied to their field of expertise and can be appreciated in other discipline contexts also.
- Use multidisciplinary challenge-based learning with SD-related problems. This will raise the SD awareness in non-SD teachers who participate in the projects.
- Earn respect from your colleagues by doing a good job, and then ask them for some feedback and collaboration ideas.
- Acknowledge ESD teaching and research excellence by linking professors to SD research, rewarding ESD pioneers and promoting excellence in research on SD and in staff promotion applications.

Table 5.2.2 Drivers and strategies for ESD and its relation to faculty practice dimensions

Drivers/strategies for ESD		*Strategies*		
Drivers Cluster	*Description*	*Facilitate*	*Sign*	*Incentivise*
Structural	Top management support	x	x	x
	Creation of a specific unit in ESD	x	x	x
	Faculty training, coaching			x
	Clear and shared definition and concepts	x		x
	Quality certification and accreditation	x	x	x
	Information in freshman orientation programs	x		x
	Institutional framework for sustainability	x	x	x
Resource	Interdisciplinarity collaboration	x		x
	Promoting sustainability research	x	x	x
	Promote sustainability learning community	x	x	x
	Promote minors in sustainability	x	x	
	Provide funding for additional courses	x	x	
	Availability of teaching resources			x
Awareness	Incentive scheme		x	x
	Increase awareness of activities, events, courses	x	x	x
	Efficient internal management		x	

In order to change the faculty's attitude towards ESD, we need to create a teaching/learning arena in which reflection processes question disciplinary principles and values and enable lecturers to experience the added values of systemic thinking and transdisciplinary approaches.

SD learning requires more than classroom discussion; it requires practice in real-life settings. The university campus can serve as a useful laboratory to test ideas and methods of SD implementation and could become an important ESD demonstration arena. From an education and research perspective, opportunities to learn about sustainability exist across the campus. Some experiences of this campus learning environment approach have already been implemented (Steinemann, 2003; Pujadas, 2004).

A crucial aspect to this success is the commitment of the university board in supporting the process of change towards ESD in universities. This commitment has to embrace different strategies, from promotion and tenure to university SD strategic plans, across all key areas of the university including research, in-house operational management, social communications and interactions and, of course, in university education programs. In other words, the ESD strategy should be encompassed within a broader strategy of embedding sustainability across all university life. This is commonly referred to as the "practice what you preach" approach which further reinforces and legitimises the ESD process. As in any other management activity, it is also necessary to develop a quality operational management plan which encompasses the closed quality loop philosophy: plan, develop, assess-monitor-control and re-plan. In this sense, indicators and external audits have shown to be useful to help evaluate progress. Some institutional assessment tools of sustainability in higher education (Shriberg, 2002) already exist, and they can help to monitor this process.

It is also important to have a centralised group who is responsible for developing, delivering and monitoring progress of ESD in university policy. This group can both apply the ESD policy and also catalyse the SD embedding process across the campus. Moreover, all university departments should be somehow involved in the development and delivery of ESD across their areas of influence. Therefore it is important to find allies in each department who become the committed actors and agents for change that then push ESD within their own discipline/department.

Successful ESD strategies

This section introduces the main features of successful strategies that have been applied in higher education in order to enhance the attitude and capability of faculty in ESD. The strategies are developed according to the current faculty ESD profile they need to affect: Facilitating (F), Signing (S) and Incentivising (I).

Strategy: to have a clear and shared definition of ESD concepts (F&I)

In Chapter 4.3 in this volume Segalas and Tejedor highlight what ESD and ESDGs encompass in terms of learning: which competencies and learning objectives in different domains. There are universities which have promoted a shared definition of what sustainability means in terms of learning in the degrees they are offering to their students. One example is the sustainability competency maps developed in the framework of the EDINSOST2-SGD project (Sánchez-Carracedo et al., 2021; Valderrama-Hernández et al., 2020; Manresa et al., 2021), where 11 Spanish universities defined a set of sustainability learning outcomes that students have to master when graduating in the fields of education, business or engineering.

Strategy: to create a specific group to promote ESD (F, S & I)

ESD needs clear university board support to be effective. It requires a specialist and experienced faculty to lead ESD development and its embedding in the HEI. Some universities have created a specific group (chair, institute, department, school) which is in charge of enhancing sustainability knowledge within the institution by training the sustainability change agents of the future in specific sustainability degrees and by catalysing the introduction of sustainability in other programs in the university. At Arizona State University, this role is played by the School of Sustainability (https://schoolofsustainability.asu.edu/) where they run undergraduate and graduate degrees in sustainability and also offer specific sustainability courses and minors to all students at the university (Boone, 2015).

Strategy: quality certification and accreditation (S & I)

The relevance of sustainability competencies requires recognition by university degree accreditation agencies. Engineering degree accreditation agencies (ABET; CEAB, 2017; ENAEE, 2018) include accreditation criteria related to sustainability competencies. We take the ABET[1] accreditation agency as an example. Among its General Criteria for Baccalaureate Level Programs, Criterion 3 establishes Student Outcomes whose attainment prepares graduates to enter professional engineering practice. Among them, Student Outcome number 4 refers to "The ability to recognize ethical and professional responsibilities in engineering situations and to make informed judgments, which should also consider the impact of engineering solutions in global, economic, environmental, and social contexts".

An increasing number of HEIs are approaching sustainability in their teaching programs as a result of governmental requirements to be more sensitive towards sustainability, forcing HEIs to adapt to that external pressure. In Sweden, for example, the Higher Education Act contains provisions that HEIs shall promote SD to ensure that present and future generations are afforded a sound and healthy environment, economic and social welfare and justice (Swedish Council for Higher Education, 2019).

Strategy: faculty training and coaching in ESD (F)

Training is a typical need of a faculty that wishes to embed sustainability in their teaching practice. There are a number of courses available to help train faculty in ESD, which are typically run internally within the HEI. One open online course which has received several awards is "The Global Dimension in Engineering Education" (Pérez-Foguet et al., 2018) project which is an initiative that focuses on integrating sustainable human development (SHD) as a cross-cutting issue in teaching activities, which improves the competencies of academics and engages staff and students in initiatives related to SHD. The course structure and syllabus are available on the project website (https://gdee.upc.edu/en). To train faculty, the project edited textbooks on relevant topics which are also open source and available via this link: https://upcommons.upc.edu/handle/2117/26502

Strategy: interdisciplinary collaboration (F & I)

What happens when you bring together experts and researchers from diverse and even disparate disciplines and ask them to collaborate on a grand challenge? Interactions that push us out of our disciplinary comfort zones and encourage us to think differently about problems and solutions are the foundation of many knowledge communities. The Centre for Unusual Collaborations (CUCo) is an initiative of the Young Academies of the strategic alliance between Eindhoven University of Technology, Wageningen University & Research, Utrecht University and University Medical Center Utrecht. Their mission was to facilitate unusual collaborations through workshops, trainings and networking events and grants. The TdAcademy platform for transdisciplinarity brings together an international research community on central topics of transdisciplinary research and strengthens the joint production of knowledge. Its supporting partner institutions have a proven track record in transdisciplinary research including Frankfurt ISOE – Institute for Social-Ecological Research, Leuphana University Lüneburg, Center for Technology and Society (ZTG) at Technische Universität Berlin and Oeko-Institut in Freiburg.

Strategy: promote a sustainability learning community (F, S & I)

The Universitat Politècnica de Catalunya (UPC) created the Sustainability, Technology and Excellence Program – STEP2015 (Busquets, 2010) to face the challenge of incorporating the competency "Sustainability and Social Commitment" (SSC) in undergraduate curricula. The program was born with the objective of helping different UPC engineering schools to create learning communities to implement the competency of SSC in undergraduate studies. The main mission of STEP2015 was to support teachers to advance the conceptualisation of "sustainable technology", to help identify technological references, to develop new models of education for sustainability and to make available practical tools to train graduates in the SSC competency. The learning community involved faculty, university staff and students. It is worth highlighting that students were very active and self-organised themselves, raising their voice through the report "The Education We Want: Commitment and Social Responsibility at the UPCr", where students made explicit the need for sustainability education at UPC.

Conclusion

HEIs can approach many complementary strategies to empower faculty in ESD, dependent on faculty needs and practice. There is no silver bullet nor one-size-fits-all approach. HEIs should analyse the needs of faculty and then facilitate and incentivise ESD in a way that supports university culture and strategy. The ultimate goal is to transform the university itself (education, research, in-house management, urbanism, mobility, stakeholders outreach, etc.) into an SD-focused organisation. This transformation itself is an experiential learning opportunity which should not be undervalued. Universities are by definition places of reflection and experimentation where new future-focused SD knowledge should be created and experienced by all faculty and students.

However, the ultimate target of ESD should be our students. Students will have the responsibility of catalysing the necessary change towards SD and, by design, are one of the most important driving forces of renewal in HEI (Dawe et al., 2005; Kelly, 2006).

The sustainability education change management process at universities should not only involve reforms in order to create ESD consensus amongst academics but also transform faculty into education structures which themselves will help drive the ESD agenda forward.

Note

1 https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2021-2022/

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5.3

EDUCATION FOR SUSTAINABLE DEVELOPMENT IN ONLINE TEACHER TRAINING

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Key concepts for sustainability education

- It is necessary to develop teaching-learning models of education for sustainable development for virtual environments.
- Faculty is responsible for designing this training, preparing the activities and basic resources and planning the evaluation.
- To carry out these tasks, it is necessary to provide teacher-training, which considers the role of supervisor.
- In the current digital world context, teacher-training must be planned so that it can also be done online.

Introduction

What is and what is not e-learning?

The economic model of contemporary society has generated social inequalities and injustices culminating in an environmental crisis that endangers the survival of future generations. These problems demand a holistic approach in which the education of the citizenship is fundamental (Svanström et al. 2008). An important part of this education must be oriented to sustainable development (SD). In 1987, the Brundtland report (Brundtland 1987) defined SD as one that meets the needs of the present without compromising the needs of future generations.

Education for sustainable development (ESD) seeks to make citizens aware of the problems facing the world today so that they are able to act responsibly and become drivers of change.

The United Nations General Assembly declared on January 1, 2005, the beginning of the Decade of Education for Sustainable Development and designated the United Nations Educational, Scientific and Cultural Organization (UNESCO) as a body rector of the promotion of the Decade, with the objective of preparing a draft plan for international application in which the relationship of the Decade with ongoing educational projects is clarified (UN 2005a). The work carried out during the Decade to try to fulfill the Millennium Development Goals (UN 2005b) contributed to the development of different investigations in the

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teaching-learning processes of ESD (Tilbury 2011). However, few examples exist of how to put into practice the theoretical proposals developed for ESD (Tilbury and Wortman 2005). For this reason, today more than ever it is essential to define how to implement different ESD teaching-learning proposals in different fields and academic levels, since young people play a fundamental role in the advancement of ESD.

In 2015, the United Nations defined a new reference framework to replace the millennium goals: the Sustainable Development Goals (SDGs). The SDGs (UN 2015) consist of 17 goals to be achieved by 2030, while ESD is focused on training people to attain these goals, both personally and professionally. In 2017, UNESCO published a document (UNESCO 2017) containing the educational objectives of all the SDGs. Fifteen learning objectives were defined for each SDG, classified according to a three-level taxonomy: 5 cognitive objectives, 5 socio-emotional objectives and 5 behavioral objectives. In total, 255 objectives were defined for development at different educational levels.

The EDINSOST2-SDG project (Segalàs and Sánchez-Carracedo 2020) has analyzed these 255 objectives in order to identify those that should be developed in engineering degrees (Sánchez Carracedo et al. 2019), education degrees and economics and business degrees. Figure 5.3.1 shows the result obtained for engineering degrees. The columns of the matrix correspond to the 17 SDGs, while the rows correspond to the 15 learning objectives of each SDG. In the left-hand column, the first letter of each objective identifies the level within the taxonomy (C-Cognitive, S-Socioemotional and B-Behavioral). Objectives shaded in green should be developed in all engineering degrees, objectives shaded in purple should be developed in some engineering degrees and objectives shaded in red in degrees other than engineering (both undergraduate and non-university degrees).

In such a context in which COVID-19 has completely disrupted educational models around the world, it is necessary to develop teaching-learning models of ESD for virtual environments (Sánchez-Carracedo et al. 2020). These virtual environments may serve as a support for the face-to-face teaching conducted in many institutions, but they may also constitute the basic working environment, as in the case of centers whose teaching-learning method is based exclusively on e-learning or on blended learning. These environments can also be used to train teachers who need expertise in how to use e-learning tools in order to introduce ESD into their teaching.

	SDG																
Learning Objectives	SDG1 POVERTY	SDG2 HUNGER ZERO	SDG3 GOOD HEALTH	SDG4 QUALITY EDU.	SDG5 GENDER EQ	SDG6 CLEAN WATER &	SDG7 ENERGY	SDG8 DECENT WORK &	SDG9 INDUSTRY &	SDG10 REDUCE INEQUALITY	SDG11 SUSTAIN. CITIES &	SDG12 PRODUCTION &	SDG13 CLIMATE	SDG14 LIFE WATER	SDG15 LIFE LAND	SDG16 PEACE & JUST.	SDG17 PARTNERSHIPS
C1	Other	Other	ENG	Other	Other	Other	ENG	ENG	ENG	ENG	ENG	Other	Other	Other	Other	Other	Other
C2	Other	Other	Other	Other	Other	Other	Any ENG	Other	ENG	ENG	Any ENG	ENG	Other	Other	Other	Other	ENG
C3	ENG	Other	Other	ENG	Other	Any ENG	ENG	Other	ENG	Other	Any ENG	ENG	ENG	Other	Any ENG	Other	Other
C4	ENG	Any ENG	Other	ENG	Other	ENG	Any ENG	Other	ENG	ENG	Any ENG	ENG	Any ENG	Other	Any ENG	ENG	ENG
C5	Other	Any ENG	Other	ENG	ENG	Any ENG	Other	Other	ENG	Other	Any ENG	ENG	Any ENG	Other	Any ENG	ENG	ENG
S1	Other	Any ENG	Other	Other	Other	Any ENG	ENG	Other	Other	ENG	ENG	Other	Any ENG	Other	Other	Other	Other
S2	Other	Any ENG	Other	Other	Other	Any ENG	Any ENG	Other	Other	Other	ENG	ENG	Other	Other	Other	Other	Other
S3	Other	Other	Other	Other	Other	Other	Any ENG	Other	Other	Other	Other	Other	ENG	Other	Other	Other	ENG
S4	Other	Any ENG	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	Other	ENG	Other
S5	ENG	Other	Other	Other	Other	Other	Any ENG	Other	Other	ENG	Other	ENG	Other	Other	Other	Other	Other
B1	ENG	Any ENG	Other	Other	Other	Other	Other	ENG	ENG	ENG	ENG	ENG	ENG	Other	Other	Other	ENG
B2	Other	Any ENG	Other	Other	ENG	Other	ENG	Other	ENG	ENG	ENG	Other	Other	Other	Any ENG	Other	Other
B3	Other	Any ENG	Other	Other	Other	Other	Any ENG	ENG	ENG	ENG	Other	ENG	Any ENG	Other	Other	Other	Other
B4	Other	Other	Other	Other	Other	Any ENG	Other	ENG	Other	ENG	ENG	ENG	Any ENG	Other	Any ENG	Other	Other
B5	ENG	Any ENG	Other	Other	Other	Other	Any ENG	ENG	ENG	Other	ENG	Other	ENG	Other	Other	Other	ENG

Figure 5.3.1 Objectives to be developed in all engineering degrees (ENG), in some engineering degrees (ANY ENG) or in degrees other than engineering (Other), according to the EDINSOST2-SDG project.

Due mainly to the emergency situation caused by the COVID-19 pandemic in the years 2020–2021, training via the internet has increased enormously. According to UNESCO (Guanche 2020; Vidal Ledo et al. 2021), in March 2020 more than 1200 million students from 186 countries were affected by the closure of schools because of the pandemic. The countries hardest hit by the coronavirus have seen unprecedented growth in distance education enrollment. Given the disruption caused by the lockdowns imposed by different countries, e-learning has been placed at the center of the global educational scene. The acceleration that this transformation has entailed in the development of e-learning may signify its definitive takeoff in this decade. In fact, industry forecasts predict that between 2021 and 2027 the e-learning market will grow at an exponential compound annual growth rate (CAGR) of more than 21% (Global Market Insights 2021).

E-learning is not just any kind of transmission of knowledge through the internet. A face-to-face master class recorded on video and transmitted via the internet can be considered either as emergency virtual teaching (Sánchez-Carracedo et al. 2020) or as an adapted face-to-face teaching with internet support, but not as a comprehensive educational e-learning action. The definition of e-learning has evolved over time, from the first definitions focusing more on the use of technology and the system of access, to training through the internet: from "E-learning is the use of new multimedia and Internet technologies to improve the quality of learning by facilitating access to resources and services as well as collaboration and remote exchange" (Alonso et al. 2005), to the most current definitions based more on educational objectives and the new training opportunities provided by IT (Sangrà et al. 2011): "E-learning is a teaching and learning modality that can represent all or part of the educational model in which it is applied, which exploits electronic media and devices to facilitate access, evolution and improvement of the quality of the education and training". This broader vision of e-learning, which promotes a new way of learning, is what we advocate in this chapter, by applying it both to hybrid models combining face-to-face and full online teaching (blended learning) and to teaching-learning models carried out exclusively online (online learning).

The first models of online higher education are already 25 years old (such as the model at Universitat Oberta de Catalunya [UOC], www.uoc.edu). In the following section, we discuss how ESD can be conducted in an e-learning model.

Characteristics of online teaching

The most characteristic feature of online teaching is the face-to-face mismatch between teachers and students. Online teaching has different variants depending on whether it is asynchronous or synchronous, as well as on whether students are able to advance at their own pace (self-paced) or whether the pace is set by the teacher (facilitated).

The transition from face-to-face teaching to e-learning-based teaching is not automatic. E-learning requires a very detailed planning and learning design, which must follow the constructive alignment model proposed by John Biggs and Catherine Tang (Biggs and Tang 2011), in which learning objectives and activities must be aligned with assessment and learning resources. The six key issues of e-learning are shown in Figure 5.3.2.

The issues presented in Figure 5.3.2 must be present in any e-learning model and therefore must also be addressed in online teacher-training.

A fundamental and distinctive aspect in e-learning is the need to design and plan all the teaching-learning processes before starting the course. This can be achieved by adopting the

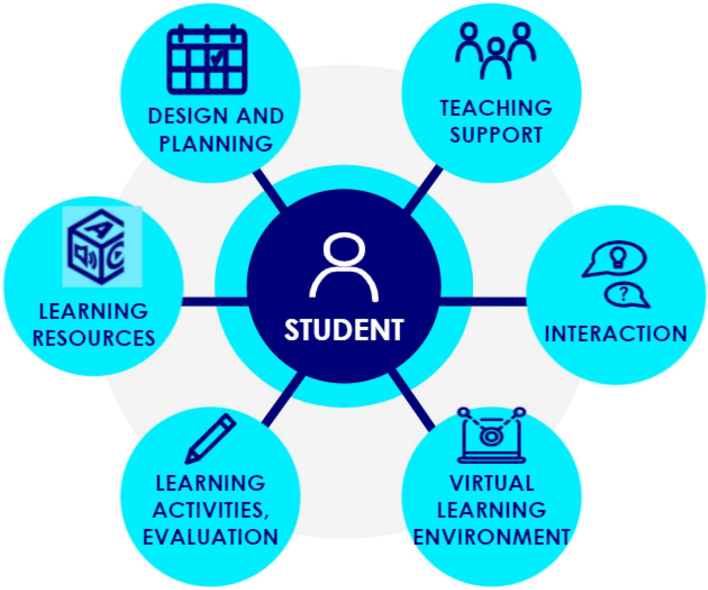

Figure 5.3.2 Key issues in e-learning.

learning design approach without overlooking any of the key issues involved in the process: (1) the teaching support represented by the didactic strategies; (2) the typology, schedule and planning of activities; (3) the learning resources; (4) the evaluation of activities and feedback; (5) the integration in the virtual learning environment (VLE) and (6) the teaching dynamization and interaction in the classroom.

ESD learning design must be done from a competency perspective that integrates knowledge, know-how and know-how-to-be, aimed at achieving the learning objectives shown in Figure 5.3.1.

Likewise, it is interesting to consider the perspective of situated learning (working on the SDGs in a contextualized way rather than in an isolated or theoretical way) and to propose a formative evaluation model aligning learning activities, learning outcomes and feedback. Situated learning is based on practical learning in contexts close to real scenarios and uses techniques such as project-based learning, collaborative learning and case studies. The formative assessment focuses on helping students to detect, understand and overcome their difficulties and to be aware of their progress during the learning process.

The technological dimension of design is represented in the VLE, the set of tools and applications that serve as a support or infrastructure for the design and implementation of the course. This VLE, in which the teaching-learning process occurs, usually but not necessarily takes place in a virtual classroom. The virtual classroom should enable the organization of the subject according to a schedule of activities, the publication of these activities, access to all the necessary resources in a variety of formats, collaboration in the performance of group tasks and communication and interaction among all group members, students and teachers.

Student learning is planned through the learning activities calendar, which are also continuous assessment activities. Learning activities are the central axis of the teaching-learning strategy to achieve meaningful learning in e-learning, the nucleus around which teaching and the rest of the elements must be organized (function of tools and resources, role of the teacher, interaction and communication processes with classmates, etc.). For e-learning of sustainable development (eSD), practical activities are suitable, contextualized in situations that are as real as possible and using collaborative learning (debates, practical work, problem-solving or simulation games). The activities in an e-learning environment must be very well defined and described, starting from the competencies they intend to work with and the learning outcomes. In addition to the deadline and form of delivery, the expected learning results must make the evaluation criteria very clear, as well as the way in which students receive the feedback of the activity.

Together with the activities, following a competency-based formative evaluation model involves the design, the system and the tools for monitoring and evaluating each activity and the feedback mechanisms. This model requires that learning activities be oriented towards the development and evaluation of a set of competences, as well as establishing specific mechanisms that facilitate teacher feedback based on the monitoring and evaluation of the process carried out and the learning results achieved. The use of tools such as rubrics or e-portfolios is recommended in this model.

In e-learning, the more traditional and strictly accrediting assessment, limited to the context of a single subject or assessed through traditional exams, loses relevance and even fades into the background. Other assessment scenarios take center stage, such as self-assessment, peer-to-peer assessment and cross-sectional assessment of competencies carried out in different subjects.

The learning resources should not be designed as if one were writing a book or a scientific article or as a simple transcript of what a teacher would explain in a master class. Instead, they must be designed so that the student can solve the proposed activities, build learning, establish relationships between the activities and learn how to analyze and apply them in order to facilitate their evaluation and to encourage and motivate the student. In addition, they must be designed by taking into account the subject as a whole, that is, all the elements pertaining to the learning design.

During the e-learning teaching action, the teacher acts as a guide and supervisor rather than a transmitter of knowledge, promoting self-organization and the constructivist process of self-learning, thereby guiding students towards the established learning objectives. The teacher invigorates the classroom, promotes interaction between students for collaborative learning and facilitates the most appropriate organization of resources, thereby favoring maximum personalization. Faculty remains essential in a VLE. The supervision, criteria and support that a teacher must provide in an online education context, or even in a hybrid one, are fundamental for ensuring the quality and achievement of the students' educational objectives.

Faculty is also responsible for designing the training, carrying out prior planning to enable students subsequently to work on their own and preparing the activities and basic resources and planning the evaluation. To carry out all these tasks, it is necessary to provide teacher-training which takes into account both the role of supervisor and the characteristics of e-learning. Teachers also require specific training in technological tools, not only from an instrumental point of view but also from a methodological perspective, in order to make the appropriate pedagogical use of e-learning.

All of these factors are linked together by the interaction between students and teachers and between students themselves, as well as between students and the different resources and tools by means of the VLE communication spaces.

The interaction in the model proposed in this chapter should be considered mostly asynchronously, carried out through forums and email and combined with specific and more informal asynchronous communication actions, such as the use of chat in the case of teamwork. The model proposed in this chapter is intended for courses that require many hours of student work (typically more than 50 hours). Courses of a reduced number of hours (fewer than 15) may have a strong synchronous component.

Learning in a VLE offers new opportunities of interaction that are difficult to achieve in a face-to-face environment and are especially interesting for ESD, such as the possibility of sharing the learning experience with students from different degrees and cultures.

Ways of introducing ESD into the curriculum of a degree

In both face-to-face teaching and in e-learning, there are three ways to introduce ESD into the curriculum of a degree:

1. Introducing one or more specific SD subjects
2. Incorporating ESD-related objectives into existing subjects
3. Developing ESD in the final degree thesis (bachelor or master)

The three alternatives are not mutually exclusive, and in an ideal scenario they should be applied simultaneously. When applied independently, each alternative has its advantages and disadvantages.

Alternative 1 has defenders and detractors. On the one hand, having specific ESD subjects provides the following advantages:

- It allows the introduction and development of general concepts without the need to link them to the degree, and it is possible to explore them more deeply because more time is available.
- More specific resources may be available to work on ESD.
- It is possible to have teachers proficient in ESD, instead of having to train teachers of other subjects.
- Teachers will be highly motivated, as it is a subject specifically designed for ESD.
- Ease of coordination. The subject is designed and implemented like any other subject in the curriculum, with links to the rest of the subjects, but quite independently.
- Being a specific ESD subject, the objectives related to ESD can be developed more intensively.

On the other hand, the very existence of specific ESD subjects may give rise to some problems:

- Some teachers may think that ESD is sufficiently represented in specific ESD subjects, and therefore do not consider it necessary to introduce ESD in other subjects of the degree.
- Some students may not establish a direct relationship between ESD and their profession, because ESD is not covered in the technical subjects of the degree.
- From the point of view of the teaching-learning process, the concept of learning transfer should be considered. The transfer of learning "occurs when a student can rely on the

knowledge or skills acquired in a specific context or through specific activities to achieve new purposes, be it solving new problems, answering new questions or learning new concepts or skills" (Perkins and Salomón 1992, cited by Ruiz-Martín 2020). There are two kinds of learning transfer: near (occurs between identical or very similar activities or contexts) and far (occurs between seemingly different contexts or activities). Transferring learning from one context to another is really complicated and infectious, and therefore far transfer is really exceptional (Barnett and Ceci 2002). For this reason, having only specific subjects in ESD is not a good option, because it would require far transfer of learning. To solve this problem, it is also necessary to include ESD in other technical subjects of the curriculum, so as to facilitate the near transfer.

Alternatives 2 and 3, however, facilitate the near transfer of learning and allow the introduction of ESD in the degree in a transversal way by developing it together with the technical competencies of the curriculum. This makes it easier for students to regard ESD as a fundamental part of their profession and to be able to integrate it alongside specific competencies. Nevertheless, Alternatives 2 and 3 may pose some implementation problems:

- Many teachers are not adequately trained to introduce ESD into the subjects they teach or are simply not interested in doing so (due to lack of motivation or time). This makes the implementation and evaluation of ESD more difficult for them.
- It seems more difficult and expensive to prepare activities in which ESD can be developed in an integrated manner simultaneously with the specific competencies of the subject.
- The time spent on ESD in each subject is much less than for Alternative 1.
- The cost of designing and planning the ESD is higher than for Alternative 1 because teachers and activities of different subjects have to be coordinated. This is one of the most complex points to solve in Alternatives 2 and 3.
- In the third alternative, the ESD is not developed until the end of the degree. Furthermore, the supervisor of the final degree thesis may not be proficient in ESD, so it may be difficult for her or him to guide the student on how to orient the thesis from an SD perspective. Or, simply, the teacher may not be interested in doing so, as in Alternative 2. Moreover, the time spent on taking SD into account in the final degree thesis may be insufficient, or it may be done too superficially. However, the final degree thesis is already a task in itself that integrates various specific and generic competences of the degree. As the use of rubrics to evaluate the final degree thesis is a common practice, including criteria in the rubrics for analyzing whether the final degree thesis is compatible with sustainable development is easy

Figure 5.3.3 presents a graphical representation of the influence of each of the key aspects of e-learning for the three alternatives described earlier.

E-learning of sustainability is just as important as the sustainability of e-learning. Virtual environments are very sensitive to organizational failure. Planning in a virtual environment is much more important than in face-to-face teaching, because there is no room for improvization or the introduction of big changes during the semester. Modifying any of the elements of the model (resources, classroom elements, evaluation system, etc.) requires the intervention of various people other than the teacher (as well as the teaching support staff). In an e-learning model, everything must be perfectly described in the teaching plan at the beginning of the course. The teaching plan establishes a commitment from the school and

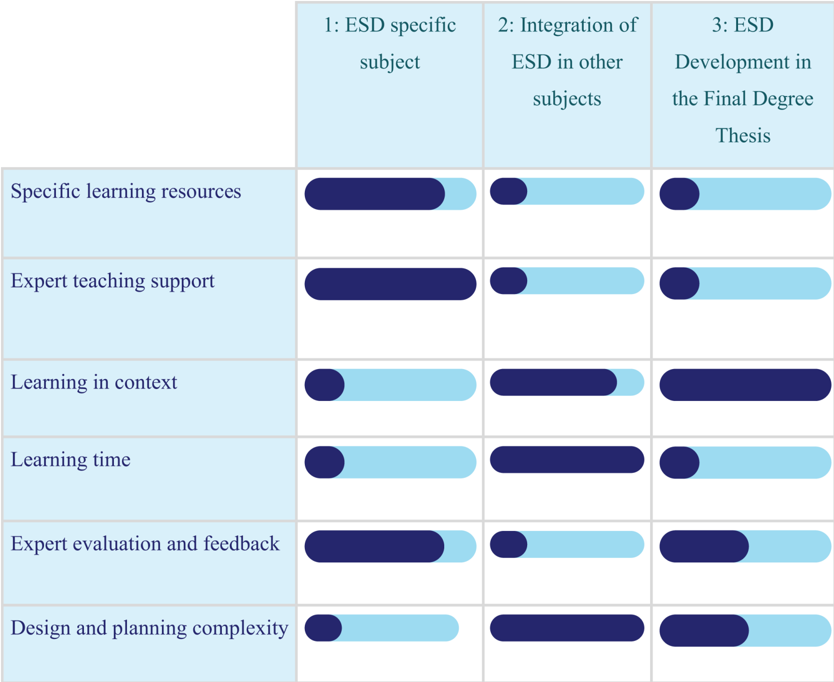

Figure 5.3.3 Influence of each of the key aspects of e-learning in each of the three alternatives to include ESD in the curriculum of a degree.

the students regarding how the subject will be developed, the objectives, the expected learning outcomes, what resources the student will have at their disposal and, very importantly, on what dates the students must deliver each activity and how they will be evaluated and receive feedback. For this reason, whatever the route finally chosen to incorporate ESD into a degree, prior training of teachers in both e-learning and ESD is necessary.

Online teacher training and e-learning of sustainable development

For effective e-learning training in ESD, teachers need to be trained in the following three areas:

- Pedagogy in online education: planning online activities, developing and organizing online teaching resources, online evaluation system, the importance and types of feedback and the role of the teacher supervisor.
- Use of specific e-learning environments and tools: virtual campus, synchronous and asynchronous communication tools, planning tools, automatic correction, resource editing, collaborative work, etc.
- Specific didactics of SD: what is SD, how to develop SD from one's own discipline, with what resources and how to assess competence in SD, etc.

Teacher-training can be conducted in an e-learning format by using the concepts developed in the previous sections. A good example of online teacher-training in SD is the course developed by the EDINSOST2-SDG project (Segalàs and Sánchez-Carracedo 2020; Sánchez Carracedo et al. 2019, 2021) for university professors, which is already being taught in six Spanish universities: the Universitat Politècnica de Catalunya UPC-BarcelonaTech, the Universidad Politécnica de Madrid, the Universidad Internacional de Catalunya, the Universidad de Sevilla, the Universidad e Murcia and the Universidad de Extremadura. This course is fully developed in a virtual workshop format during two four-hour sessions. The VLE is very simple: the workshop is conducted using Google Meet as a tool for interaction between attendees and Google Drive as a document repository and workspace. As the course is of short duration, it has been decided to teach a part (workshop) in a synchronous format instead of the asynchronous format proposed in the model described in this chapter for courses with a greater number of hours.

Those attending the course are required to carry out prior personal asynchronous training work. This training includes readings and videos on the SDGs (UN 2015) and on the ESD-related learning outcomes expected from graduates of a higher degree (these learning outcomes depend on the degree). The objective of the workshop is to enable assistant teachers to learn how to design activities in the subjects they teach, thus allowing students to achieve these learning outcomes.

In the first session of the workshop, the attendees discuss the previous work carried out and clarify their doubts with the trainers. They are then divided into groups of three. Each group selects a subject and a set of learning outcomes to develop in that subject. Subsequently, they define textually a set of activities for students to achieve the selected learning outcomes.

In the second session, each group must fill out an activity sheet (García et al. 2009; Velasco Quintana et al. 2012) based on one of the activities defined during the first session. The activity sheet is a template that describes the steps to be followed to fully and precisely define in a subject an activity based on a set of operational objectives.

Table 5.3.4. a presents the activity sheet used in the EDINSOST2-SDG project teacher training workshop.

The activity sheet provides teachers with a methodology for designing activities in their subjects to enable them to introduce educational objectives concerning ESD. These objectives should be introduced in an activity that also develops a specific objective of the subject in order for students to perceive that SD forms part of their profession. The learning outcomes of the engineering sustainability map are provided (Sánchez-Carracedo et al. 2018)

Table 5.3.4 a Activity sheet of the EDINSOST2-SDG project

Name of the people in the group	
University and school	
Degree	
Learning outcome(s) of the sustainability map to be developed (Include number and full text)	
Related SDGs	
Competency unit(s) (Include number and full text)	
Sustainability map competency(ies) (Include number and full text)	
Name of the activity (Include title, two lines maximum)	

(*Continued*)

Table 5.3.5 (Continued)

Name of the people in the group	
Objective(s) of the activity (Include the desired end result. It will be measured by specific indicators). Specific objectives of the subject described in the teaching guide + sustainability objectives (related to the learning outcomes of the sustainability map to be developed). **Degree competencies** that are developed in the activity **Session characteristics:** (Specify clearly) • Number • Duration • Type of session (theory, problems, lab, others) **Description of the activity** (Include a textual description of the work to be done by students in a summary of 100–200 words. Do NOT copy the tasks to be done that are requested in detail in the subsequent sections, but summarize them.) This description should provide a clear idea of the work the students are going to do and how they are going to do it. **Subjects** for which the activity is proposed: • Degree • Subject • Total number of participants • Work modality (Individual/collaborative)	
Description of work/tasks to be performed and time estimate In this section, a distinction will be made between the tasks that are carried out ONLY the FIRST TIME the activity is prepared and those that are undertaken EVERY TIME the activity is carried out. <u>A well-designed activity is reusable</u>, and therefore requires a LITTLE EXTRA dedication from the teacher (outside of class) EACH TIME it is undertaken. However, it may be necessary to spend more time on the design the FIRST TIME it is done. An accurate estimate of the time needed to carry out EACH TASK, both inside and outside of class, must be made for the teacher and the student. The time spent on each task should be indicated as precisely as possible.	
Teacher work/tasks OUTSIDE OF CLASS EXCLUSIVELY to PREPARE the activity <u>THE FIRST TIME</u> it is done (do not consider the tasks performed each time the activity is undertaken or the tasks in class because they are performed every time). Indicate the time dedicated to EACH task.	**<u>FIRST TIME</u>** Total time the FIRST time: Enter number of hours
Teacher work/homework in and OUTSIDE OF CLASS to DO the activity <u>EVERY TIME</u> (but not to prepare it the first time, when planned). Indicate the time dedicated to EACH task.	**<u>EACH TIME</u>** Total time EVERY time: Enter number of hours
Student work/homework IN CLASS Indicate the time dedicated to EACH task.	

(*Continued*)

Table 5.3.5 (Continued)

Name of the people in the group	
Student work/homework OUTSIDE OF CLASS (before and after). Indicate the time dedicated to EACH task.	**BEFORE** Total time before: Enter number of hours **AFTER** Total time after: Enter number of hours
Material necessary to carry out the activity (books, notes, objects, documentation, material, instruments, etc.)	
Material necessary for the student (detail with precision)	
Material necessary for the teacher (detail with precision)	
Boundary conditions necessary for the development of the activity by the school, the teacher and the students (role of the teacher, type of classroom, number of students per group, equipment, etc.)	
Assessment This section shows how the activity is evaluated. The instruments and criteria with which each indicator will be evaluated and the evaluating agent for each indicator must be defined.	
Assessment instruments **How is each indicator going to be evaluated?** • Exams • Tests • Practices • Problems • Works • Oral presentations • Others Identify which instrument will be used to evaluate each indicator (various factors, or indicators, in the activity can be evaluated, and each indicator can be evaluated differently)	
Assessment instruments **How are the correction criteria for each indicator established?** • Rubrics • Descriptive text • Others	
Which **agent** will carry out the assessment of **each indicator**? • Students (Self-assessment) • Peer evaluation • The teacher (Hetero-evaluation)	
Additional comments	

to help teachers select the ESD-related objectives. Once a set of learning outcomes has been selected, the group defines the teaching-learning strategies to be implemented, both within and outside the classroom, in order to carry out the activity. Subsequently, the group calculates the time required by teachers to design and prepare the activity the first time and to carry it out on each occasion. The group also calculates the time that students must spend inside and outside the classroom in order to complete the activity. Afterwards, the group defines the material necessary to carry out the activity and the restrictions, if any, that must be adhered to. Finally, the indicators to be evaluated are defined, as well as how they are to be evaluated. Practical and collaborative learning activities are suitable for eSD and contextualized in situations that are as real as possible, such as debates, practical work, problem-solving or simulation games. It is necessary for the activities in an e-learning environment to be very well defined and described, starting from the competencies and the learning outcomes that students are required to achieve. The activities must therefore clearly express the expected learning outcomes, the deadline and form of delivery, as well as the evaluation criteria, and finally the way in which students receive the feedback.

Once all the groups have completed the activity sheet, teachers are assigned to new groups in accordance with the Aronson puzzle technique (Aronson 1978). In these new groups, each teacher explains to his or her colleagues the activity sheet developed in the previous group, so that all attendees are familiar with all the sheets completed by all the groups during the workshop. The second session ends with a short debate on the results obtained in the workshop.

Conclusion

A pedagogical approach with a constructivist orientation is required in an SD e-learning environment aimed at action and the promotion of autonomous, collaborative and reflective learning in which students show their capability and take responsibility for self-regulating their own learning. This approach must take into account the six key issues of e-learning: learning design and planning, learning resources, learning activities and their evaluation, the VLE, teaching action and interaction.

ESD can be incorporated into a degree curriculum in three different ways:

- Create one or more ESD-specific subjects. A learning design will be required that considers the six key issues of e-learning.
- Incorporate ESD-related objectives into existing curriculum subjects. It is necessary to decide which SD-related learning objectives will be developed in the program and also to distribute the objectives in different subjects and train teachers in e-learning and ESD.
- Develop the ESD in the final degree projects. Both this alternative and the previous one allow the introduction of ESD in the degree in a transversal way by developing it together with the technical competencies of the curriculum. This makes it easier for students to regard ESD as a fundamental part of their profession.

Faculty is responsible for designing this training, carrying out prior planning to enable students subsequently to proceed autonomously (with teachers' support) and preparing the activities and basic resources and planning the evaluation. To carry out all these tasks, it is necessary to provide teacher-training which takes into account both the role of supervisor and the characteristics of e-learning

Since COVID-19 has completely disrupted educational models around the world and has accelerated the transformation towards virtual learning models, it is necessary to develop teaching-learning models of ESD for virtual environments. These virtual environments may serve as a support for the face-to-face teaching conducted in many institutions, but they may also constitute the basic working environment, as in the case of centers whose teaching-learning method is based exclusively on e-learning. These environments can also be used to train teachers who need training on how to use e-learning tools in order to introduce ESD into their teaching. Teachers also require specific training in technological tools, not only from an instrumental point of view but also from a methodological perspective, in order to make the appropriate pedagogical use of e-learning. Consequently, more teaching training in SD is likely to be done online into the future. Online teaching training could be the best way to re-training of teachers, and it will promote a valid methodology for business training. SD and sustainability teacher training are one and the same thing and are interchangeable.

Education constitutes the transforming engine of people and groups, and therefore quality of education for all is essential. So that no one should be left behind, it is necessary to facilitate equitable and inclusive access to all education levels; to train global and socially responsible citizens; to approach research from the social impact; and to establish alliances with academic institutions and international agencies, cultural institutions or third-sector entities. The United Nations SDGs will make it possible to advance in this direction, for which purpose it is vital for citizens to receive the training required to reach this goal. Before citizens can be trained, however, it is first necessary to train teachers, and e-learning provides a great opportunity to achieve this end.

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5.4
THINKING DIFFERENTLY
Developing pre-service teachers' understanding of sustainability through inquiry and problem-based learning

Rachel Sheffield

Key concepts for sustainability education

- Pre-service teachers need to be supported to specifically learn the key pedagogical approaches to enable them to best support their students in school classrooms.
- Teacher educators must be encouraged and supported to develop interesting and engaging units to support pre-service teachers and not be overly burdened by compliance issues.
- Pre-service teachers need to be supported to specifically develop a sustainability mindset that will enable them to best support the development of this mindset in the students in their school classrooms.
- Universities must be willing to engage in sustainable education and help pre-service teachers, providing them with the modelling, support and evidence of the value of this approach in global citizenship.
- Pre-service teachers also need to be supported to develop their sustainability knowledge in a more holistic way in order to support students' sustainability knowledge development.

> Education is a powerful enabler of positive change of mindsets and worldviews and that it can support the integration of all dimensions of sustainable development, of economy, society and the environment, ensuring that development trajectories are not exclusively orientated towards economic growth to the detriment of the planet, but towards the well-being of all within planetary boundaries.
>
> (UNESCO, 2021. p. 2)

Introduction

Designed in 2014, case study one is a first-year unit which focuses on developing inquiry skills using secondhand environmental data, for example, topics such as critically endangered woylies from the Upper Warren Region in Western Australia, which uses an inquiry process to examine the changes in the numbers of woylies in the southwestern region of

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Western Australia (upper reaches of the Warren River) and the issues and possible solutions. Designed in 2018, case study two uses a problem-based approach that starts with the identification of the United Nations Sustainable Development Goals and encourages pre-service teachers (PSTs) to explore an issue or problem within their local community that they then explore and develop possible solutions for.

Definitions used in this chapter are described next. ***Pre-service teachers (PSTs)*** or ***student teachers*** both describe the undergraduate tertiary students in the Bachelor of Education degree who participate in these units. **STEM** is defined to provide the most flexibility for the unit design: "the deliberate full or partial integration of any or all of the key components of science, technology, engineering, art and mathematics, including skills and content knowledge". Pedagogical approaches relate to how the PSTs are taught to teach the content knowledge, in this case, either using an inquiry approach or a problem-based learning approach. **Mindset** relates to the way in which the student approaches an area including actions, values, attributes, skills and knowledge.

The challenge of 21st-century tertiary educators is to help PSTs develop their thinking beyond the acquisition of content knowledge in their tertiary classroom and also in their classrooms as teachers. Acquisition of knowledge is no longer the primary focus in current classrooms, with employers looking to schools to develop future employees with 21st-century skills who are agile, think critically and creatively to solve problems, are excellent communicators and collaborators and are lifelong learners ready to solve the complexities of life in the age of the Anthropocene, and possibly renegotiate a world of sustainable development (Care & Luo, 2016). The Anthropocene is a proposed geological epoch dating from the commencement of significant human impact on Earth's geology and ecosystems that was coined in 2000 by climate scientist and Nobel laureate Paul Crutzen, who popularized it (Stromberg, 2013). There has been much debate about this being 'a geological era' but in essence it is linked to a time when the action of humans influences the global ecosystem. Alongside this term is the term 'sustainable development' which has been defined in the Report of the World Commission on Environment and Development: Our Common Future as "development which meets the needs of current generations without compromising the ability of future generations to meet their own needs" (Brundtland, 1987. p16). There has been an awareness of the impact of humans on the world since the early 1960s when in 1962, the UN held the first conference on the environment. In 1986, NASA's report on the global impact of humans was delivered, and in the 1990s came the first definitive proof that humans were impacting the Earth's systems. In 2001, the statement was published "Global change is real and happening now". In 2015 the Paris Climate Agreement was signed by 195 countries with a commitment to act and to educate the population. In 2015 the United Nations launched the 17 Sustainable Development Goals (SDGs), "the most important global agenda of all times, which had the aim to shape and create a world that works for all", in the words of former Secretary-General Ban Ki Moon (United Nations, 2015).

Despite concerns being held for over 50 years and the term sustainability being coined so succinctly in the Brundtland report in 1987, there has been very little taught coherently in schools and in teacher preparation courses. Preparing PSTs for the role of champions for 'sustainable development' then requires universities to prepare the teachers of the future, current PSTs, with the skills and opportunities to develop their sustainability mindset as well as the expertise to support the development of a sustainability mindset in their future students. This chapter describes the creation of a sustainability mindset and then illustrates how this mindset is developed through two tertiary units within the school of education.

There is plenty of discussion around the notion of a sustainable or sustainability mindset and what that might look like and how it could be enacted. One useful definition by Kassel et al. (2016) defines a sustainable mindset as:

> a way of thinking and being that results from a broad understanding of the ecosystem's manifestations, from social sensitivity, as well as an introspective focus on one's personal values and higher self, and finds its expression in actions for the greater good of the whole.
>
> *(Kassel et al. 2016, 5)*

From this definition, Kassel, Rimanoczy and Mitchell (2016) produced a framework which linked the notion of knowledge, values and competency, or thinking, being and doing as described in Table 5.4.1.

This framework and Figure 5.4.1 help to articulate the components of the sustainable mindset that we need to develop in students. This is not the only framework; there is the UNESCO's (2014) (Figure 5.4.2) ways of knowing which was adapted to become a sustainable mindset, with the key indicators of action, decision making, planning, reflection, transformation and discussion being actions emanating from the values.

Figure 5.4.1 (Kassel et al., 2016) and Figure 5.4.2 (UNESCO, 2014) both show aspects that authors have considered to create a mindset that is conducive to PSTs seeking to explore and ultimately teach sustainability. This chapter brings these two frameworks together to consider not only knowledge, values and competency but includes collaboration and how the knowledge and values of others support our approach to sustainability.

The diagram encompasses the competences for educators in education for sustainable development, which has the 1996 UNESCO pillars of (Jacques, 1996) underlying education and life: learning to know, learning to do, learning to be and learning to live together. Despite these being developed originally in 1972, they continue to be built upon. The model develops each pillar under the areas of 'holistic application – integrative thinking and practice', 'envisioning change – past present and future' and 'achieving transformation – people, pedagogy and educational system'.

This chapter brings together the framework from UNESCO and amalgamates the framework with the framework of Kassel et al. (2016), creating a sustainability framework that is summarised in Table 5.4.2.

This has been elaborated in Table 5.4.3, which outlines what each aspect of the framework looks like, and it is against this framework that the two case studies from the school of education that the PST program will be mapped against.

Research indicates that the students with a sustainable mindset demonstrate a range of characteristics and they can:

- integrate/combine/consider relevant knowledge, skills and values when planning, deciding, acting, reflecting, transforming and discussing in their professional field
- collaborate with others in the professional, public and private environment, when planning, deciding, acting, reflecting, transforming and discussing

Table 5.4.1 Kassel and Rimanoczy's (2016) framework for a sustainable mindset

	Knowledge thinking	*Values being*	*Competency doing*
Systems perspective or thinking	**System theory** It incorporates concepts related to system theory and suggests approaches to problems and solutions that are inclusive of different perspectives and needs of stakeholders	**Interconnectedness** Regards a sense of interconnectedness and development. It draws attention to shared qualities and to the realization that we are all dependent on all other beings	**Stakeholder community** Considers engagement with all relevant stakeholders and the need to account for externalities as well
Ecological worldview	It can be developed through eco literacy, which includes a systems thinking approach in terms of relationships, connectedness, context and a sense of place	Understanding the individual and the business impact on the biosphere is critical to developing strategic thinking and addressing social, economic, and environmental challenges	Protecting and proving restorative action to halt further degradation in areas that have not been – or have been little – affected by human activities
Emotional intelligence	**Self and others** It can be developed through self-awareness, that is, being able to recognize your moods, emotions and drives. Journaling about situations is a way to develop such a dimension	**Compassion and multiple perspectives** Understanding another's emotional make-up and reactions and responding accordingly. Motivation is another subcomponent of this dimension.	**Practical global sensitivity** Being proactive; being able to interact, understand and negotiate teamwork and decision making in a variety of social settings; being able to adjust to the emotional state of individuals
Spiritual perspective intelligence	**Purpose and mission** Reflecting on one's purpose and mission in the world, making a social contribution providing meaning to one's life.	**Oneness with all that is** Recognizing or developing a sense of connection to the web of live, a sense of oneness with all that is.	**Contemplative practices** Focusing on mindfulness (attention to the moment) and reflective practices (to identify the impact of actions and decisions before they are made)

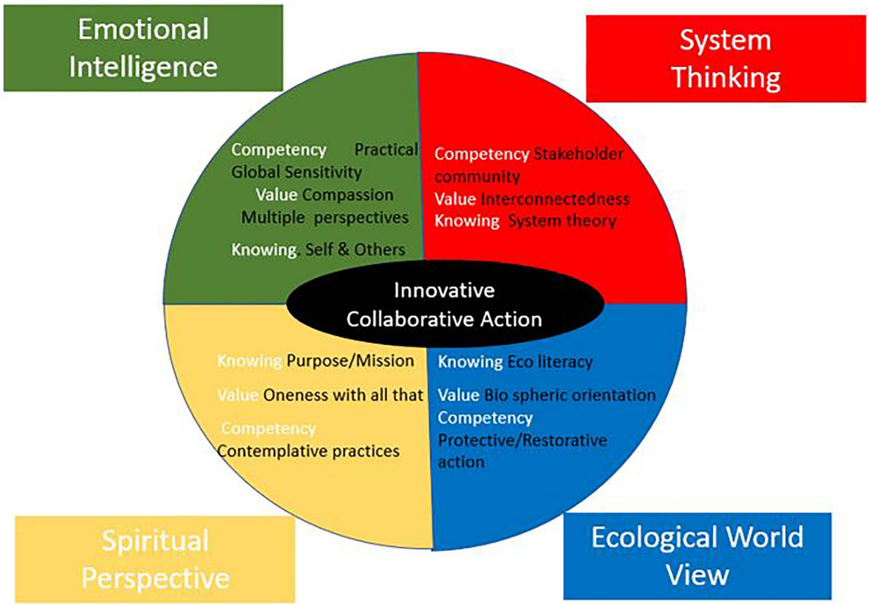

Figure 5.4.1 Kassel, Rimanoczy and Mitchell's sustainable mindset: Connecting being, thinking, and doing in management education.

Source: Kassel, K., Rimanoczy, I., & Mitchell, S. F. (2016). The sustainable mindset: Connecting being, thinking, and doing in management education. In Academy of management proceedings (Vol. 2016, No. 1, p. 16659). Briarcliff Manor, NY 10510: Academy of Management.

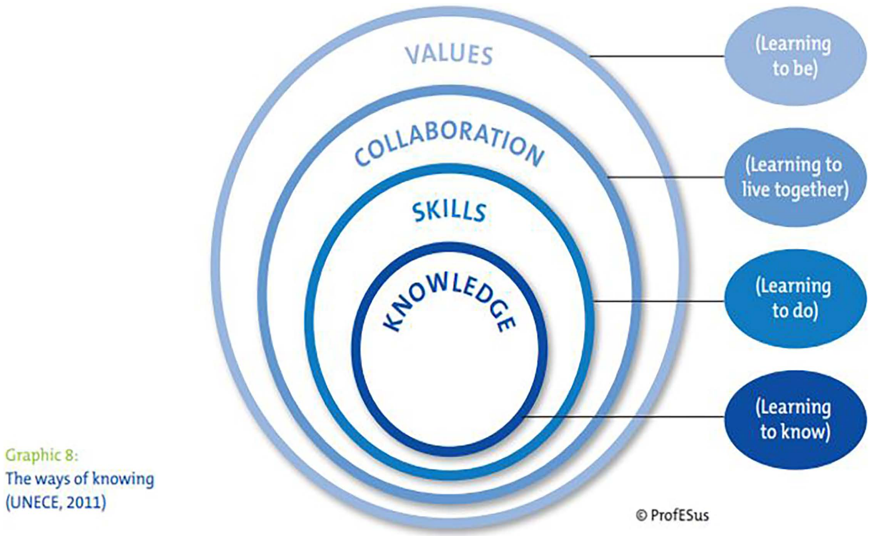

Figure 5.4.2 UNESCO (2021) ways of knowing framework.

UNESCO (2015): Rethinking Education? Towards a global common good. UNESCO publishing 2015. ISBN: 978-92-3-100088-1. Retrieved from http://unesdoc.unesco.org/images/0023/002325/232555e.pdf

Table 5.4.2 The UNESCO, Kassel, Rimanoczy and Mitchell sustainability framework

		UNESCO 2011			
		Knowledge and skills	*Collaboration*	*Values/being*	*Competency/actions*
Kassel, Rimanoczy, and Mitchell	**Systems perspective or thinking**	System theory	Bringing experts together	Interconnectedness	Engage with **stakeholder community**
	Ecological worldview	Eco-literacy	Listening to others' knowledge and sharing	Biospherics orientation	Consider **protective and restorative actions**
	Emotional intelligence	Self and others, becoming more self-aware.	Supporting others	Compassion and multiple perspectives	**Practical global sensitivity.** Demonstrate proactivity and negotiate
	Spiritual perspective intelligence	Purpose and mission	Empathizing together	Oneness with all that is	**Contemplative practices** being mindful and reflective regarding one's impact

Table 5.4.3 The elaborated UNESCO, Kassel, Rimanoczy and Mitchell sustainability framework

	Knowledge thinking	*Collaboration*	*Values being*	*Competency doing*
Systems perspective or thinking	**System theory** It incorporates concepts related to system theory and suggests approaches to problems and solutions that are inclusive of different perspectives and needs of stakeholders	Working with data and expertise from an interdisciplinary approach	**Interconnectedness** Regards a sense of interconnectedness and development. It draws attention to shared qualities and to the realization that we are all dependent on all other beings.	**Stakeholder community** Considers engagement with all relevant stakeholders and the need to account for externalities as well
Ecological worldview	**Eco-literacy** It can be developed through eco-literacy, which includes a systems thinking approach in terms of relationships, connectedness, context and a sense of place	**Listening to others** within the disciplines and also with those connected with the world	**Biospherics orientation** Understanding the individual and what the business impact on the biosphere is critical to developing strategic thinking and addressing social, economic and environmental challenges	**Protecting and proving restorative action** to halt further degradation in areas that have not been – or have been little – affected by human activities

(*Continued*)

Table 5.4.3 (Continued)

	Knowledge thinking	*Collaboration*	*Values being*	*Competency doing*
Emotional intelligence	**Self and others** It can be developed through self-awareness, that is, being able to recognize your moods, emotions and drives. Journaling about situations is a way to develop such a dimension	**Supporting others** in their views and perspectives and through negotiation. being able to adjust to the emotional state of individuals	**Compassion and multiple perspectives** Understanding another's emotional make-up and reactions and responding accordingly. Motivation is a subcomponent of this dimension	**Practical global sensitivity** Being proactive; being able to interact, understand and negotiate teamwork and decision-making in a variety of social settings; being able to adjust to emotional state of individuals
Spiritual perspective intelligence	**Purpose and mission** Reflecting on one's purpose and mission in the world, making a social contribution providing meaning to one's life	**Empathizing together** to share the overarching needs and future	**Oneness with all that is** Recognizing or developing a sense of connection to the web of life, a sense of oneness with all that is.	**Contemplative practices** Focusing on mindfulness and reflective practices (in order to be able to identify the impact of actions and decisions before they are made)

- describe the context of tasks, processes and activities in the local and global economic, ecological and social structures/system, when planning, deciding, acting, reflecting, transforming and discussing
- point out critical local and global economic, ecological and social questions and look behind the curtains, when planning, deciding, acting, reflecting, transforming and discussing in their professional field
- develop innovative strategies to fulfil tasks, processes and activities effectively, to support economic ecological and social perspective as much as possible, when planning, deciding, acting, reflecting, transforming and discussing in their professional field (strategic thinking)
- consider implications for the economic, social, ecological future (future thinking) when planning, deciding, acting, reflecting, transforming and discussing in their professional field.

(v. Laufenberg-Beermann et al., 2019, p. 64)

Within the teacher education program, PSTs need to meet the Australian Institute for Teaching and School Leadership (AITSL) teaching standards. These standards for teachers require graduates to be competent with information and communications technology (ICT), numeracy, literacy and sustainability within the context of the Australian Curriculum (Australian Curriculum Assessment and Reporting Authority, n.d.). In Australia, the Melbourne Declaration on Educational Goals for Young Australians and the Mparntwe Education Declaration

(Department of Education, 2022; Ministerial Council on Education Employment Training and Youth Affairs, 2008) identify essential skills for 21st-century learners in literacy, numeracy, ICT, thinking, creativity, teamwork and communication. It describes individuals who can manage their own wellbeing, relate well to others, make informed decisions about their lives, become citizens who behave with ethical integrity, relate to and communicate across cultures, work for the common good and act with responsibility at local, regional and global levels (Ministerial Council on Education Employment Training and Youth Affairs, 2008). These goals marry the other international change drivers from UNESCO and the United Nations SDGs.

The case studies that follow are both units in the undergraduate courses of the Bachelor of Education in early childhood, primary and secondary not all secondary students complete EIATW.

Case study 1

Curricula must enable re-learning how we are interconnected with a living, damaged planet (UNESCO, 2021).

Description of the unit

The first-year unit developed within the Bachelor of Education course focuses on the process of inquiry within the context of environmental sustainability. The compulsory unit *Educators Inquiring About the World*, a 13-week unit, is composed of ten workshops. The tertiary inquiry unit is the first in a series of inquiry units that progressed PSTs from first year to a science inquiry focus in the second year, a social science inquiry focus in the third year and then a research-based unit and integrated inquiry–focused unit in the fourth year. The unit was designed to ensure PSTs have a deep understanding of the inquiry process through an immersive process that would then be transferable into their teaching. It would also provide an engaging and motivating experience by embedding open-source tools, mainly Web 2.0 tools, and used a website as the platform to bring these tools together and create the narrative (www.inquiringabouttheworld.weebly.com). University diversification has resulted in courses being offered both on campus and online in a hybrid model and also to Open Universities Australia (OUA) students, so the website met the online and face-to-face needs of the PSTs (Sheffield & McIlvenny, 2014).

The design framework of this unit focuses on a pedagogical approach through inquiry within the context drawn from environmental sustainability. Sustainability is one of the cross-curriculum priorities in the Australian Curriculum and has a broad application for developing authentic learning opportunities, especially in a science context. Students chose a relevant problem of interest. Research has determined that students often lack confidence in science understanding and inquiry, with some being reluctant to teach science once they are qualified (Rennie et al., 2001; Tytler, 2007). By allowing students to select their own topic, they felt more confident and motivated to undertake the inquiry, as it was something they felt strongly about rather than something that was unconnected to them (Sheffield & McIlvenny, 2014).

Design of the learning environment

The inquiry needed to be authentic, engaging and contextual, and the unit focused on local and regional issues to encourage students to do the same (Herrington et al., 2014). The first workshop focused on the debate about sharks in the ocean and how there are changes to the shark populations and how to make swimming safer in and around the Western Australian coastline, from Geraldton to Albany.

Students consider environmental issues that interested and engaged them, that preferably were connected to their local communities to investigate. PSTs used secondary data and not primary data, so they needed to work with the available data. The process was scaffolded; however, there were many opportunities for individual coaching tutors and students and also for students to work in collaborative critiques to provide feedback to their peers (Herrington et al., 2014). The pedagogy was also influenced by the selection of an online/blended learning approach. Students from online and on-campus groups used collaborative tools such as Google Plus, and on-campus groups experienced a non-traditional classroom environment consisting of large workshop groups (50 students) co-facilitated by two tutors (one technology and the other inquiry focused). These approaches sought to 'close-the-gap' regarding equity and access to the unit, with both groups working in a flexible, self-paced learning environment.

Table 5.4.3 demonstrates how each workshop was created with a focus on different stages of the inquiry and information literacy processes. Mind mapping and question creation tools were used to develop a problem statement and then create more highly refined questions. Students were shown advanced search strategies and were exposed to a range of appropriate search engines to help develop their search skills.

While unit materials were hosted on an external website, there was a requirement for the assessment tasks to be submitted on the internal learning management system (LMS), Blackboard, as part of university assessment protocols. The unit was examined using one assessment divided into three components; a formative report was extensively reviewed and

Table 5.4.3 Example of two weeks of the program including the focus, technology tools and learning outcomes

Workshop	*Tools*	*Outcomes*	*Resources*
Identifying a problem			
3. Defining	Collaborative strategies	Examine collaborative strategies to form a critique to provide feedback to others	www.inquiringabouttheworld.weebly.com/working-together
	Mind mapping	Identify a research areas.	
	Concept mapping	Using one mind mapping tool to identify prior knowledge and possible questions.	www.bubbl.us www.popplet.com
		Explore the topic of emotional bias about sharks on websites that use of emotive language.	www.bagtheweb.com www.voki.com
		Create an avatar to provide a brief overview of the topic.	
Questioning and predicting			
4. Creating focus questions	Five whys/question matrix, Bloom's Taxonomy	Synthesize a variety of questions using the five whys and a question matrix	www.inquiringabouttheworld.weebly.com/questioning www.padlet.com

Source: (Sheffield & McIlvenny, 2014).

Table 5.4.4 Assessment in inquiry unit

Assessment	*PSTs*	*Tutors*
Formative (20%) Week 4	• Created a mind map outlining the parameters of the problem • Constructed their problem statement and rationale	• Refined the RQ to ensure they were answerable • Reviewed their problem statement and rationale
Summative (50%) Week 10	• Using secondary data to answer the research questions • A non-emotional position was presented • Specific and careful links made to the sustainability aspect of the Australian Curriculum	• Ensuring the data were accurate through careful curation • Links were reviewed and detail around the sustainability focus of the program were examined and marked
Presentation (30%) Week 12	• Presented their evidence visually and now were able to exhibit an emotional perspective on their issue	• PST colleagues and tutor were able to examine the evidence and empathize with the students' position.

then PSTs built on the feedback to provide a summative report that was displayed through a written document and a presentation. The extensive feedback provided after the formative assessment often caused the PSTs distress, as they were only used to marks and not detailed feedback, and the tutors would refine and rewrite the PSTs' research questions as necessary to enable the PSTs to continue to complete their research.

In the vignette that follows, an example of a PST's project is examined to demonstrate how various aspects of the sustainable mindset are developed during this unit. Not all students are able to respond to the changes so positively and with a sustainable and flexible mindset. After feedback, the PST completely reviewed the questions they had written and rewrote them as required to continue with the inquiry.

In another example, an indigenous student developed her research topic around the impact of hunting on dugong numbers by members of her community in the northwest area of Western Australia. She explored primary and secondary sources of data and information that both informed her research and enhanced her personal understanding of the topic.

Vignette example

The Impact of Single-use Plastic Pollution on Green Turtles in Western Australian Coast

Initially the research questions were related to the pollution and included these:

1. What threat do plastics in Western Australian (WA) waters pose to green turtles?
2. Who is responsible for single-use plastic pollution in WA?
3. Why should concern be raised regarding declining green turtle populations?
4. What programs are in place to reduce plastic pollution in WA and resultantly recover green turtle populations?
5. How will resolving this issue promote environmental sustainability in Western Australia?
6. What are some recommended solutions to this issue?
7. Where in Western Australia do plastics affect marine life most and why?

Figure 5.4.3 Vignette example. Pre-service teacher's use of an emotive image to evoke a response in colleagues and tutor during their presentation.

Source: Made by chapter author. Image created by DALL-E. (2023, June 5). Retrieved from https://openai.com/dall-e/

However, after extensive feedback and support, the research questions were reframed and the title changed

Anthropogenic Impacts on Green Sea Turtle Populations in the Great Barrier Reef

1. What is a green sea turtle (GST) and where are they commonly found?
2. What is the current population of GSTs on the Great Barrier Reef (GBR) and how has this trend changed over the last 10 years?
3. What anthropogenic impacts affect GST populations in the GBR?
4. What other species do anthropogenic factors affect within the GBR?
5. What mitigation programs are in place to reduce anthropogenic impacts on GSTs in the GBR and to what extent have they worked?
6. What recommended solutions could reduce anthropogenic impacts on GSTs in the GBR?

The PST was able to relate this to sustainability in the Australian Curriculum through the completion of the proforma, which illustrated their capacity to connect their issue to the curriculum, which is an important skill for a teacher.

Code	Specific statement from sustainability	How specifically relates to YOUR project
OI.8	Designing action for sustainability requires an evaluation of past practices, the assessment of scientific and technological developments, balanced judgements based on projected future economic, social and environmental impacts.	To develop successful conservation strategies that will promote environmental sustainability and protect GST populations, research must be conducted around past events such as population declines, previously implemented recovery programs and possible future impacts.
OI.2	All life forms, including human life, are connected through ecosystems on which they depend for their well-being and survival.	GSTs provide services essential to the survival of all marine ecosystems in the food chain as predators and prey. Through foraging behaviours, they structure seagrass meadows which provide food and protection for species valued by commercial fisheries. Therefore, habitats, marine species and humans depend on GSTs.

Presentation assessment included emotive language such as "*threats* by humans on these populations including dredging has also caused population *declines* by directly *causing injury and mortality* and *destroying* nests and feeding habitats including seagrass beds".

Table 5.4.5 outlines how the PST used as an example in the vignette was demonstrating a sustainability mindset.

- GST, Green sea turtle
- GBR, Great Barrier Reef
- PST, Pre-service teacher

Case study 2

The unit for second-year PSTs uses a problem-based approach (PBL) to engage in deep meaningful learning and encourage conversations and debate on local and community issues. This was a complex design challenge as the cohort of PSTs was enrolled in primary, early childhood and secondary education streams of the bachelor of education program and included both online and on-campus modes of study. As well, the unit needed to be situated in the context of other units in the bachelor of education program, meet overarching course outcomes and align with national teaching standards. It used the PBL approach to help PSTs explore complex ideas and develop their own understanding and then, through agency, develop solutions. Educating citizens with a strong background in STEM-related knowledge and skills is a priority for responding successfully to pressing global challenges, including climate change, as advocated by the United Nations Educational Scientific and Cultural Organization (United Nations Educational, Scientific and Cultural Organization, 2014). These challenges include but are not limited to a range of environmental and community issues pertaining to the United Nations SDGs (UN, n.d.). To meet these challenges the Australian government has proposed that STEM education be a major focus of the curriculum in both primary and secondary schools (Education Council,

Table 5.4.5 The sustainability inquiry–focused unit examples of the learning related to the (United Nations Educational, Scientific and Cultural Organization, 2014); Kassel et al., 2016) sustainable mindset framework

	UNESCO 2011			
	Knowledge and skills/knowing	*Collaboration*	*Values/being*	*Competency/ actions*
Systems perspective or thinking	Reviewing the issues around pollution and expanding the thinking to include all aspects of human intervention, renaming and refocusing on anthropogenic impact.	Reviewed curated websites and papers to find experts in green sea turtles, including on maturing of green sea turtles, issues around light pollution and rise in sea temperatures.	**Interconnectedness** PSTs were able to recognize in their research that connectedness of an issue such as the GBR and tourism and the GST, and this made it challenging to address.	**Stakeholders and community** In this example the recovery plan for marine turtles engages with all the stakeholders, including researchers, to consider the future
Ecological worldview	Found that plastic and green sea turtles was too broad so refined topic to focus on the factors impacting the GST on the Great Barrier Reef which included food webs, predators and measurable human impact	Using a range of data from the IUCN (red list) site, Great Barrier Reef and researcher papers from *Global Change Biology*, *Genes* and *Current Biology*. Sought to interview Professor Colin Limpus (UQ) on the issues.	**Bio-spherics orientation** This is seen as the balance between the protection of the GST and the tourism dollars that are spent on their habitat	**Protective and restorative actions.** The recovery plan for marine turtles outlines a range of strategies that can be considered, although the PST is reporting on this only in their report and presentation.
Emotional intelligence	Self and others becoming more self-aware. During the unit there are times when PSTs are concerned with what they are finding out and how this is impacting on GSTs.	Supporting others through the in-class presentation by listening and asking questions about the topics that other PSTs are exploring.	Compassion and multiple perspectives. Recognize the power of the imagery used to elicit a strong emotional response in the presentation.	**Practical global sensitivity.** Demonstrate negotiation of a solution in class with their peers, and this does not progress into actions in life

(Continued)

Table 5.4.5 (Countined)

	UNESCO 2011			
	Knowledge and skills/knowing	*Collaboration*	*Values/being*	*Competency/ actions*
Spiritual perspective intelligence	**Purpose and mission** were to explore the anthropogenic impact on GSTs and consider the impact on themselves as part of the anthropogenic problem.	**Empathizing together** through an in-class presentation when the PST presented their problem and graphic impact if changes to the GST environment are not addressed	**Oneness with all that is.** Recognize through their project findings with empathy that we have a significant impact on the GST	**Contemplative practices** Considering how they could advocate or change their practice; however, a practical solution was not always possible.

2015). Consequently, PST education programs have been developed to prepare new teachers to teach STEM across all levels of education, and this unit provides a useful medium to focus on the embedding of the content and skills required for environmental education with a specific focus on climate change. The challenge, therefore, was to develop for PSTs a meaningful and interesting STEM-related program, incorporating both general capabilities, cross curriculum priorities and disciplinary knowledge and skills that would enable them to create engaging learning experiences for their own future PST, and these can be focused on ***sustainable education.***

Sustainable Development Goals

The unit was designed for PSTs to select one or more of the United Nations SGDs (UN, n.d.) and to develop a solution to a real-world problem they had identified, prototyped and tested. The SDGs are expressed as targets to be achieved by the year 2030, and Australia's progress towards achieving its targets are reported on the website: https://www.sdgtransformingaustralia.com/#/2772/1369//. The unit directed PSTs to relate these targets to their own lives. This provided an opportunity for them to have unique, personal and perhaps vulnerable experiences as they struggled to design projects that stimulated their awareness of sustainable development values.

Design thinking

A PBL approach was implemented, with most of the PSTs unfamiliar with this pedagogical model. This included the identification of an ill-structured, messy problem and using the five-stage Harvard University Hasso-Plattner design thinking model (2017) (see Figure 5.4.4) to identify and gather data (see Chapter 4.4 in this volume). The model had a number of strengths including ensuring that student learning followed a natural progression in designing a solution strategy for a complex problem. In doing so, it would

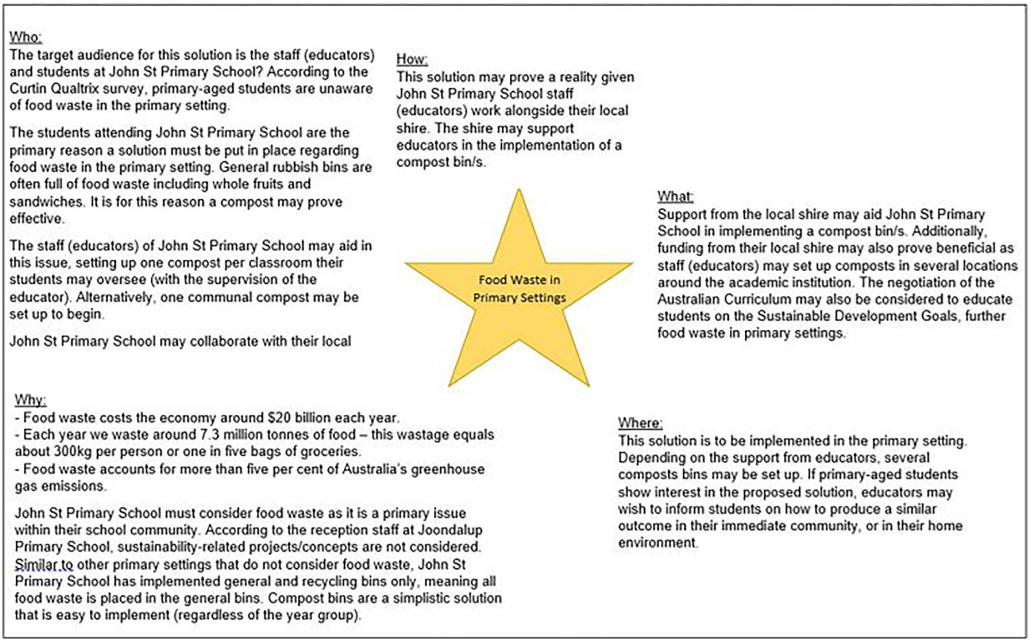

Figure 5.4.4 An example of ideation in the form of a starburst.

Source: Made by chapter author

encourage PSTs to view the problem from multiple perspectives, thereby blending science understandings, mathematics competencies, digital technology and digital arts.

These key stages were:

1. Empathise
2. Define
3. Ideate
4. Prototype
5. Test.

An additional stage of storytelling was added to the Hasso-Plattner design model (see Figure 5.4.5) to enable PSTs to articulate and reflect critically on the learning process undertaken (Hasso-Plattner Design School, 2017).

Vignette example: How can the food waste be dealt with in a school?

Link: https://istemsocialissues19448741.weebly.com

To help PSTs create an organic and permanent example of their project using a web platform – *Weebly* –a website was created for the unit: https://istempbl.weebly.com. The website provided a range of online tools to support student learning, including links to the UN's sustainable goals and targets. PSTs used these tools to curate and store examples of

Lean Canvas Design Thinking

1. Problem:	Proposed Solution:	Unique Value Proposition:	Unfair/ Advantage:	2. Customer Segment
Ensure Sustainable Consumption and Production Patterns. This issue regards food waste produced by John St Primary School. Students place all food waste, primarily whole fruits and sandwiches, into the general rubbish. This assessment aims to consider alternate methods of combatting food waste. **Existing Alternatives:** - Compost Bins - Bokashi Bins - Chickens - Worm Farms - Waste Free Wednesdays - Sustainability Program/s Alternative solutions are dependent on funding, student commitment, and space provided.	Compost: Decayed organic material (vegetable matter) used as a fertilizer for growing plants. Compost bins may prove most effective as they are easy to maintain, cost-efficient, beneficial to the school gardens, and provide students with additional classroom duties that link to sustainability. As composts are cost-effective, several compost bins may be implemented within Primary School. **Key Metrics:** Key Metrics may be tracked using surveys (Curtin Qualtrix) taken by both educators and students, and visual observation. Student communication regarding the concept may also prove as a success indicator.	Composts should be considered within the John St Primary School community as they are simple to maintain and cost-effective. Additionally, students often enjoying taking on diverse tasks that benefit the school community. It is for these reasons compost bin/s should be considered. Education surrounding sustainability is essential, this way, students may consider combatting food waste within their home environment. **High Level Concept:** As mentioned above, composts should be considered within the John St Primary School community as they are simple to maintain and cost-effective. Often, composts lead to vegetable gardens, bokashi bins, or the introduction of a sustainability program. Such ideas may aid in combatting food waste, extending students' understanding of sustainability.	Composts should be considered above other existing alternatives as they are simple to maintain and cost-effective. Additionally, composts take up the least amount of space and allow students to gain knowledge surrounding sustainability. Through visual observation of several primary schools, composts often prove most effective as they offer students independence and leadership and are small and compact. **Channels (Communication):** Emails will be used as the primary method of communication between researcher and educator. Newsletters may be considered to include the local community. Word of mouth prior to and following school	The target customers are staff (educators) and students of John St Primary School. Additionally, the school community may be considered a sub-group target customer if they wish to implement compost bin/s in their home environment. These customers are considered a target as the education provided links to Sustainable Development Goal "Ensure Sustainable Consumption and Production Patterns". **Early Adopters:** The characteristics of an ideal early adopter may be primary-aged students or staff (educators) who show interest in sustainability (food waste) or obtain prior knowledge.
Potential Costs: Funding may be obtained through the local shire, or through educators themselves as compost bins are often cost-effective. The school community may wish to purchase soil to enhance the compost, improving the rate of success.		**Potential Revenue Streams:** Given compost bin/s are successful within the academic environment, students may consider a "Sustainability Sale" selling composts or starter kits to the John St Primary School community. Brochures/pamphlets may be made by upper-school students that may be sold for a small cost.		

Figure 5.4.5 An example of prototype in the form of a Lean Canvas.

Source: Made by chapter author

their learning. This would enable them to showcase their product and be a useful resource for their future teaching.

UN Goal and Target: Ensure Sustainable Consumption and Production Patterns

- Target 12.3. By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses.
- Target 12.5. By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.

Empathise

At the emphathise stage, the what./who/ how is the problem currently being solved? It involved researching and critically analysing three existing solutions to the identified issue.

An example of research summary: the Western Australian–based Waste Wise Schools Program (WWS) was established to address what to do regarding uneaten food within Western Australian academic institutions (Waste Wise Action Plan, n.d.). Food waste is a minor issue that may sum up to be disproportionate if not considered within learning environments (Waste Wise Action Plan, n.d.). Most children consume the majority of their food within assigned recess and lunch periods; however, some children do not (WA Waste Authority 2021). When several children do not consume their food, food waste becomes a concern within academic institutions (WA Waste Authority 2021 (see Chapter 2.4 in this volume)). The solutions considered here in other schools (Table 5.4.6) are listed at this stage to enable students to see how others have solved this issue.

Table 5.4.6 An example of other alternatives in schools as part of the empathy phase

Existing solutions	*Woody Primary School*	*Hillside Primary School*	*Parkerside Primary School*
What are they providing?	Woody Primary School applies these programs to reduce food waste: – **Chicken Duty/Roster**: Year 3 students collect their food scraps from recess and lunch periods (fruits, vegetables and breads only) to feed the chickens before and after school. Laid eggs are stamped and used toward breakfast club. – **Waste-Free Wednesday**: Students prepare waste-free lunches (no plastic packaging), reducing plastic waste. Points awarded per faction.	Hillside Primary School applies these programs to reduce food waste: – **Sustainability educator**, Rachel Roberts, co-ordinates a sustainability program that teaches food harvesting, compost management and worm farming – **Compost Bins**: Students categorize their food waste to compost within the sustainability program. – **Bokashi Bin**: Students work with the school canteen to gain knowledge surrounding bokashi bins. The liquid is used in the school garden. – **Worm Farm**: Students categorize their food waste to feed to the worms within the sustainability program. – **Waste-Free Wednesday**: Students prepare waste-free lunches (no plastic packaging), reducing plastic waste. Points are awarded per faction.	Parkerside Primary School applies these programs to reduce food waste: – **Waste-Free Wednesday**: Students prepare waste-free lunches (no plastic packaging), reducing plastic waste. Points are awarded per faction.
Who are their target audience?	– School students – School staff – Members of the school community	– School students – School staff – City of Bayswater (Shire) – Members of the school community	– School students – School staff – Members of the school community
Are they free?/what do they charge for this service or product?	– Chicken Duty/Roster: Costs include shelter, maintenance, laying pellets, additional food, straw/bedding and chickens – Waste-Free Wednesday: Free	– Sustainability program: teaching resources, school funding – Compost Bin: Costs of compost tools/equipment and the compost bin – Bokashi Bin: Costs of bokashi tools/equipment and the bokashi bin – Worm Farm: Costs include maintenance, shelter, soil and worms – Waste-Free Wednesday: Free	– Waste-Free Wednesday: Free

(Continued)

Table 5.4.6 (Continued)

Existing solutions	*Woody Primary School*	*Hillside Primary School*	*Parkerside Primary School*
What gaps do you see in their service or product?	As Chicken Duty is for year 3 students exclusively, other students miss the opportunity to learn about sustainability.	As several programs/sub-programs are offered, it may be difficult to manage each program.	Additional programs may be offered to combat food waste.
References	All information was gathered through practitioner observation or contact with admin/school reception.	All information was gathered through professional practitioner observation or contact with admin/school reception.	All information was gathered through observation or contact with admin/school reception.

Define

The next part of the PBL cycle is the define stage, where the aspect of the goal is researched and specifically targeted. For example, *Food waste in primary setting Specifically, Analyzing the Food Waste of St. John's Primary School and Methods of Reduction*.

Ideation

At the ideation stage, the student creates a mind map of all the possible ideas to address the defined problem,'food wastage at St John's Primary School', and then creates a starburst which considers the who, what, where, why and how. This considers the target audience for the waste management and who would be impacted if a solution was implemented and, very importantly, why this is an important issue to solve for the key stakeholders.

Prototype

In the prototype stage, the solution is reviewed against cost, potential adopters, risks and the revenue and presented in the Lean Canvas. The Lean Canvas considers how the solution would be implemented, and who would be needed, and what the success indicator would be. For the example here, the PST considered the proposed solution of a compost bin and investigated the advantages and disadvantages in the compost bin's ability to reduce the food waste in the school, whilst providing the necessary science concepts to primary students.

Test

In the test stage, the PSTs' learning experiences were assessed with them, providing a video explaining the issues they had identified, the solutions they had prototyped, their development of general capabilities, and disciplinary knowledge/skills, and their ability to understand and accept this innovative pedagogical approach for their own teaching practices. The documented the trials, tribulations and anxieties of the PSTs and reflected on how well they were supported (Kuhlthau, 1999).

Table 5.4.7 maps the learning in the unit to the sustainability mindset using the vignette example of how food waste can be dealt with in a school.

Table 5.4.7 The PBL SDGs-focused unit with examples of how the learning related to the UNESCO, Kassel, Rimanoczy and Mitchell sustainable mindset framework

		UNESCO 2011			
		Knowledge and skills	*Collaboration*	*Values/being*	*Competency/ actions*
Kassel, Rimanoczy, & Mitchell	**Systems perspective or thinking**	System theory considering the financial issues, school issues and the environmental issues that impact complex problems	Bringing experts together, so talking to people and using websites to determine how other schools solve this issue	Interconnectedness demonstrating that all perspectives are valued and acknowledged as the PST searches for information	Engage with all stakeholders and the community by speaking to the school administration, teachers and students
	Ecological worldview	Eco-literacy around the different composting ideas considering the science and feasibility	Listening to others and sharing through visiting stores and websites to search for information	Bio-spherics orientation. Understanding the nuances around each solution.	Consider protective and restorative actions in the land and also in the compost solution chosen
	Emotional intelligence	Self and others becoming more self-aware. Be aware of the sensitivities of others to addressing a global issue at the school.	Supporting others by listening to their project story and asking questions	Compassion and multiple perspectives. Able to see the issue around composting for a safety and health issue.	Practical global sensitivity. Demonstrate proactivity and negotiate to find a suitable site and a safety solution.
	Spiritual perspective intelligence	Purpose and mission. Understand that even this small solution contributes positively to the health of the planet.	Empathizing together on how challenging and complex issues are difficult to solve and often cause anxiety and concern.	Oneness with all that is. Acknowledging that everyone has a view and all have value, even those who do not agree (so those that oppose a compost solution)	Contemplative practices, being mindful and reflective regarding their impact.

Final projects

Some projects also included connections to geography, history and economics and therefore were wider than the design brief. Including the UN SDGs broadened the initial focus on the discipline of science to encompass a more holistic sustainability perspective. This paved the way for PSTs to explore their homes, jobs, neighborhoods and their own lives as they designed projects that were personally interesting and engaging. Once PSTs had become emotionally invested in their projects, they became vulnerable and therefore sensitive to feedback. Building a community within the classroom and developing trust with the PSTs was a key part of the unit. During the design and teaching of the PBL unit, emotions resonated deeply, and this enabled PSTs to empathize with the stakeholders and hopefully enable them to support them and solve issues. It would also encourage them to be empathetic towards their own future students and to help their students develop empathy. It was hoped that the unit encouraged PSTs not to be judgmental of themselves or others and to step back and reconsider compassionately the social problem or issue that they were seeking to solve. This focus on compassion and empathy aligned with the sustainability mindset around emotional intelligence and spirituality.

Conclusion

Education is a global issue; it is also a deeply personal one. None of the other purposes can be met if we forget that education is about enriching the minds and hearts of living people. . . . All students are unique individuals with their own hopes, talents, anxieties, fears, passions, and aspirations. Engaging them as individuals is the heart of raising achievement. (Robinson & Aronica, 2016)

PSTs must be champions for creating a sustainable future. They must learn how to negotiate with students, their families, and multiple or diverse cultures to ensure that controversial topics around sustainability with knowledge of the complexity of the system and the ecology. They need to then demonstrate the ability to work with and alongside others, with compassionate listening and supporting others. These undergraduate units, whilst not addressing all aspects of the sustainability mindset, do seek to move beyond the current knowledge focus and encourage a more holistic view of learning 'sustainability'.

All teacher educator courses at universities should collaborate to teach in this more holistic way, encouraging their PSTs to learn how to problem solve and then how to develop lessons around this pedagogy. If we expect the students of tomorrow to solve the wicked problems of today, then we must insist that our teachers of tomorrow are furnished with the skills, pedagogy and mindset to support this task. If we do not prepare our PSTs, then we will surely fail to create the problem-solvers that we need for a sustainable future.

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5.5
MOVING AN ELEPHANT
The role of teachers in university sustainability education development

Antonio Gomera, Miguel Antúnez and Francisco Villamandos

Key concepts for sustainability education

- Teacher training in education for sustainable development is a critical component in advancing sustainability education.
- There is a need to prioritize education for sustainable development in modern teacher training.
- There is a responsibility and an opportunity for teachers to be a fundamental part of sustainability education development processes in educational institutions.
- It is important to incorporate sustainability criteria in student learning.
- It is necessary to identify those variables that paralyze us, to overcome them, and those that activate us, to enhance them.
- There is a need to operate "levers" to accelerate the transformation processes towards sustainability in coherence with the urgency that is being requested for it.
- Teacher training within the framework of education for sustainable development is a key tool to advance towards sustainability in universities.

Introduction

The game board

The current crisis in global sustainability calls for an urgent change in our lifestyles and a transformation in the way we act and think. To achieve this, new competencies need to be developed which can contribute towards making our societies more sustainable, and in this, universities play a crucial role. However, if students are to acquire these new competencies, the principles they are based on must be fully assimilated and integrated by the university institutions.

Our proposal is built on the main premise that we should consider the university teaching staff as the key factor around which the possibility of achieving a sustainable university revolves. Although the teaching staff are clearly not the only relevant actor, we feel they constitute the key agent in the process (Villamandos et al. 2019), not only because they

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organize teaching at the university but also because it is precisely from this group that the management positions in these institutions are selected.

The second premise clashes somewhat with the former:

> "I still really don't know how I could include sustainability in my subject"
> "We're all clear about the theory, but we don't know how to put it into practice"
> "If we are going to incorporate sustainability, we need to reflect on the results of our own behaviour"
> "I understand sustainability as an environmental issue and I don't know if it refers to anything else"
> "We have no clear concept or definition of sustainability"
> "These ideas have nothing to do with my subject"
> "I already comply, because my subject contains units about the environment"
> "The vast majority of university teachers have no idea whether the university is involved or not in these issues"
> "The first thing is to raise awareness among the teachers themselves, because until now, most of us have not given it much thought"
> "We need to convey the need for coordination between the subjects in each degree course"
> "Since there is no clear policy coming from the university, what I do in my class has little practical use"

These reflections were voiced by teachers taking part in training courses on the introduction of sustainability in university teaching, which the authors of this chapter have been running for several years. They express these difficulties, quite openly, while we work with them to help them learn techniques to enable them to teach competencies in environmental education – and they all have something in common: they talk about what paralyzes them.

What paralyzes us?

We are paralyzed by environmental hyperopia

Using this analogy with an eye disorder, Uzzell (2000) put forward this interesting concept, which has proved extremely useful in the field of environmental psychology: we perceive environmental problems as being more serious the further they are from the perceiver, since the increased distance leads to a reduced feeling of individual responsibility for them, fueled by a feeling of helplessness. This results in the global environment affecting us in terms of concern and not influence, since the perceived possibilities of control are non-existent. From this it follows that the global perspective is perceived as something more distant from the person, something that is "out there" and does not directly imply us. This perception can condition the intention of conduct and the environmental behavior of the individual, raising the idea of the low connection between concern for global problems and involvement in action related to the management of immediate environmental issues of a local nature.

We are pulled, therefore, into a vicious cycle of inaction and frustration: we feel guilty because we do not believe we can do anything, so we do nothing – and that makes us feel even worse.

In the sphere of the near, of the most local, we behave as farsighted, without fear of the ability to get to define well the scenario in which we move and in which we can act. The environmental problems that surround us appear more diffuse, less relevant and with little connection with the individual capacity to act in the social context in which we move. Indeed, this paralyzes us, since we are not able to easily find the way to travel so that our effort is minimally effective.

We are paralyzed by a simplistic view of complex problems

The idea of being faced with a complex issue which is, by definition, difficult to solve, immobilizes us, or at least discourages us, if we do not find our own way of managing the complexity. The science of complexity studies world phenomena by assuming their complex nature and seeks predictive models that incorporate the existence of chance and uncertainty, as a way of approaching reality that extends not only to experimental sciences but also to social sciences (Balandier 1989). However, we tend to contemplate reality from a simplistic perspective, from which we tend to employ short-term measures to try to solve problems, attributing instant results to the actions we intend to take. However, this only works in relatively simple contexts – when faced with problems we understand to be extremely complex, we do not usually feel comfortable taking steps that do not produce immediate, tangible results. We therefore perceive our actions to be useless, although this can be balanced to a large extent by ethical positions (environmental awareness) or by external stimuli, which we perceive as "normal" in our context (the perceived norm) (Ajzen 1991).

Therefore, the perception of complexity comes to add to the lack of clarity with which we visualize the environmental problems that surround us. Given the complexity, we do not usually have mental instruments that facilitate us to visualize what to do. We are aware that the simple solutions that we come up with or that we usually apply to other areas of life are not going to work in this complex scenario. But we do not have the resources to face the management of complex systems with some guarantee.

We are paralyzed by the dilemma of acting individually or as a group

Numerous studies reflect the gap between the possession of knowledge and awareness about the environment, on the one hand, and behaving and making decisions in favor of the environment, on the other. One of the key obstacles in this contradictory situation, which occurs frequently with complex systems and uncertain contexts (Morin 2011; Prigogine 1987), is precisely the idea that the group has no part to play. One of the main factors which influences the previously mentioned gap is the perception that we are faced with a dilemma whether to act as a group (through the so-called "top-down" strategies, which are imposed by those who manage organizations) or as an individual (by raising awareness and promoting "bottom-up" strategies which are suggested by individuals) (Disterheft et al. 2012, León-Fernandez et al. 2017). As mentioned earlier, when our environmental awareness is insufficient to spur us into action or when we perceive that our social environment is governed by rules which do not prioritize or support sustainable measures, we may become blocked as individuals. This leads us to think that it should be the group, the society, which should lead the transformation, and this thought serves as a reassuring excuse for our inaction. This very human reaction occurs commonly among teachers, too, who, although they are aware of the issues, feel isolated and unable to initiate transformative action.

The feeling of loneliness or feeling out of place, of not fitting into the perception we have of what is "normal" in the environment to which we belong prevents us from moving. At least it prevents us from moving determinedly enough where we think we should be heading.

What activates us?

A motivating context activates us

The international community seems to be ready to quicken the transition towards sustainability. One clear symptom of this general, global trend is the United Nations (UN) 2030 Agenda. This agenda, drawn up in 2015, replaced and took the Millennium Goals one step further, when a confluence of scientific, educational, cultural communities, non-governmental organizations (NGOs), trade unions and other groups and organizations met to establish the universal Sustainable Development Goals (SDGs), which were approved by the UN, with their sights set on 2030 (UN, 2015). The 17 SDGs make up a universal sustainable development agenda, and all countries are called on to follow a global strategy combining economic development, social inclusion and environmental sustainability to try to respond to the world's most pressing challenges together. They represent a shared global vision about how to combine these three dimensions of sustainable development in measures implemented on local, national and international levels.

We can and should feel part of this huge global network which is currently exploring the answers to such complex challenges. Organizations such as the United Nations Educational, Scientific and Cultural Organization (UNESCO) are leading the call to action to radically change the way we live. In the field of education for sustainable development (ESD) (also understood as "education for sustainability", which in this chapter we consider interchangeable concepts that are taken to mean the same thing), the framework for 2030 adopted by UNESCO will intensify action in five priority areas: policies, educational environments, the training and empowerment of educators, youth empowerment and action at a local level (UNESCO 2020), which are areas that are also fully applicable in universities.

The first of these, "Advancing policy", explains how ESD should be integrated into global, regional, national and local policies related to education and sustainable development. To achieve this, it proposes steps such as integrating ESD into education policies or systematically strengthening the synergistic relationships between education and formal, non-formal and informal learning.

With regard to the second priority action area, "Transforming learning environments", the aim is for educational institutions to change so that the institution as a whole conforms to the principles of sustainable development.

The third priority action area in the roadmap for ESD is linked to strengthening the skills of educators. The focus here is on empowering educators with the necessary knowledge, skills, values and attitudes for the transition to sustainability. The idea of "curricular sustainability" is a key concept here: this process involves providing students with the transversal competences needed to understand how their professional activity interacts with society and the environment (CRUE 2012).

Another priority action area is that relating to youth, with whom the plan is to use all the available resources to share messages about the urgency of the challenges to achieve sustainability, to promote ESD in their educational environments and to encourage self-empowerment and transformative action.

The fifth and final priority area of action, relating to mobilizing resources on a local level, emphasizes the importance of actions on the part of communities, as it is here where meaningful transformative actions are most likely to take place. Active cooperation between educational institutions and the community should therefore be promoted to ensure that the latest knowledge and practices in sustainable development are implemented in order to advance the local agenda (Gomera et al. 2021).

This roadmap marked by UNESCO is undoubtedly a reference tool that each educational institution can apply and adapt to its own context.

This complex collage of action on a global, national, regional and local level should help us become aware that we are part of a vast team which is seeking to empower people to take on responsibility with the current and future generations and actively contribute towards transforming society in terms of sustainability.

Identifying where our sphere of control and responsibility lies activates us

We all suffer from environmental hyperopia, albeit with differing diopters. "Think globally, act locally", the motto used for many years to drive environmental action, can be a great way to correct this "environmental eye disorder". In this context, based on Covey's proposal (1996), it is definitely worth knowing which problems or situations concern us; however, it is even more vital to identify the areas where we can make an impact, where we can potentially take action. What is more, we need to understand clearly which of the things we can potentially do we are doing already, here and now. Identifying the circles of concern, influence and action in this way paves the way for us to take on responsibility and take action in the personal, work and social spheres, which is a crucial step for teachers, given the multiple roles they play.

In the same way, our attitude, reactive or proactive, will determine how malleable our circle of influence is. People with a reactive attitude dwell on what they can do little or nothing about, ending up with a highly negative view of the world and their own capacity to be useful. On the contrary, people with a proactive attitude focus on what they can do personally and they remain constantly alert for ways in which they can exert and expand their influence (Murray 2011). Both attitudes are in a continuous struggle: being proactive or reactive is all in the mind.

The acceptance that individual and collective actions are interrelated activates us

One of the greatest challenges of ESD is to clarify that no such dilemma in fact exists between acting as an individual and as a group and to emphasize the need to begin to tackle environmental problems through empowerment for action on both an individual and a group level. From an individual perspective, ESD requires each citizen to acquire or deepen their environmental awareness, which can lead to pro-environmental action which goes further than merely harboring good intentions (Gomera et al. 2012). The term "environmental awareness" can be understood as the system of knowledge and experiences that the individual actively uses in their relationship with the environment (Febles 2004). It is a multidimensional concept, which encompasses knowledge, beliefs, values, attitudes and behaviors related to the environment in an interrelated way. This awareness is particular in each context and must be oriented to real behaviors framed in these scenarios. On the other hand, from a group perspective, ESD should contribute to an individual's perception of the system as a "sustainable ecosystem" (Conceição et al. 2006). This concept, the perceived norm, was included in classic theories of social psychology about planned action devised by Ajzen (1991) and has subsequently been used in countless studies in social and environmental psychology. This author notes that perceived behavioral control is determined by external and internal variables. The combination of attitude, subjective norm and perceived behavioral control would result in behavioral intention, the most immediate precursor of behavior.

Therefore, environmental awareness and perceived norm are constituted as possible interrelated, allied and synergistic indicators: by consolidating a perceived norm of respect towards the environment, it will be possible to have a direct impact on the way in which each individual behaves and, therefore, help to reinforce their environmental awareness. As a result, the entire system could be strengthened and ever higher levels of sustainability could be reached.

How to get an elephant moving

In the processes of making universities more sustainable, both the individual and the administration have a part to play. In addition, universities are organizations which have the capacity to learn and evolve. Therefore, there is a need to transform higher education in order to address the challenges of the global crisis within the framework of sustainability. Universities have a key role to play in achieving compliance with the SDGs, while at the same time they can accrue enormous benefit from committing to the 2030 Agenda (SDSN 2017). However, when it comes to putting things into practice, we find that universities are often huge organizations which are staggeringly complex in the way they are organized and run and often excruciatingly slow-moving. We need "levers" which are capable of accelerating the transformation processes towards sustainability which match the urgency which is required in this case.

One pressing need is to provide methods of identifying and fostering any feedback loops which can generate transformation flows towards more advanced levels of sustainability. In this context, in a recent work (Gomera et al. 2020), we put forward a model for accelerating the transformation towards sustainability in universities, which are systems that have a highly complex framework (Figure 5.5.1).

The model incorporates criteria used to specify the actions and processes in the framework of organizational learning, such as the direction and the level where they start (Crossan et al. 1999). It also identifies the main actors: the governing body, the scientific-technical administrative structure, the community and allies. The actions and processes flow in both directions and provide feedback to each other: on the one hand, within the university community, actions and processes emanate mainly from agreements between internal agents, with a bottom-up approach from the individual/group level to the organizational level. This feedforward process enables environmental awareness to be strengthened on all fronts. On the other hand, and in a complementary and synergistic way, the governing body reacts by organizing feedback on actions and processes arising from strategic commitments and

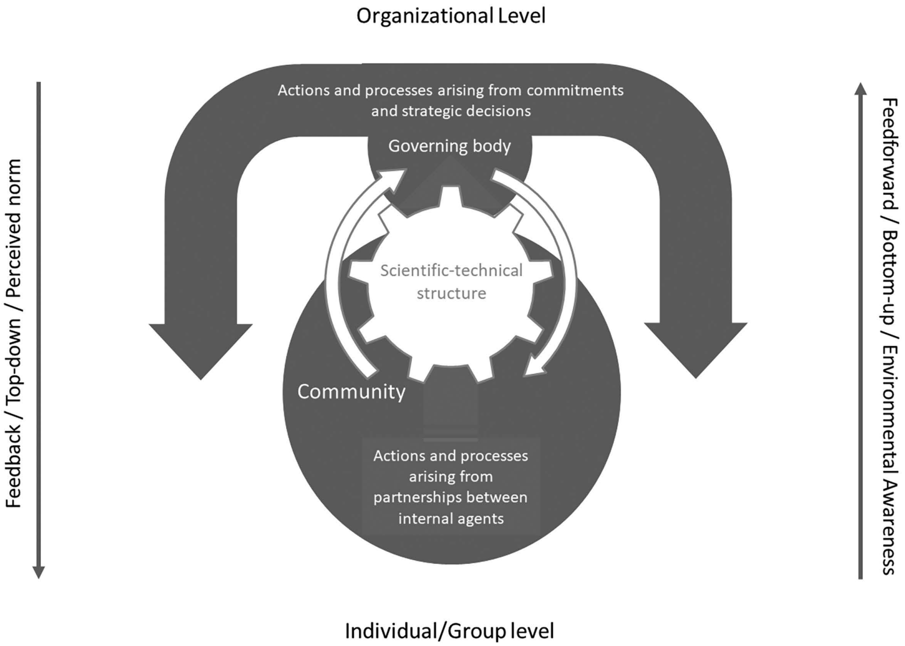

Figure 5.5.1 Proposed organizational model for a university that is learning environmental sustainability.

Source: (Gomera et al. 2020.)

decisions, which permeate all structures and groups in a top-down direction, acting on the perceived norm. This model highlights the role of a scientific-technical administrative structure as the stabilizer, catalyst, facilitator, attractor and, to a large extent, executor of the organization's transformative flows, and it is able to play a key role in the evolution towards sustainability. These flows, taking into account the fact that organizations such as universities are highly complex, could provide a catalyst for propelling the system up towards more advanced levels, thus fueling a spiral of continuous improvement in the organization's environmental performance, bringing with it progressively higher levels of environmental awareness and perceived norms.

One clear example of this type of action which enables feedback processes in both directions is the training of teachers in curricular sustainability (Antúnez et al. 2017). As we have commented previously, our experience as organizers and catalysts of these courses has shown us how processes like these, in which particular attention is paid to activating or boosting environmental awareness and responsibility and techniques are taught to implement them, can generate a transformative flow in teaching that in turn contributes to modifying the perceived norm on how the perspective of sustainability can be incorporated into teaching. This is undoubtedly of immense value, as it persuades universities to accept that one of their greatest challenges is to train professionals who are critical of the direction our society is currently taking and who are capable of acting to promote more sustainable development.

The identity of the anthill does not undervalue the role of each ant

And, as you may have guessed if you work as a teacher at any level, we have a message for you: you have a unique opportunity, and also the responsibility, to contribute towards solving the current environmental crisis by incorporating sustainability criteria into your teaching and your students' syllabus, so that every sphere of your teaching is infused by sustainability. The role of teachers and what they teach are fundamental. It is teachers who teach the subjects and train the future professionals, who plan training activities for teachers, who prioritize certain research topics over others and who can be appointed to positions of responsibility in the governance of educational institutions.

Perhaps you have not been fully aware until now, but it forms a part of your circle of influence. Why? Because all future professionals, regardless of their field, can choose whether they carry out their work from the perspective of sustainability or not. And this, to a great extent, depends on how those who plan the degree courses and the teachers themselves are able to incorporate sustainability as a key competency in the syllabus. Furthermore, we need to go beyond "the environment" and beyond the knowledge of the subjects and to make changes to the whole teaching-learning process: in its competencies, methodology, syllabus, assessment and good practices.

It is extremely heartening to witness those moments when the teachers who participate in the courses we teach start to see things through "sustainability-tinted spectacles" and reach the awareness that every degree contains or may contain competencies related to sustainability, in a direct or indirect way, and that progress can be made with the existing techniques (such as teachers' guides, learning objectives, the existing competencies or active methodology), without waiting for more in-depth changes (although these are urgently needed) in academic planning or in the university institutions themselves. "Perhaps we are already incorporating sustainability" is one of the most inspiring reflections that participants often express when they have completed their training.

There are no magic formulas or recipes, and there is still a long way to go and many questions yet to resolve. Fortunately, however, we already have a large stock of research, tools, networks and experiences available to universities to help us advance in curricular sustainability.

The teaching staff, therefore, are the key actor in effectively achieving a global transformation in university teaching-learning processes which can guide them along the same lines as their commitment to sustainability.

Conclusion

Learn to walk before you run

On this path, many challenges still remain to be addressed and many barriers still need to be broken down. However, we should remember that we still can act in those areas where we have the most influence, while other, more ambitious changes are being advocated. There is plenty to opt for before you pick up speed.

Teacher training within the framework of ESD is such a vital tool in the move towards sustainability in universities and in society in general that one of the indicators of SDG 4 should be an evaluation of the contribution of universities to the 2030 Agenda (Gomera et al. 2021) (see Chapter 5.4 in this volume). For teachers to be prepared to facilitate ESD, they have to develop not only key competencies in sustainability but also competencies in ESD – in other words, the skills teachers need to help others develop competencies in sustainability through innovative teaching and learning practices.

It is vital therefore that universities offer students a wide range of training which is fully up-to-date with current needs and the international context. In addition, they should not forget to offer incentives to teachers who prove their motivation and capacity for innovation in this area. Above all, they should ensure that the learning environments in the educational institutions are transformed, so that that their entire organizational culture and management are in tune with the principles of sustainable development they aim to transmit. Transforming the university to, in turn, contribute to transforming our world into a better world. Step by step we have to increase the speed of the race.

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5.6

PROMOTING FIRST NATIONS UNDERSTANDINGS OF SUSTAINABILITY IN BOTH TEACHER PROFESSIONAL DEVELOPMENT AND IN UNDERGRADUATE COURSE LEARNING

Aleryk Fricker, Grant Cooper, Shannon Kilmartin-Lynch and Rachel Sheffield

Key concepts for sustainability education

- Australian First Nations people have different sustainability-related understandings and connection to Country than Western understandings of land use and sustainability.
- Indigenous and local place-based knowledge systems promote sustainable ways to live and care for community and intrinsically place 'care of Country' as one of many core values that First Nations people live by.
- Higher education professional learning models are needed that promote both the valuing and teaching of First Nations' perspectives to undergraduate students as well as important First Nations' knowledge and thinking around caring for Country, of which, sustainability and sustainability responsibility is an outcome rather than a focus.
- Core sustainability values are embedded in story, lore, song, dance, ceremony, and law. They are part of First Nations' ontologies and not easily separated from concepts of language, culture, community, and Country. To attempt this is to simplify and distort the complexity of understandings and culture that both reflects and constructs First Nations' cultural understandings and practices.

First Nations' sustainability-related understandings and teaching the next generation

A common theme across all First Nations' cultures in Australia is a connection to Country (Moreton-Robinson, 2015; Rose, 1996).[1] At the heart of this connection is a focus on the relationality between the person, their community, culture, language, and Country (Pierotti

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& Wildcat, 2000; Rose, 2005; Ingold, 2006; Muir et al., 2010; Bawaka Country et al., 2013; Muller et al., 2019; Steffensen, 2020; Russell et al., 2020). Together, these also contribute more broadly to the person's 'Dreaming'.[2] For First Nations Peoples, the relationship with Country is complex. For many, the relationship with Country differs from non-Indigenous people in terms of what it is not. Country is not a commodity to be bought, sold, mined, extracted, and exploited (Chan et al., 2018). It is also not a mechanism to be used to stratify society. It is also not conceptualised in the relationship being one way; that is Country only being owned (Bawaka Country et al., 2013; Kealiikanakaoleohaililani & Giardina, 2016). For many, the relationship with Country is so much more. It is our food, medicine, our lore, and law. It is our stories, language, community, dances, songs, and ceremony. It is our culture, sacred places, ancestors, past, present, and future. It is also our responsibility; we are Country.

Before colonisation, our relationship with Country was a central part of our learning. Engagement with Country was both a specific and unique part of our traditional pedagogies, as well as profound and central knowledge that would shape many lessons relating to all parts of our cultural, community, and family learning (Jackson-Barrett & Lee-Hammond, 2018). For First Nations Peoples, there was, and still is, a strong understanding that individual and collective wellbeing was entirely dependent on how well Country was cared for. As such, First Nations' conceptualisations of caring for Country was a central focus and outcome of caring for Country. For many, caring for Country was indistinguishable from caring for self (Bawaka Country et al., 2013; Kealiikanakaoleohaililani & Giardina, 2016; Steffensen, 2020).

Caring for Country was also a way of showing respect for the spirits and ancestors that formed and cared for Country in the previous generations and who also created and shared the important stories, songs, dances, and ceremonies that continued to guide the people in the present to maintain the landscape. Caring for Country was also a way of showing respect for the spirit generations yet to be born (Muller et al., 2019; Steffensen 2020). By caring for Country, one can draw comparisons to Western-formed practices of sustainability. Through cultural artefacts like song and dance, a pedagogy of caring for Country is nourished in the next generation, which could be compared to the intergenerational teachings of sustainability education. Forms of First Nations' storytelling and how they may be included into sustainability education are timely to explore. Such exploration aligns with a broader research focus examining how educators can effectively design learning experiences that embrace First Nations' representations (Cooper et al., 2023).

In this chapter, we explore how an innovative professional learning model called *Yarning to Learn*[3] can promote First Nations' perspectives of sustainability in undergraduate courses. The structure of the chapter is as follows: First, we briefly unpack the *Yarning to Learn* model, providing further context for this research. We make the case for decolonising partnerships as a strategy for promoting effective sustainability education. Second, we discuss methodology, participants, and our research questions. As part of our learning journeys, we finally evaluate themes in our own reflections as we work towards modelling how Indigenous and non-Indigenous educators can collaborate to decolonise[4] our teaching about sustainability.

'Yarning to Learn': a model for improving the teaching and delivery of sustainability education in Australia

There is a wealth of research that has explored the efficacy of yarning[5] as a method and methodology when considering research in a variety of disciplines (Bessarab & Ng'andu, 2010; Poirier et al., 2022; Osmond & Phillips, 2019; Rider et al., 2021; Kennedy et al., 2022;

Hughes & Barlo, 2021). There has, however, been limited engagement with this technique as a pedagogical approach to support learning and teaching, particularly in university environments (Brigden et al., 2020; Mills et al., 2013; Fleming et al., 2020). Yarning is defined as an authentic and culturally safe way of communicating with First Nations people which is an 'informal and relaxed discussion' where the 'researcher and participant journey together visiting places and topics of interest relevant to the research study' (Bessarab & Ng'andu, 2010).

In terms of Yarning to Learn, we were inspired by research such as Mills et al. (2013) who used yarning as a pedagogical approach to facilitate understanding, reflection, comprehension, and inspiration. In the context of this research, we consider ways to decolonise STEM teaching within a higher education context. Yarning to Learn is a model where we have sought to consider how the act of yarning together can be used to support student learning and experience as part of a dynamic, cross-institutional model that is designed to mutually support university educators. Our model consists of the creation of a circle, either online or in person. In the Yarning to Learn circles that are in person, the object is usually a ball of yarn that is unwound as it is passed around and across the circle, and this is a visual representation of participants' communication and interactions; this could also be an important cultural object used to communicate like a message stick as well. In the online space, this is usually represented through the use of an online interactive whiteboard and the drawing tool which allows for a virtual presentation of the learning.

The model usually has three stages. The first is the pre-yarn expectations-setting phase. From experience, this is necessary more for the non-Indigenous participants, as this is often a new experience for them. The expectations usually focus on the yarn being a non-judgemental, authentic, and safe space to reflect and share thoughts and learnings. This is also a point where the instructor is explicit around the concept and experience of being mutually vulnerable in order to breakdown the hierarchical structures inherent in learning environments.

Once this phase is completed, beginning with the convener of the yarn, begins by providing the first provocation. This is often a 'low-stakes' and light-hearted prompt to build engagement and ease any concerns of the participants. An example is to request the participants to introduce themselves and then respond to the question, 'if you could be any animal other than human, what would you be and why?' The convenor answers first and then passes the yarn, while holding onto the end of the yarn and unwinding it to the person sitting in the circle next to them. From this point each participant responds to the provocation while unwinding and passing the yarn to the next person until the circle is complete with every person holding the thread from the ball of yarn.

This leads to the third phase of the Yarning to Learn model. At this phase, the instructor states that the yarn will now be thrown around the circle as participants wish to speak. The convener states that this is entirely voluntary, and no one will be forced to speak if they do not wish to. The convenor then provides the topic of the yarn, in this case, First Nations STEM, and the participants consider and respond as they wish.

This model provides ample opportunity for participant reflection – a sense of safety through mutual vulnerability that helps to disrupt the formal classroom hierarchy and the cultural limitations of sharing that are often placed on non-Indigenous people. We consider this process a slow pedagogy as defined by Collett et al., (2018), where we have broken from an 'instrumentalist approach to teaching and learning' that creates space for 'an authentic and deep level of engagement and support' to 'disperse time and bring in aspects of collaboration, attentiveness, responsibility, competence, responsiveness, and trust' (p. 121). We also acknowledge that this approach has provided additional support for the participants and how they are able to engage with First Nations content (Fleming et al., 2020). This approach can also support a dialogic structure that is required in sustainability problem solving where various views and opinions are necessary to help unpack the complexity of the problem and to better understand multiple perspectives.

'Yarning to Learn' development and participants

The current study draws on autoethnographic methodologies as a way of promoting deep reflection of our involvement in Yarning to Learn. Autoethnography is a form of self-narrative that places the researchers' experiences at its centre (Cohen et al., 2009), exploring relationships and connections with communities and cultures (Adams et al., 2015). Consequently, we delve into our own stories, thoughts, and feelings (Ellis et al., 2011). We embrace the former as we take a journey of not just pedagogical but concurrent self-discovery. Authors Al (Fricker) and Shannon (Kilmartin-Lynch) explore their own stories related to leading, delivering, and mentoring the Yarning to Learn program. And authors Grant (Cooper) and Rachel (Sheffield) self-reflect on their pedagogical and personal reconciliation journey. Our reflections are presented as tidy vignettes for the purposes of this chapter, but please note our pedagogical and personal reconciliation journeys do not conclude with the publication of this research. It is only the beginning of a life-long mission. The research questions that guided this study are as follows:

Research Question 1: What was it like to be a mentor and mentee in Yarning to Learn?

Research Question 2: How might Yarning to Learn have implications for how universities advance efforts to decolonise their syllabus, practices and priorities?

Before progressing further, it is important to make the cultural identity of the research team transparent to give the reader a better understanding of why the team can tell both Indigenous and Western stories:

- Al is a proud[6] and sovereign[7] Dja Dja Wurrung man whose ancestors come from the Central Goldfields region of Victoria and European colonists and is a lecturer in Indigenous education at Deakin University.
- Grant identifies as Anglo-Saxon and has expertise in equity-related challenges in education-including how to improve STEM participation of under-represented groups, including First Nations cohorts, at Curtin University.
- Shannon is a proud Taungurung man whose ancestors are from the Yowong-illam-baluk and Natarrak-baluk clans located within the Mansfield and Heathcote regions of Victoria and is an Associate Professor in the Department of Civil Engineering at Monash University.
- Rachel identifies with predominately an Anglo-Saxon ancestry and is relatively new to exploring Indigenous perspectives of science at Curtin University.

Al's reflection: yarning, discomfort, decolonisation, and solidarity

Yarning is a practice that is as old as the people of the Australian continent. It is a process that has been passed on for countless generations and has helped to support the cultural continuity which has contributed to the First Nations Peoples being the oldest continuing cultures in the world. For me, yarning is something that I have done my whole life and is something that I experience as an authentic and vulnerable way of communicating with another person or group of people to encourage trust and relationships. When we yarn in social contexts, we have an opportunity to share parts of ourselves that we feel are important. In a professional and pedagogical context, this is about being able to explore topics considered by some to be 'unsafe' in a space that is collaborative, collegial, and supportive.

In this context, as part of a more formal discussion relating to decolonising sustainability education, many of these same principles remain, but with the shared outcome being educational reform in addition to the establishment and maintenance of meaningful relationships with each other. My experiences of yarning with non-Indigenous people has provided me with some contrasting experiences and insights that were not immediately apparent from my experiences yarning with First Nations people. The first is an understanding of the context of the people I am yarning with. I have never been able to take for granted the contexts of the non-Indigenous people I am yarning with, and this has often required me to provide some explanations relating to the expectations, experiences, and outcomes of the yarning process with them. For some, this is such a different experience that they leave the yarn commenting about how different it was compared to the colonialist ways they communicate on a daily basis. For others, there is a realisation that there can be different ways of communicating that they could use to better connect with others.

At the beginning of the yarning session, I articulate what the processes, aims, and outcomes of the yarn would be and make a point that this would be a session where safety was prioritised, both in a cultural sense for Shannon and myself but also in a professional sense for the benefit of Grant and Rachel. Shannon and I had met prior to the yarn to set our expectations and were able to articulate that we were comfortable to invite Grant and Rachel to ask 'unsafe' questions but were also comfortable that if these became inappropriate or malicious[8] that we would end the yarn accordingly. We recognised that this was not a likely outcome, but it is one that I have experienced in many yarns with non-Indigenous people over the years I have been doing this process.

I knew that establishing the safety for all parties at the beginning of the yarn was important, because one of the first topics that we discussed was the First Nations' concept of Country and how sustainability related to it. From my perspective, this was a possible risk, as I was, with the support of Shannon, challenging the Euro-centric Western perception and understanding of this content on an ontological and epistemological level, and in doing so, providing a direct provocation that the Western concept of sustainability was not complete. As expected, Grant and Rachel responded with authentic curiosity and reflection, and both agreed that there was a need to expand their relatively limited understanding of sustainability from a Western perspective.

Once we had explored the ontological and epistemological contexts, reasons, and justifications for the adjustment of Grant's and Rachel's STEM subjects within their respective programs to include the First Nations' concept of caring for Country and sustainability, the yarn shifted to the question of how they would be able to apply these adjustments. This part of the yarn covered many different subtopics relating from sector-wide reforms to exploring the week-to-week topics and how First Nations' contexts could be included. It was a heartening experience to experience my non-Indigenous colleagues respond to this project with such enthusiasm, and it was also heartening to be able to contribute to this yarn and process with another 'deadly blackfulla'[9] on the collaborative team.

Once we had yarned about the potential places where First Nations' contexts could be integrated into Grant's and Rachel's respective subjects, the yarn moved onto a discussion about progress and timing. Shannon and I were both in agreement that any significant changes would have to be consulted with the local First Nations' community where their university was situated to ensure that the local protocols had been followed. As such, we advised that they should get in contact with the relevant people and begin the engagement process. One aspect that we did acknowledge was that this process would likely take some time and there would be expectations that the relationships formed as part of this approach would last beyond the scope of the adjustments of the subjects.

The yarn finished with a great amount of enthusiasm from Grant and Rachel, and for Shannon and I, we felt that it had been successful as we had been able to establish a safe space to yarn, had used the process to support the authentic engagement of us all, and had been able to articulate the ontological and epistemological foundation for the justification to adjust their subjects to include more First Nations' contexts. We all left the yarn knowing that this was always going to be a marathon rather than a sprint, but nonetheless, there was a great sense of positivity and optimism.

Grant's reflection: this stuff takes time

I need to adjust my pace. By this, I mean the speed at which I can usually establish collaborations, build working relationships, get insights from stakeholders, design learning content for students, action changes to units, etc. The rules are different in this space. I sent a lot of emails and got few responses. I reached out far and wide, with few acknowledgements. Thinking about the hyper-paced speed of my academic life and the neo-liberal university, one of the most significant challenges I experienced in Yarning to Learn was recognising the need for and importance of *pedagogically slowing down*. In most other aspects of the university environment, a brisk pace works for me – it gets the paper submitted, the project completed in time, it gets the job done. In this space, I think it might be a burden. A stark reminder that significant change like embedding First Nations' perspectives into my teaching was never going to happen in one semester. A realisation that I am on a much bigger personal and professional journey of self-discovery.

Grant's reflection: embedding First Nations themes also involves rethinking pedagogy

Another key insight from yarning was the importance of adapting pedagogy when exploring non-Western perspectives of sustainability. First Nations people represent understanding of the environment through various modalities such as oral history, songs, pictures, and dance. These forms of storytelling have been used for thousands of years by First Nations people to represent understanding and relationality between people and the environment. The challenge for non-Indigenous educators is drawing on these rich forms of representation in an authentic way that goes beyond the trivial or tokenistic. In my delivery of the unit, I was inspired to embed the '8 Ways of Learning' framework (8-ways herein). 8-ways emphasises narrative-driven learning, land-based learning, and connectedness to community. The pedagogical model aligned with exploration of Country, a strong synergy between the content of examining non-Western perspectives of sustainability. It made sense to me to emphasise the use of narrative and oral history using 8-ways when teaching about non-Western perspectives of sustainability. From the trust I had built up with staff who worked with Indigenous students in my faculty, they suggested several strategies. One strategy suggested was to reach out to various people from various universities in the state. Most never responded, and I shared my disappointment when yarning. Al and Shannon said don't be offended, email reach-outs might not be the best technique for connecting with the 'Indigenous Mob'.[10] Another strategy suggested was to embed and expand on stories shared on YouTube, for instance: *Noongar Stories from Forrestdale Lake* (Perth Region NRM, 2014). Genuine, carefully planned experiences need a strong synergy between pedagogy and content. While the use of story is something I am comfortable with, I am reluctant to try more ambitious pedagogy like dance or song. I'm not there yet, and to be honest, I'm probably never going to be comfortable dancing in a tutorial. However, I've learnt that there are ways of embedding First Nations' perspectives into my teaching that align with my educator identity. For example, the use of narrative, drawing on media clips, and inviting First Nations people to share their stories are strategies I feel comfortable to draw on.

Grant's reflection: advocates for change without speaking for First Nations people: a complex professional tension

From some conversations I had outside the yarning circles about my ongoing reconciliation journey, I was quietly cautioned several times about discussing First Nations' perspectives of sustainability as a non-Indigenous person. This caution didn't always appear in words, but typically in micro-communications via prosody and body language. I experienced similar reactions from people who, despite the best of intentions, cautioned me when they enquired about my intentions. "Oh Grant, just be careful in this space"; they took the chance to remind me of my non-Indigenous ancestry. Thanks for the reminder, I quietly thought. I usually responded with the argument that most university educators are non-Indigenous: *we need to advocate for First Nations Peoples but not speak for them*. It is a complex professional tension. In our teaching and research, if we don't advocate for First Nations people, we rob our students of something special. We should learn from First Nations' perspectives of taking care of Earth, by understanding different perspectives, we can understand the notion of sustainability in a deeper, and richer way. From these conversations, I did think about what students might be thinking in my class, "who is this white guy trying to teach me about Aboriginal knowledge?" Especially if they themselves identified as First Nations. Here we go again, a white person telling people about First Nations issues. It's tricky stuff. How do we include First Nations students in this learning experience without first knowing who are First Nations people in the class? I don't feel comfortable asking students if they identify as First Nations or accessing universities records that might hold this information.

I know teaching First Nations and Western sustainability concepts alongside each other allows students to see how the two knowledges are both of value and important to society. Al and Shannon emphasised during yarns that decolonising education must be a shared aspiration, "we are not going to achieve this without non-Indigenous people making changes". Throughout my participation in Yarning to Learn, my confidence moved like a pendulum, on one side feeling empowered to effect change and on the other, moments of despair and hopelessness. This pendulum is still in motion. It is fair to say that there is less force in the pendulum, after my many discussions with Al and Shannon. "Don't be afraid", they both said at different times when yarning. It's a constant tension in my teaching, and there is a sense of fragility here. I wouldn't have been able to adapt my pedagogy without having the confidence Al and Shannon gave me. I continue to be on this pedagogical journey; depending on the day, I feel more confident than others. Some days, I can move beyond fear. On other days, I tread more carefully.

Shannon's reflection: why are we learning this?

Some of the most interesting conversations come from spontaneous decisions; being a proud Taungurung man from northeast Victoria, my mindset regarding sustainability aligns nearly identical to Al's, in such ways that sustainability from an Indigenous context should be looked at as an outcome of specific actions of caring for Country opposed to as an aim in and of itself. Initially when meeting with Grant and Rachel for a yarn, the complexities of navigating Indigenous topics and ideologies became very noticeable. However, when people demonstrate a willingness and a positive mindset to learn, I believe it is essential to reassure non-Indigenous people that we operate in a safe place. There is a vast difference between slipping up with good intentions, having the willingness to learn from mistakes, and being wilfully ignorant. We operate in colonised worlds and are seen to be fragile in the mind of the coloniser or maybe that's how they want us to think, too ashamed to admit that they themselves are too timid; people are too hesitant to comment or even ask questions in a willingness to learn as they don't want to offend, thinking that every Indigenous person is going to criticise them on the slightest slip-up.

Another critical insight into our yarns was the dedication brought forward by our non-Indigenous colleagues to be able to take a step back from a Eurocentric way of thinking and operating in a predominately white academic space and gain a deeper understanding of the complex cultural contexts that relate to Indigenous culture. To be able to incorporate these contexts into courses developed primarily for non-Indigenous people, I explained to Grant and Rachel that firstly there was a need to understand what Country is and what Country means to an Indigenous person; it is not simply a place, but an identity. It embodies lore, culture, place, language, and spirituality among much else. It is also critical to understand that the Eurocentric university system or the educational system doesn't cater to Indigenous people. As such, there is a recognition of a deficiency in these education systems, and there are efforts being made to incorporate First Nations' knowledges and cultural beliefs into these education systems, especially given that they were not initially designed for us to learn in.

There have been many times on my own educational journey, whether it be as a lecturer or as a student, where there are common remarks in seminars questioning the relevance of First Nations' knowledges. My students and peers will often ask: "why are we learning this?", "how does this affect us?", and claim that "this isn't science". This was a point of similarity and between us as a research team, and it is clear that this isn't something that only I have dealt with.

When I consider an approach to embedding First Nations' contexts into course work, especially from a STEM perspective, there first has to be a discussion around rethinking curriculum and the theoretical positioning of STEM; both student and teacher have to be willing to unlearn the standard Eurocentric outputs on sustainability and STEM as concepts. What is commonly taught in schools and embedded into the classroom, and, in turn, the minds of students is a very Eurocentric version of STEM, where science is all about physics and chemistry, engineering is all about technology and new ways forward, and astronomy is related to a branch of space science. When we explore sustainability from an Indigenous perspective, we need to understand that it is as much about the science as it is with humanity at the centre of it all, and we can see the relationship between caring for Country and caring for self. There is a holistic relationship present between Country and mob, and this was recognised as something that needed to be further explored. Within our discussions, the Eurocentric ideology of sustainability became very relevant; everything is about results and sustainability performance. Whether it is looked at from an environmental point of view or an economic point of view, results are the key factors and sustainability is the aim. To highlight sustainability approaches from an Indigenous perspective I found it important to draw from a story, not from my mob particularly, but a story by Boon Wurrung Elder Na'rweet Aunty Carolyn Briggs: The Filling of the Bay – The Time of Chaos (Couzens, 2014). For me, this story highlights the importance of caring for Country; it demonstrates how neglecting Country not only affects the environment and the ecology of Country but also affects the people on Country, and when Country is cared for with an eco-centric view it results in a sustainable balance of Country. This was a turning point within our discussion as we navigated the fine balance of sustainability between the importance of centring sustainability as an outcome of caring for Country as well as the Western concept of an overall outcome of land management.

I first raised awareness of these issues within our yarn by stating when we talk of astronomy; someone taught a white version of STEM would initially think toward Galileo Galilei, commonly referred to as the 'father' of observational astronomy; however, First Nations people were reading and mapping the stars long before this so-called 'father' of astronomy. Coming from a First Nations perspective, and I share these thoughts strongly supported by Al, the first things that come to my mind when astronomy is mentioned are storytelling and knowledge; the learner doesn't necessarily need to be looking at the stars through a lens to gain an understanding of how Country is speaking and how that knowledge is being translated. The stars were being used as a navigational tool long before the Eurocentric application of astronomy; there is continuing knowledge held within the stars that have travelled through generations of First Nations Peoples relating to law and lore, stories detailing how to live our lives appropriately giving us life lessons around our relationships, and our relationality to each other and to Country. There is a deep interconnectedness between First Nations Peoples, Country, and stars, but this information is bypassed within the colonialist education system. By bridging these barriers and introducing First Nations themes into coursework, we are not only acknowledging First Nations people, but we are also acknowledging First Nations culture beyond the contemporary colonial oppression. And by framing this coursework with the Country as a core focus throughout the ideation, we can continue to further the importance of First Nations' knowledge systems, ways of thinking, and cultural practices together on one journey.

Rachel's reflection: sustainability mindset and First Nations' knowledges

Teaching about environmental education or environmental sustainability has been challenging, especially when trying to determine how people feel about the environment and how it is valued. In the research there have been models, one recently looked at behaviour, attitudes, and knowledge towards the environment. The issue with knowledge is that it is specific, and sometimes students do not have the knowledge to support their assessment. Broadening the framework to capture Indigenous perspectives has led to the consideration

Sustainability mindset framework		
Content areas	*Principles addressed*	*Desired outcomes*
Ecological worldview	Eco-literacy Contribution	Protective and restorative actions
Systems thinking	Long-term thinking Flow in cycles Interconnectedness	Stakeholder engagement Sense of interconnectedness with others
Emotional intelligence	Creative innovation Reflection Self-awareness	Compassion Sensitivity to others
Spiritual intelligence	Purpose Oneness with nature Mindfulness	Contemplative practices

of a mindset and what a sustainability mindset should include. The sustainability mindset framework (Kassel & Rimanoczy, 2018) includes:

- Ecological worldview
- Systems thinking
- Emotional intelligence
- Spiritual intelligence

The sustainability mindset framework encompasses spiritual intelligence, and this connects to the deep spiritual connection to Country that First Nations Peoples possess. I found that I have come to this position traversing the landscape from two opposing directions. What this demonstrates is that to measure and make changes to people's thinking around environmental sustainability requires a deep spiritual connection to Country.

Finding a space to embed the thinking

Embedding First Nations' knowledges into the first-year unit around inquiry has been much more complex than I anticipated. I was able to embed the 8-ways more easily into the first unit inquiry in the 'On Country' program working with First Nations students. Many of the First Nations students didn't need me to explain the 8-ways; they were comfortable in this space. They found inquiry topics easily as their connection with Country was so strong, they were interested in the lives of the animals and the issues around the lakes and rivers. The topics were diverse and included dugongs and how they were hunted and sustained on the Dampier Peninsula; the history of the sawfish and how these animals created the Fitzroy and other rivers in the north of Western Australia (WA); and finally, an examination of Lake Ewlyamartup, 17 kilometres east of Katanning, exploring its cultural importance and the environmental significance.

Embedding indigenous knowledge into the course

I thought I would be able to include data collection from a First Nations perspective, that is encourage students to reflect on collecting data that was not traditionally gathered. However, I found adding this into the weekly topic on big data and data in Topic 4 was trickier, and I wasn't able to embed it. I felt, rightly or wrongly, that the current undergraduates were more comfortable with less traditional forms of knowledge, but some of the knowledge they used was less reliable and included the challenges of large data estimates and averages. I felt that this would be a challenge for first years as they were struggling to drill down to a concrete level and work with data and evidence rather than focusing on broad generalised statements. I did wonder that the idea of stories and the data in First Nations stories would be more nuanced than I feel that first years can handle at this stage. This may be incorrect, but students already struggled with this unit and therefore providing them with additional structure seemed to be helpful.

In this unit I have been working with two First Nations students that have been identified by the Indigenous coordinator, and I have been encouraging them to embed their traditional stories into the rationale into the why have they chosen their topic. This, I hope, encourages them to feel that this brings relevance, and their story is accepted and valued, and the information held by Indigenous rangers and Aunties would be included.

Mindfully not my story to tell

I feel that choosing a story is challenging, and I do feel more comfortable asking First Nations colleagues to share their knowledge on what story to pick and then confer their deep knowledge to provide me with the expertise to step up with confidence. Creating a space to share and encourage students to sit in class in a circle to share a story of sustainability practices is an aim to show that the 'sustainability' is not new and has been around for thousands of years. It may also be an opportunity to discuss where the knowledge can come from and how it can be presented.

Learnings from the 'Yarning to Learn' and ways forward

From the previous reflections, it is clear that the yarn was experienced quite differently between all the participants. For Al and Shannon, the yarn had two broad focuses: the first was to ensure safety for all participants, and the second was to explore the ontological and epistemological contexts of First Nations conceptions of sustainability, and by extension, those for STEM. Al and Shannon wanted to ensure that they could provide a foundation for their non-Indigenous colleagues to consider the underpinning philosophical concepts that we were sharing in order to empower them to craft resources and learning experiences, as well as to engage with the relevant literature that would support both their and their students' authentic engagement with Indigenous concepts of self and Country being inextricably entwined and core to concepts of sustainability.

Al and Shannon felt that by articulating and exploring the ontological and epistemological positions of First Nations sustainability as a direct outcome of caring for Country, rather than as a stated managed aim like in a Western STEM context, they would be able to support Grant and Rachel to also avoid tokenistic incorporation of this as a concept with their students. As such, the yarn also included conversations about working in partnership with local First Nations people, as well as specific pedagogical approaches that they could implement in their subjects to support the outcomes and engagement of all their students.

Finally, this was also an opportunity to explore how this model would not require a complete 're-invention' of their subjects and the content within it and that the incorporation of First Nations' contexts would initially only require some small adjustments to the weekly topics. In addition, we were also able to explicitly comment that this would be an ongoing project, and one that would likely take several years, and several iterations of their subjects to build effective ongoing threads in the content.

For Al and Shannon, it was heartening to see the enthusiasm of Grant and Rachel, our non-Indigenous colleagues, and their willingness to gain confidence from the 'Yarning to Learn' process, that they were able to immediately implement into their practice and planning for their subjects.

For Grant and Rachel, this process provided insight into the different ways of conceptualising sustainability education as well as providing confidence and advice to be able to build First Nations perspectives into their subjects. By exploring the different epistemological and ontological contexts of First Nations sustainability, they were able to consider how to weave these into the subjects alongside the Western concepts of sustainability without the risk of positioning one type of knowledge above another.

By doing this as well, it allowed Grant and Rachel to observe and consider how the colonial concepts of STEM and sustainability education have dominated this space and how it continues to seek to legitimise western concepts, and in turn the Australian colonial education system by either ignoring or placing at a deficit First Nations' knowledges, ontologies, and epistemologies.

Conclusion

The 'Yarning to Learn' model highlights the important difference between Western concepts of sustainability as an outcome-focused activity and First Nations' concepts of sustainability as an outcome of the process of caring for Country. Beyond providing an opportunity to consider the different ways of conceptualising sustainability, Yarning to Learn also provided a valuable opportunity for non-Indigenous teachers of sustainability to engage with First Nations' knowledges and gain comfort and confidence when considering how they could begin to revise their STEM subjects to include more First Nations contexts.

Educators must do more to promote First Nations students' sense of belonging (Cooper & Berry, 2020; Cooper et al., 2018), in part by explicitly critiquing forms of knowledge and the hegemonic positioning of Western perspectives in sustainability education, and other STEM fields more broadly. We acknowledge that some educators in higher education may be resistant to embedding First Nations' knowledge into their sustainability courses, and therefore institutional supports must be in place to support educators to embed such perspectives.

Secondly, whilst the changes to pedagogy and curriculum we are advocating for in this chapter are not easy: they take time, effort, capacity to think critically about pedagogy, and a university environment where educators are supported to meaningfully embed First Nations' knowledge. Another significant challenge is an over-casualised teaching workforce in contemporary universities, who are less likely to have access to this kind of professional learning model, even if it was offered. Despite these challenges, we argue that First Nations' perspectives and experiences in their sustainability courses are too valuable to leave out.

'Yarning to Learn' empowered Indigenous university educators, decolonised Western framing of sustainability teaching, promoted undergraduates' understandings of First Nations' worldviews, and valued-added meaningfully to their university experience. This First Nations professional development learning model provides a more holistic definition of sustainability, whereby 'caring for Country' becomes the focus of sustainability management.

This knowledge and way of thinking we believe should be central to all sustainability education across the globe.

Notes

1 Throughout this chapter we use the terms Indigenous and First Nations interchangeably. We acknowledge that these terms include both Aboriginal and Torres Strait Islander people, but they are not without problematic connotations. We use these terms with respect.

2 The origins of this term stem from a problematic translation of a concept that has many different names in First Nations languages across the continent of Australia and the adjacent islands. In short, the concept of 'dreaming' relates to the ontological, epistemological, axiological, and methodological concepts that inform belonging, identity, and relationality with self, community, language, culture, Country, time, ancestors, creation, spirituality, and the cosmos, among many other aspects. Dreaming informs all aspects of First Nations life including law, lore, story, song, dance, art, science, teaching and learning, and all the aspects of ourselves and our environments that constitute existence. At the centre of Dreaming is the love, respect, and honouring of all things and an understanding that we are only ever temporary caretakers as we navigate from the non-living to the living worlds and back. Our Dreamings are our inspirations and our legacies.

3 Yarning is a concept that describes a type of informal, yet authentic communication that is widely practiced by First Nations people in Australia. It is a uniquely First Nations Australian way of communicating that fulfills many community requirements including, collaboration, therapy, research, and social interactions. It is based on listening, reflection, consideration, and vulnerability that facilitates the creation or maintenance of relationships and trust between community members. For over two centuries in Australia, the inability of non-Indigenous people to communicate with First Nations people in authentic and culturally appropriate ways has been a source of much frustration and misunderstandings. For more information about this concept please see: (Bessarab & Ng'andu, 2010).

4 This is based on the premise that the Higher Education system in Australia is a colonial construct that has specific agendas that negatively impact the outcomes of both First Nations students and their success, and the continued lack of awareness of First Nations contexts by non-Indigenous students. This creates a context where Higher Education itself becomes a barrier to First Nations students choosing to access or stay in that system. Decolonising education seeks to remove these barriers and position First Nations contexts as having equal ontological and epistemological value as western contexts.

5 This is a common structure often used when yarning with non-Indigenous people. The circle supports the creation of relationships, where everyone has the potential to communicate with every other participant without obstructions, as well as being a structure that will flatten and disrupt common hierarchical power structures present in classrooms across the entire education system in Australia.

6 The term proud in relation First Nations heritage fulfils an important response to historical and contemporary contexts of race and racism in Australia. For over two centuries, being associated with, or as, a First Nations person was positioned as something to be ashamed of. As such, for many First Nations people in Australia today, it is important to directly challenge the historical legacy of shame and the associated trauma this contributed to the community by openly and proudly identifying as First Nations.

7 The term sovereign relates to the unfinished business in Australia relating to the dispossession of land and genocide committed against First Nations Peoples across the continent and adjacent islands. Australia still does not have a treaty with the First Nations people, and by asserting sovereignty, First Nations academics are able to maintain awareness of this ongoing struggle and ensure that this issue remains in the public consciousness in the hope it will lead to a resolution.

8 These would consist of malicious questions or comments made with the intent to harm other members of the yarning circle. All questions were welcome from a place of unknowing rather than from a place of bigotry.

9 This is an Aboriginal English phrase that denotes a male First Nations person who has been deemed excellent in a particular context.

10 Mob is an Aboriginal English word that can be used as a collective noun for First Nations people. It can also be used in more specific way when seeking to find out a First Nations person's cultural affiliations, i.e. Who's your Mob?

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SECTION 6

Pedagogy and strategies for teaching sustainability education

"To halt the decline of an ecosystem, it is necessary to think like an ecosystem."

(Douglas P. Wheeler, EPA Journal, Sept–Oct 1990)

This section examines the important role of teaching pedagogy in providing structure and support in sustainability education development. Several successful strategies and teaching pedagogies in sustainability education and education for sustainable development (ESD) are reviewed, as are a variety of different teaching pedagogies in the delivery of sustainability education and the role of pedagogy in achieving transformative sustainability education.

Frolich (see Chapter 6.1 in this volume) contends that developing potential teaching strategies and core competencies within curricula will require significant effort and investment by education institutions. Mapping the SDGs may be a useful approach in the development of ESD programs together with the sharing of 'responsible management education' and corporate social responsibility learnings from business education models.

Birdsall (see Chapter 6.2 in this volume) notes that Mezirow's transformative learning model (2003) suggests that teachers need to recognise that the ways learners interpret and reinterpret their experiences are central to their learning. This model of transformation has three perspectives (psychological, convictional, and behavioural) that all influence the effectiveness of the learning made. Being cognisant of these differing perspectives helps the educator assist the student in moving from critical reflections into perspective transformation and action. Transformative learning theory suggests ways in which an environmental ethic can be developed that enables a perspective change in students and influences their future actions.

Prototyping in sustainability education is an action-centred learning pedagogy which can be used to transform student thinking and engender a sense of responsibility and action towards sustainability thinking and management through in-class, hands-on design and development of sustainable products and services. Runacres (see Chapter 6.3 in this volume) suggests that 'Fab Labs' provide an extended opportunity for students and the

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community to work together and become active contributors to sustainable product design and development.

Similarly, Masseck (see Chapter 6.4 in this volume) explores the role of Living Laboratory experiments and workshops and how they can be developed to both influence and encourage sustainable lifestyles and habits. They also involve real-life test and experimentation and ideation between students and societal stakeholders, with the aim of promoting sustainable lifestyles. Such experiential, collaborative, and transdisciplinary project-based learning environments can be helpful in transformative teaching and learning.

Collaboration is a key skill in working through the many dimensions of sustainability management. Teaching a collaborative approach to problem solving provides students with the skills necessary to approach problem solving as well as to engage in more effective methodologies for successful collaboration. Ferrer and Tejedor (see Chapter 6.5 in this volume) note that collaboration is an important sustainability competency because the ability to understand and facilitate engagement across values and cultures is a necessity in modern sustainability management.

Transdisciplinary learning communities (TLCs) explore the role of many disciplines influencing sustainability outcomes through the lens of different disciplines, cultures, and norms. Dentchev and Alba (see Chapter 6.6 in this volume) suggest that TLC can be a highly effective pedagogical tool in sustainability education. TLCs provide a collaborative approach to resolving sustainability problems whilst engaging students with a variety of discipline perspectives and different practitioners which help to better contextualize the sustainability issue.

Community service learning is another approach that can be used in presenting students with the challenges of trading off one sustainability outcome for another. Aramburuzabala (see Chapter 6.7 in this volume) examines how this can be done through engagement with community programs which can encourage students to provide their own ideas/desires/values and perspectives on sustainability management. This approach gives students first-hand experience in both understanding the vital role of sustainability management and the challenges faced in trying to achieve all the sustainability outcomes desired, given finite resources and technology and time limitations.

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6.1
MAPPING THE SDGs IN UNIVERSITY EDUCATION
A responsible management education approach

Lisa Fröhlich

Key concepts for sustainability education:

- The role of business schools is becoming increasingly important in developing a modern-age curricula to enable future managers to find solutions for social and ecological challenges.
- The "SDG Teaching Map" serves as a pedagogical roadmap for SDG education and guides educators to develop innovative teaching formats to achieve the SDGs in the classroom.
- Systems thinking with a focus on the future and values to build collaborations for sustainable transformation are core competencies for sustainable management in business education.
- Responsible management curricula in business education currently support the implementation of SDGs 1, 2, 7, 8, 9, 10, 12 and 13, leaving gaps in sustainable management education that only collaborative teaching approaches can fill.
- An innovative teaching format like the 21-day challenge helps to integrate SDGs in business school curricula.
- Business schools need to develop a curricula around "The new normal in business" and include much more focus on responsible management education.
- Business schools are responsible for educating these sustainable leaders who will establish effectively led business models.

Introduction

The recent Intergovernmental Panel for Climate Change (IPCC) climate report (2023) has once again shown us the fatal consequences for our planet if we do not change our behaviour. Together with the continuing negative effects of the COVID-19 pandemic, the call for responsible management education (RME) is becoming louder and louder. This chapter does not focus on a specific, innovative teaching format for sustainability; instead, it lays the ground for improving and adapting teaching content in order to integrate the Sustainable Development Goals (SDGs) into a university's curriculum. Giselle Wybrecht (2022)

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states in one of her latest articles that only one in ten schools analyse their curricula according to the implementation of SDG keywords to show how committed the business school is to environmental and social transformation. This highlights the importance of providing business schools with tools to better integrate SDGs into teaching and research. As a result, the "SDG Teaching Map" introduced herein supports the development of a strategy for teaching sustainability. This paper can be used to align a university's teaching formats with content that enables aspiring managers to successfully integrate the SDGs in a business context.

This chapter deals with this crucial question of how to succeed in reorienting teaching in business schools. Different approaches are considered and provide the reader with a good overview of the options available, as well as initial hints as to which direction teaching at one's own university might head. It is undeniable that we have to educate responsible leaders for a more sustainable future, but at this point we need to address the crucial question of HOW to educate them.

Why is sustainability so important in management education?

To explain the necessary changes in sustainable management education, the author chooses a somewhat different path. Two quotes from Wayne Visser illustrate the challenges facing responsible management education. The pessimistic news about the social and environmental shape of our world leads to a very negative interpretation of the risks with which managers have to cope:

> We live in a world where "risk" has become a dirty word – something to be avoided at all costs. We encounter warnings against risk at every turn: at work, at home, on the roads, on products, in the media. But sometimes taking risks is the way to get the most out of life. As Ben Fogle tells us in his book "Up: My Journey to the Top of Everest," without risk we cannot grow, we cannot improve, we cannot experience. In fact, we are in danger of never really living.
>
> *(Visser 2020)*

What Visser is saying is that only challenge inspires our creativity. Fear is not a good advisor for innovative solutions at this point. He also makes it very clear in his poem "Be an optimist" (Visser 2021) how important optimism is in the context of this process of rethinking and reshaping our future:

> I am optimistic, not because the future is bright but because bright people are working to make the future better; not because the news is good but because good people are showing that change is always possible; and not because the world is fair but because fair people are fighting for justice wherever it is needed.

The four scenarios – a planned new world, the race for sustainability, a minimum viable masterplan and everyone for themselves – developed by Roland Berger (2020) for 2050 give us something to think about. Do we really want to go back to greenwashing (or rainbow-washing in the context of the SDGs) and optimising profit on a short-term basis? Should regulators really take control and be the driving force in pushing for strong laws and policies? Or do we prefer the "Race for Sustainability" scenario, where society is supposed to be the driving force. This leads to a "Circular Economy Plus" approach where transparent supply chains are the norm, climate change is under control and human rights are respected. Sustainability, liberal regulations and transparency promote progress and innovation and enable companies to "give back to society" (Roland Berger 2020).

Especially in these times of change and reorientation, it is clear that higher standards for corporate social responsibility (CSR) are becoming necessary. As described in the previous scenario, society no longer tolerates irresponsible behaviour, and the concerned companies and organisations' licence to operate seems to be under threat. Therefore, learning has been highlighted as one of the crucial tools for implementing sustainable development in general, as specified earlier, and the SDGs in particular (Filho 2021):

> More specifically, learning about sustainable development may mobilise society by targeting specific learning content and outcomes, and by linking them. It allows people to learn about the need for sustainability and to make informed decisions about how their actions influence the environment, the economy and society, reminding [them] about the need to respect and take into account others. This, in turn, assists in fostering a more favourable world for the present and future generations.
>
> *(Filho 2021, 1)*

In the case of a business school, our future students will take on multiple stakeholder roles as customers, responsible managers and investors – with a great deal of power to address the changes required to define this "new normal" in business life.

Rethinking business: eco-effectiveness instead of efficiency

Adam Smith (2002) offers a good starting point from which to explain the need for a new business model. The so-called "invisible hand" provides the best possible allocation of resources and thus the highest achievable level of prosperity in a society. However, it is often overlooked that the concept is built on the theory of moral sentiments, which entails that the mechanism of the "invisible hand" only functions in an economic environment characterised by "sympathy" and "empathy." Since this "moral context" does not exist in our society, governments are expected to interact in order to prevent the market from malfunctioning. And with this theory in mind, we are back to the previously discussed scenarios relating to a sustainable future, where higher education institutions have to take over responsibility to shape a clear vision for a future world in which we would all like to live.

Business activities still focus on efficiency, which (EPEA 2021), in the context of sustainability, refers to minimising negative impacts, e.g. reducing the carbon footprint, water pollution and the violation of human rights. The problem with this understanding is that we try to reduce the use of finite resources, for example, in order to minimise negative impacts and therefore stick to the "good old days" of doing business. This economic behaviour hampers innovation and will never lead to creative new ways to replace harmful materials or reduce any kind of toxic environmental pollution. Companies are simply trying to optimise their traditional business model without questioning the strategies they are currently using to promote change. Optimising stakeholder value is still the name of the game when a proper CSR strategy is in place. Thus, in our current situation, efficiency appears to be the only way out in terms of the direction of climate neutrality or resource conservation. But there is effectiveness (EPEA 2021) in the context of sustainability, on the other hand, which seeks to highlight the positive impact of business on the environment and society. In this sense, business is an integral part of our society and the environment, similar to the holistic worldview of Fullerton (2015). In line with this vision, business development is defined as the result of efficient solutions, and businesses evolve into value-creating enterprises through problem-solving. Innovation will enable companies to create qualitative improvements that benefit our society and the environment. Finally, managers and company leaders no longer have to ask themselves whether they are "doing things right" (efficiency); instead, they can question whether they are "doing the right things" (effectiveness).

The SDG Teaching Map: a bridge to interdisciplinary co-operation within responsible management education

Sustainable management is at the service of all relevant stakeholders, whereby information on environmental, social and economic issues must be taken into account equally in any corporate sustainability strategy (EPEA 2021). The creation of a common value base along the entire global value chain has to be the focus of sustainable leadership (Shriberg and MacDonald 2013). This calls for a new understanding of leadership that acquires the necessary knowledge and capabilities to achieve this vision and work towards a more comprehensive economic worldview (Zahid et al. 2021).

The increasing importance of so-called "non-conventional learning" (UNESCO 2017) is used as a guideline for discussing the next steps within this chapter. First of all, a foundation for this discourse must be laid to enable the meaningful exchange of information. This "basis" will be realised by establishing the SDG Teaching Map to demonstrate where the current shortcomings in responsible management education lie. To move away from decentralised learning, a focus on the teacher (Barth and Michelsen 2013), student-centred learning (focus on the learner) and new educational formats is needed (Fröhlich et al. 2021). This is because new insights and a broad canon of different competences are needed to bring about the previously discussed changes in entrepreneurial acting and thinking (Filho 2021). Based on SDG 8, the aim herein is to show which "gaps" have been identified in an example business school's chosen from the German higher education market curriculum and which additional teaching formats have been suggested by experts to close these gaps. Based on an analysis of lighthouse examples from other universities in the context of innovative teaching formats combined with a concrete innovative teaching format, the so-called "21-day challenge" has been devised (output of an Erasmus+ project (ISSUE 2021)). In this regard, a specific example is given of how the previously identified gaps in the curriculum can be closed in order to consider the requirements of a non-conventional learning concept.

The SDG Teaching Map: a brief description

The SDG Teaching Map is based on the empirical results of a master's thesis. Further elaborations are based on a publication by Fröhlich and Kul (2020), who developed the results of the aforementioned thesis. With reference to the explanations just given on the non-conventional learning approach, the first step is to outline the process of creating the SDG Teaching Map to better understand the process. It is particularly important to the author to show that this instrument can also be applied by other business schools to promote the advancement of responsible management education. The research process is in no way complete, as the important question as to how to best fill the identified SDG gaps currently remains unanswered. This Handbook is dedicated to that very task of helping universities understand how this required change in teaching orientation can take place.

First, though, why is it so important for the author to propose a tool which enables business schools to better integrate the SDGs into their curricula? The "SDG Index," published in 2019, reveals that not even the most advanced countries at the top of the index, such as the Nordic EU countries Finland, Norway or Sweden, have succeeded in setting a transformative path that will lead to the actual achievement of all 17 SDGs (Sachs et al. 2019). However, it is even worse. Hickel (2021) states in his article that the SDG Index is not a reliable measure to describe the development of a county in terms of achieving the SDGs. Taking the example of Finland, which ranks third in the aforementioned SDG Index, a country which produces 13 metric tons of carbon dioxide per person per year, thus belongs to the most polluting countries in the world. To provide some comparable numbers, China's carbon footprint equates to 7 metric tons per person, while India's is less than 2 metric tons. Hickel (2021) goes a step further in his analysis: "if the whole world were to consume as much fossil fuels as Finland does, the planet would be literally uninhabitable."

There are still many barriers to consider, which makes it relatively difficult to come up with reliable measures and tools to evaluate a single country's impact on the SDGs. For instance, not all SDGs are well explained or offer room for individual interpretations of achievement, whilst conflicts between goals may exist. These trade-offs need to be identified; otherwise, the implementation of all 17 SDGs will be difficult. These barriers require collective actions, but they are difficult to coordinate – on the company as well the country level. Besides joint efforts, accountability is needed, because without a clear commitment to all 17 SDGs, their successful implementation in 2030 is virtually impossible (Filho et al. 2020). If successful implementation is indeed to happen, significant financial resources are needed as well as technology and data. The two barriers of major relevance herein are capacity-building and culture: This requires parties involved in the development programs to acquire all the skills, tools and education needed to carry out tasks to achieve goals. This is often not possible due to various reasons including location, finance and trained personnel (Filho et al. 2020).

Moreover, some cultures make it difficult to engage people in being open and following new paths for a more sustainable future. In this regard, therefore, it is clear that business schools could play a major role in circumventing these barriers, and the SDG Teaching Map might be a first, beneficial step in the right direction – shaping a sustainable future for all of us. Because with the shift to knowledge-based economies, higher education has become a powerhouse for environmental and social transformation (Godonoga and Schachermayer-Sporn 2022). Since many shortcomings still stand in the way of achieving the SDGs by 2030, the author would like to come back to the previously cited poem by Visser (2021): "Be an Optimist." We should not waste our remaining time lamenting these sometimes seemingly unsolvable challenges, but rather focus our actions on what happens when we lose sight of achieving the SDGs. As this chapter is based on the SDG 8 example, the article by Filho et al. (2020) offers a very insightful overview to illustrate what might happen when we stop working towards the achievement of the SDGs. At the heart of SDG 8 is current concern about a lack of employment opportunities, especially for the younger generation (Picatoste and Rodriguez-Crespo 2020), and the spread of informal employment if governments and businesses alike do not continue to commit to this goal. Moreover, this particular SDG could actually be responsible for the greatest disparities between world regions: unemployment and insufficient engagement in higher education and training could have an impact on other SDGs, exacerbating inequalities and poverty, for example.

The process involved in establishing the SDG Teaching Map is based on the previously discussed challenges of responsible management education as well as relevant pedagogical theories for teaching. There is a quite an intensive discussion going on concerning the required competences for sustainable development. The development of the SDG Teaching Map is based on the eight "key competencies" found in a UNESCO (2017) publication: system thinking, anticipatory, strategic, collaboration, self-awareness, critical thinking, normative thinking and, finally, integrated problem-solving competences – which will not be elaborated any further herein (for further insights, see Fröhlich and Kul 2020).

In a first step, the curricula of all English-language programs at the example business school were analysed. This procedure seemed to be purposeful because the chosen business school established more than ten years ago a so-called "integrated sustainability curriculum." Furthermore, this business school was among the first business schools in Germany holding a chair for "ethics and sustainable management. "Integrated sustainability curriculum" means that sustainability content is addressed in every lecture, which allows students to gain a comprehensive understanding of sustainable management at the end of their education – on the bachelor as well as on the master level. At this point, a brief reference to an ongoing Erasmus+ project is given, which promises interesting empirical data on the extent to which sustainable teaching content also supports long-term sustainable management action in a practical context. All reports, tools and teaching formats are available on its homepage (EFFORT 2021).

Figure 6.1.1 provides a brief overview of what management teaching content can be offered by a business school curriculum. The theoretical framework is based on the UNESCO (2017) report. As shown in Figure 6.1.1, SDG 8 offers a variety of teaching

Sustainable Development Goals	Possible Teaching Content
SDG 1: No Poverty	Definitions and form of poverty, social welfare protection systems, access to economic resources, new technology and financial services like microfinance, working conditions related to poverty (e.g. child labour and modern slavery) ...
SDG 2: Zero Hunger	Drivers and causes of hunger, relation between climate change and food security, trading systems concerning food, sustainable agriculture methods ...
SDG 3: Good Health and Well-Being	Direct and indirect strategies for health promotion, pollution of air, water and soil, communicable and non-communicable diseases ...
SDG 4: Quality Education	
SDG 5: Gender Equality	Gender and labour, gender and education, gender and poverty ...
SDG 6: Clean Water and Sanitation	The impacts of pollution on water quality, water scarcity, efficient water-use, recycling and reuse technologies ...
SDG 7: Affordable and Clean Energy	different energy types, the environmental impacts of energy production, bridging technologies
SDG 8: Decent Work and Economic Growth	Models of economic growth, financial systems and their relation to economic growth, entrepreneurship, social innovation, labour rights ...
SDG 9: Industry, Innovation and Infrastructure	Information and Communication Technologies (ICT´s) in supply chains, sustainable innovation and industrialization, sustainable infrastructure development ...
SDG 10: Reduced Inequalities	Fiscal, wage and social protection policies, global trade systems and regulations, international development aid ...
SDG 11: Sustainable Cities and Communities	Sustainable energies and transportation, sustainable food, waste generation and management ...
SDG 12: Responsible Consumption and Production	Environmental and social impacts of production and consumption, food production and consumption, concepts of green economy (e.g. circular economy approaches) ...
SDG 13: Climate Action	Greenhouse gases and their emissions: energy, agriculture and industry-related greenhouse gas emissions, impacts on eco-systems ...
SDG 14: Life Below Water	Oceans pollutants, the relationship of climate change and the sea , sustainable marine energy ...
SDG 15: Life on Land	Various threats to biodiversity, the extinction of species, desertification and deforestation, climate change and biodiversity ...
SDG 16: Peace, Justice and Strong Institution	Climate justice, child labor, corruption ...
SDG 17: Partnership for the Goals	Global systems and power structure, global trading systems, global governance and policies, international development aid ...

Figure 6.1.1 SDG-related management teaching content (Fröhlich et al. 2021, 486–487).

content, such as different patterns of economic growth, financial markets and their correlation to economic growth, entrepreneurship, social innovation or labour rights in global supply chains.

Based on this analysis, it is possible to determine which sub-goals of the 17 SDGs are covered and on what courses this content may be found. Referring to this evaluation, the SDG Teaching Map is derived, as illustrated in Figure 6.1.2. The data collected by analysing the different study programs are verified by the results of an online focus group conducted in a second step. Three specific questions have to be answered: (a) What SDG sub-targets, which have not been covered yet, can be integrated into the curriculum of a business school? (b) How can this missing content be integrated (for example, by creating a new lecture or integrating this new material into existing lectures)? (c) What content of the sub-goals of the 17 SDGs cannot be mapped by a business school? (d) How could this content be acquired?

These questions will guide the further course of the chapter. Furthermore, this research step has been significantly expanded in the last two years and has thus led to more reliable results. Figure 6.1.2 provides an overview in which the sub-targets are addressed in relation to the different teaching formats at the example business school. The sub-targets mentioned in the boxes cannot be covered so far.

A bridge to interdisciplinary co-operation: the SDG 8 case

The reason why it is so important to stick to the successful implementation of the 2030 SDGs has been explained previously, but it also serves as justification for the development of the SDG Teaching Map. The concrete contribution business schools can make to closing the remaining SDG sub-target gaps will now be elaborated, using the example of SDG 8.

Sustainable Development Goal 8: "Decent Work and Economic Growth"

The most important areas requiring action were determined by the United Nations in its definition of the 17 Sustainable Development Goals:

> The 2030 Agenda for Sustainable Development, adopted by all United Nations member states in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. At its heart are the 17 SDGs, which are an urgent call for action by all countries – developed and developing – in a global partnership. They recognise that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality and spur economic growth – all while tackling climate change and working to preserve our oceans and forests.
>
> *(United Nations 2021b)*

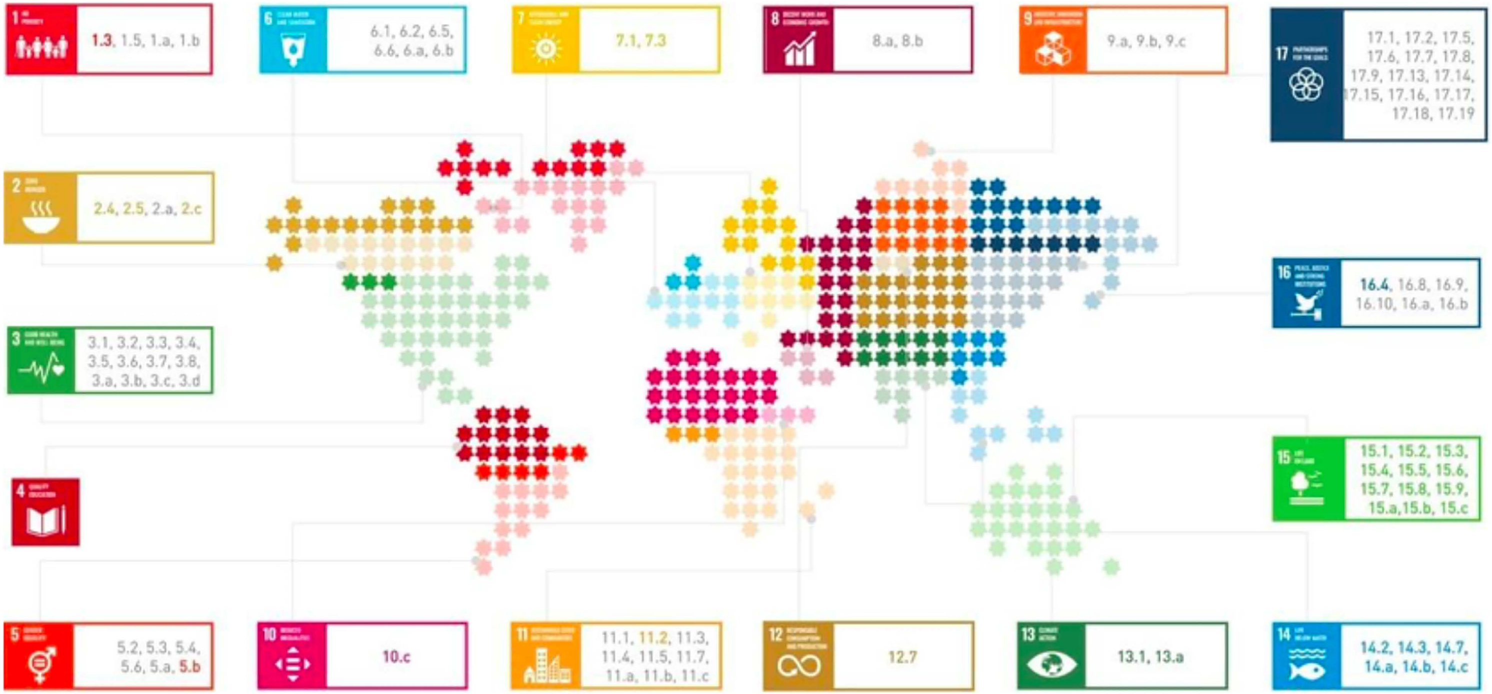

Figure 6.1.2 The SDG Teaching Map (author's illustration).

A more concrete elaboration of SDG 8 "Decent Work and Economic Growth" calls for a brief definition. The following sub-targets specify SDG 8:

- *8.1* Sustain per capita economic growth in accordance with national circumstances, and in particular at least 7% per annum GDP growth in the least-developed countries
- *8.2* Achieve higher levels of productivity of economies through diversification, technological upgrading and innovation, including through a focus on high value-added and labour-intensive sectors
- *8.3* Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services
- *8.4* Improve progressively through 2030 global resource efficiency in consumption and production, and endeavour to decouple economic growth from environmental degradation in accordance with the 10-year framework of programs on sustainable consumption and production, with developed countries taking the lead
- *8.5* By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value
- *8.6* By 2020, substantially reduce the proportion of youth not in employment, education or training
- *8.7* Take immediate and effective measures to secure the prohibition and elimination of the worst forms of child labour, eradicate forced labour and, by 2025, end child labour in all its forms, including recruitment and use of child soldiers
- *8.8* Protect labour rights and promote safe and secure working environments of all workers, including migrant workers, particularly women migrants, and those in precarious employment
- *8.9* By 2030, devise and implement policies to promote sustainable tourism which creates jobs and promotes local culture and products
- *8.10* Strengthen the capacity of domestic financial institutions to encourage and to expand access to banking, insurance and financial services for all
- *8.a.* Increase Aid for Trade support for developing countries, particularly LDCs, including through the Enhanced Integrated Framework for LDCs
- *8.b.* By 2020, develop and operationalize a global strategy for youth employment and implement the ILO Global Jobs Pact. (SDG Compass 2021)

The major focus of SDG 8 therefore falls on sustainable economic development and jobs for all. Despite the steadily rising gross domestic product (GDP) in developing countries, some of the 2030 targets seem unachievable; the COVID-19 pandemic in particular has had devastating implications for the achievement of the goal. In line with the previously cited view of Filho et al. (2020) regarding the problems with SDG 8 we have to face once we stop focusing on the future achievement of all SDGs, the latest International Labour Organization (ILO) report (2021, 14) states: "Moreover, all respondents agreed that the prospects for vulnerable groups of workers such as migrant workers and those in the informal economy have been the most impacted by the global pandemic." Due to the fact that unformal workers cannot work from home, there is only one choice for them left, namely "to risk dying from COVID-19 or from hunger" (ILO 2021, 14). Many challenges, such as regional differences in labour productivity, the gender wage gap and youth unemployment, remain unresolved and require innovative global solutions. Referring to the gender pay gap, the United Nations (2020, 8) emphasises that "the current crisis threatens to push back limited gains made on gender equality and exacerbate the feminisation of poverty, vulnerability to violence, and women's equal participation in the labour force." As highlighted in Figure 6.1.1, the contribution of a business school lies mainly in teaching formats addressing new economic business models for sustainable prosperity.

The impact of business school teaching formats on achieving the SDG 8 sub-targets

Starting with a brief discussion of the research done in terms of which lectures address SDG 8, further best practice examples will be used to explore the huge impact business schools have on the achievement of the goal. In line with the statements made earlier, namely that some of the sub-goals of SDG 8 cannot be achieved by 2030, business schools also face the challenge of not being able to influence all sub-targets. First, the results of the expert survey are summarised and initial ideas for new teaching formats are discussed. Subsequently, the innovative "21-day challenge" teaching format will be presented, and it will be demonstrated how students can be sensitised to the sub-areas of SDG 8 that cannot be tackled by existing educational approaches.

SDG 8 is one of the most extensively integrated SDGs in the example business school curricula, as most of the content covers business and economics topics. Lectures of the chosen business school include SDG 8.1–8.10. Examples of topics are economic growth in developed countries in general and policies to promote entrepreneurship and innovation, technological modernisation and innovation. When it comes to labour issues, lectures deal with topics such as full employment, youth unemployment, forced labour and modern slavery, labour rights and the working environment. Financial services for all and sustainable tourism are two additional themes related to SDG 8. These topics are mapped in a very diverse way and are found in different disciplines. General management courses, for instance, on topics such as economic growth, or courses with a focus on supply chain management, embrace themes that address challenges in supply chains such as modern slavery. This is the link to human resources–related courses covering issues such as labour markets and workforces, or finance courses covering issues related to financial services in developing countries. The example business school curricula cover the following courses dealing specifically with SDG 8: Human Resource Management, Applied Financial Management, Applied Economics, Sustainable Eco- and Nature-based Tourism and Sustainable Supply Chain Management. It is worth going through a detailed analysis to identify all of the subjects contained in the curricula of a business school in order to gain a clear picture how it affects SDG achievement through its educational approach. After finalising this research, we clearly understood the current richness of our curriculum in relation to integrating the SDG sub-targets.

In the following, we describe two selected examples that were collected during our research project. In order to find further inspiration to improve the curriculum, a detailed analysis of leading global business schools was conducted. The selected institutions were classified as "leading" if they are Principles for Responsible Management Education (PRME) signatories and have also been repeatedly rewarded for their submitted Sharing Information on Progress (SIP) reports by the UN PRME secretariat (for further information on PRME see Chapter 4.5 in this volume)

Target 8.4, "Improve resource efficiency in consumption and production," for instance, is addressed by the University of Queensland. Their SmartHarvest initiative made it to the finals of the Global Business Challenge 2020, whereby students were tasked to develop innovative and sustainable solutions that would support resource recovery and foster a circular economy: "The submission to the competition by the UQ SmartHarvest team will help farmers estimate current and upcoming demand. Through using SmartHarvest, farmers can access demand data, giving them the necessary information to make strategic business decisions, including what other farmers are currently growing" (UQ SmartHarvest 2021). Growing only food that is needed helps to reduce not only the problem of food waste but also CO_2 emissions, water consumption, fertilisers, fossil fuels and electricity. Another project – or rather its content – has been included in the example business school curriculum, namely the "Responsible Investment Module" at the University of Cape Town (UCT) Graduate School. This project explores the potential of private commercial transactions as a means of financing growth. The course offered sheds light on how private-sector capital can be used by institutional investors for growth, and it elaborates the complex idea of sustainable, responsible investment as another valuable tool in development finance. Furthermore, UCT launched in 2017 its "University Panel of Responsible Investment" (UPRI) as a formal committee advising the university on responsible investment decisions:

> UPRI believes that its work and ability to engage meaningfully with the broader UCT community requires a degree of transparency and disclosure from the UCT endowment regarding its investments. To achieve this, UPRI continues to have a serious and urgent dialogue on the matter with the appropriate parties.
>
> *(UCT 2023)*

The SDGs that are missing in the example business school curricula are SDG 8.a and 8.b. The former focuses on supporting developing countries through Aid for Trade, while SDG 8.b addresses a global strategy to tackle youth unemployment. The experts interviewed herein provided different answers to the question of how these two missing sub-targets could possibly be integrated into the curriculum of a business school. Basically, it was suggested that both sub-targets could be incorporated into foundation classes in the economics discipline, for example, by integrating discussion formats that uncover the "roots" of the related challenges. In addition, a comparison between industrialised and developing countries could serve as a method to integrate these issues into already existing teaching formats. Above all, the interviewees suggested the possibility of involving guest lecturers to integrate missing knowledge and expertise. However, some experts also expressed the opinion that neither sub-target can be embedded into a business school curriculum, as they can only be tackled on the government level; business students should instead focus on solutions that take a more individual, entrepreneurial approach. Nevertheless, the integration of SDG 8.b into a lecture on social innovation seems feasible. In addition, incubator programmes, co-operations between companies and career department initiatives at universities or service-learning projects were mentioned.

In the last section of this chapter, an innovative teaching format will be discussed, adapted from another Erasmus+ project called ISSUE (2021). As already explained, integrating sub-targets 8.a and 8.b into a business school curriculum is quite a complex task. And even though most of the SDG 8 sub-targets are already addressed by business schools, educating responsible leaders requires new approaches and perspectives to find innovative solutions to the SDG 8 challenges.

The methodology of collaborative online learning lays the foundation for the development of the 21-day challenge. Various exercises ("challenges") need to be completed in relation to the 17 SDGs. On finding a solution to each task, which they have devised collectively within their learning community, the participants receive points. Additional points are awarded for discussing and sharing these solutions. Each SDG has three components. First, a short video provides an overview of the respective topic (SDGs 1–17) and conveys the necessary knowledge to find a solution to the challenges associated with the respective SDG. The second part contains the activities that need to be carried out. Through the joint exchange of experiences and discussions, the participants receive the necessary feedback to create solutions for the different tasks. In addition to the pure processing of the problems, points are also awarded to the students for the ways in which they interact, such as comments, postings or uploads to the provided platform. This is an essential part of the 21-day challenge, as it promotes exchange and discussion between the participants. The idea is to raise awareness of the major ecological and social challenges of our time, which is highly relevant to educating responsible leaders. The 21-day challenge offers different ways of being anchored in a university's curriculum. For example, it could be part of a regular lecture whereby a "learning diary" is kept in which participants reflect on what they have learned. Campus challenges with incentives can also be initiated, in which not only students but also university staff can participate. Or university student teams from different universities could compete against each other. The PRME DACH Chapter (PRME 2021a) is currently considering organising the 21-day challenge for selected student groups. A "game guide" helps lecturers and students navigate through the challenge (Fröhlich et al. 2021).

Friederike Martin, living income expert and advisor at GIZ, the German Society for International Cooperation, explains in her introduction video dealing with SDG 8 the major challenges we face in the run up to 2030. The COVID-19 pandemic, with its latest "omicron" mutation, is once again threatening global economic growth (DW 2021). SDG 8.1 refers to "sustainable economic growth as an at least 7 per cent gross domestic product growth per annum" (United Nation 2021a). Without doubt, economic growth is one of the ways through which to increase global living standards,

> [h]owever, modern economies have lost sight of the fact that the standard metric of economic growth, gross domestic product (GDP), merely measures the size of a nation's economy and doesn't reflect a nation's welfare. Yet policymakers and economists often treat GDP, or GDP per capita in some cases, as an all-encompassing unit to signify a nation's development, combining its economic prosperity and societal well-being. As a result, policies that result in economic growth are seen to be beneficial for society.
>
> *(Kapoor and Debroy 2019)*

Consequently, we have to offer our business students new solutions in terms of how to measure global welfare and what additional "measures" can be used. Together with our students, we should discuss books written by visionaries, such as Rutger Bregman's (2021) *Utopia for Realists*. In the chapter "New Figures for a New Era," Bregman discusses a new vision of prosperity and how we can make it measurable.

One concrete example in this context is to achieve more efficient development by decoupling economic growth from environmental impacts, as proposed by the United Nations Environmental Programme (UNEP 2011). Decoupling describes the process whereby "resources use or some environmental pressure either grows at a slower rate than the economic activity that is causing it (relative decoupling) or declines while the economic activity continues to grow (absolute decoupling)" (IRP 2017, 23). Schneidewind (2018) speaks of double-decoupling in this context. At its core, it is about achieving a good life for as many people as possible. This “expanded” view gives rise to two forms of decoupling. First-order decoupling, i.e., classical decoupling, is based on eco-efficiency and consistency, for example, via renewable energies or recycled materials. This makes a country’s GDP significantly more eco-efficient. Energy efficiency, for example, has increased by 50% since 1990, but over the same period, environmental impacts have not decreased in absolute terms, either nationally or internationally. This is because growth effects have compensated for relevant savings, which is why the discussion about the second decoupling phase is so important, i.e. decoupling quality of life from economic-material growth. The central elements of second-order decoupling are thus a changed lifestyle and sufficiency. As such, we need new models of prosperity and a broader understanding of prosperity (OECD 2021).

And this is exactly where the tasks within the 21-day challenge come in, as they provide business students with a new vision of prosperity and ideas on how to make it measurable and feasible in the context of entrepreneurial action. Two examples will be sufficient to give a first impression of how the materials developed for the 21-day challenge can sensitise students to the challenge of fulfilling SDG8 and support them to develop new ideas and visions. These two exercises are taken from the ISSUE (2021) Learning Platform and cannot be properly cited, because access is limited to the universities that worked on this innovative teaching format.

Be engaged! (3 pts.)

“Reflect upon the clothing brands you are using on a daily basis and investigate whether your favourite brands are sustainable and pay their workers appropriately. Upload the snapshots/results of your findings with the percentage of sustainable clothing brands in your closet to the Forum. Discuss with others.”

Support companies with a sustainable mission (2 pts.)

“Share two stories of occasions when you bought a product from a company/brand mainly due to sustainability aspects followed by the company, such as any sustainable actions, innovations, brand image, etc. Write and share what motivated you to buy this product.”

Conclusion

“More than half the world is being left behind at the midpoint for achieving the 2030 Agenda for Sustainable Development, UN Secretary-General António Guterres told ambassadors in New York” (United Nation 2023). This chapter highlights concrete solutions that educators can implement to close this gap in achieving Agenda 2030 through innovative sustainable teaching formats. The SDG Teaching Map is a strategic guideline and tool for adopting responsible management education approaches in universities. But responsible management education can only be rethought together. Innovative teaching formats – developed in a joint research program with European partner universities – were discussed, and reference was made to “lighthouse examples” of how well-known universities are mastering the challenges of integrating the SDGs into their curricula. This chapter is meant to encourage all of us to break new ground and make responsible management education the “new normal,” no matter what challenges we still have to overcome on our way to a more sustainable economy.

The PRME Chapter work offers an excellent platform for this necessary exchange and learning from each other. As part of the PRME DACH Chapter (PRME 2021a), we organise an annual RME Research Conference. Researchers and experts in the field of responsible management education from all over the world will meet and share their experiences and expertise in order to promote the sustainable development of new business models. Furthermore, the PRME DACH Chapter has launched a platform to exchange knowledge on innovative sustainable teaching formats. RME must find its way into all universities, not just business schools. This is one of the great challenges of the future, to develop a common understanding of sustainable progress across the different disciplines, in the sense of Guterres's quote. This is where the SDG Teaching Map is a first step towards developing such a holistic understanding of RME in order to close the gap in achieving the SDGs at the global level.

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6.2

TRANSFORMATIVE LEARNING IN ENVIRONMENTAL AND SUSTAINABILITY EDUCATION

A transformation to what and how?

Sally Birdsall

Key concepts for sustainability education

- Environmental and sustainability education (ESE) researchers now realise that teaching and learning about caring for the Earth and living in a just manner for all is complex. More than knowledge is needed; changes to people's values and beliefs along with learning skills for effecting change are required. This type of learning is termed 'transformative'.
- Transformative learning is viewed as the essential component of environmental and sustainability education because it leads to deep level changes in people's values and beliefs. As a result, people develop an environmental ethic and relational worldview, learning to live within Earth's limits and seeing themselves in a relationship with other people, the Earth and nonhuman others.
- However, there is a lack of theorising about learning in ESE that could help educators design effective transformative learning programmes, especially since developing an environmental ethic is not innate and must be taught.
- Mezirow's transformative learning theory has some explanatory power to assist educators in designing effective transformative learning. For example, including strategies such as nurturing reflection and critical thinking skills, setting learning in contexts relevant to learners and making the learning holistic can foster transformative learning in ESE.
- Nevertheless, further research is needed to develop a more expansive explanation of how transformative learning can be nurtured. The most effective conceptions of transformative learning theory need clarifying, as does the domain of learning and bridging the gap between the theory and actual practice. Research that targets these gaps has the potential to enhance this theory's utility for ESE educators.

Introduction

> "Transformative learning for people and the planet is a necessity for our survival and that of future generations."
>
> *Berlin Declaration (UNESCO 2021, para 9)*

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This quote is from a declaration that was the outcome of the 2021 UNESCO World Conference on Education for Sustainable Development. It illustrates the importance placed on transformative learning in environmental and sustainability education, claiming its use is a requirement for our very survival as a species. Indeed, 'transformative' is a ubiquitous word in the field of environmental and sustainability education. It usually refers to a profound shift in one's worldview that leads to one engaging in more sustainable behaviours and/or taking action as a result of students' learning.

Furthermore, the word 'transformative' is frequently mentioned in research articles. For example, a recent search using transformative as a search term in articles found in the journal *Environmental Education Research*, a highly regarded journal in the field, yielded 782 responses. When one notes that by the end of 2019, this journal had published 25 volumes of studies with more than 1000 articles (Reid 2019), the prevalence of the word transformative is evident. The word transformative is also found in international policy documents such as the recent UN policy document *ESD for 2030*, where it is linked with pedagogies that are required to bring about the changes needed for building a more just and sustainable world (UNESCO 2019).

While often used, it is difficult to elucidate what transformative learning entails and what is shifted or changed. There is also a lack of theorising about how learning could take place in the environmental and sustainability education field (Rickinson 2006; Wals and Dillon 2012). In this chapter I explore what this word transformative entails, how such learning occurs according to theory and its potential to explain learning in environmental and sustainability education.

This chapter begins with discussion about transformation in terms of Mezirow's transformative theory of learning to establish what the word transformative encapsulates in this chapter. The problems with transformative learning in environmental and sustainability education and why transformative learning on a societal scale has yet to occur are then discussed, leading to an identification of the target of transformation. Strategies that can foster transformation are discussed along with the gaps still inherent in transformative learning theory.

The term environmental and sustainability education (ESE) is used in this chapter. It is a more recently used term, as this type of education began with the name environmental education (EE), then shifted to education for sustainable development (ESD) and then education for sustainability (EfS) before arriving at ESE (Wals and Benavot 2017). The term 'sustainability education' is also currently being used. The field has moved on from debating the 'best' term to use, and it is generally accepted that now it is up to researchers to decide which term to use. Examining this debate and the shifts between these terms is beyond the scope of this chapter.

What is transformative learning?

Currently, there is agreement that ESE should be transformative for learners (Reid et al. 2021; Sterling 2010; Wals and Benavot 2017). Transformative learning should result in fundamental changes in a person's values and beliefs (Sterling 2010), leading to them possessing an environmental ethic of stewardship for people and all living things on Earth (Reid et al. 2021). Such a change requires learning to be at a deep level and involve critical thinking skills such as reflection. Sterling (2010, 152) likens transformative learning to epistemic learning, and he argues that it can lead to "heightened relational sensibility and a sense of ethical responsibility". Wals and Benavot (2017) agree and state that transformative learning will enable people to connect with their communities and the nonhuman world by developing a relational worldview.

However, there is a lack of theorising about how learning can take place in ESE. As Rickinson (2006) argues, there seems to be a reluctance on the part of ESE researchers to engage with any learning theories. By failing to engage with learning theory, many studies neglect to portray students as active learners, something which conflicts with a key element of ESE, that of students being agentic in both their learning and participation (Reid et al. 2021). This failure is regarded as both a "concern and a weakness" (Wals and Dillon 2012, 253).

This chapter aims to begin to address this concern and weakness by exploring the potential of Mezirow's (1990) transformative learning theory to problematise how transformative learning can occur in ESE. Since Mezirow's theory is synonymous with change and ESE aims to shift students' values and beliefs resulting in development of an environmental ethic, it would seem that his theory has potential to elucidate ESE learning. It is a popular theory for understanding learning experiences that have high impact (Romano 2018), and in the four decades since its first iteration in 1978, this theory has been constantly discussed at international conferences and been the subject of books and hundreds of academic papers (DeSapio 2017).

Theorising about transformative learning

Mezirow's theory proposes that learning occurs when a person encounters information or actions that result in dilemmas or distortions that challenge their assumptions, values or beliefs. This challenge can either be ignored, or it can lead to a person questioning and thinking about their assumptions, beliefs and values. Questioning has the potential for transformative learning, but it is not until change in behaviour or practice is evident that transformative learning can be said to have taken place (Cranton and Taylor 2012). In this way it seems ideal for explaining how students become agentic and participate in informed environmental action-taking through their engagement in ESE learning programmes and in their lives.

Transformative learning theory has parallels with constructivist learning, as in both theories, the learner plays an active role and new knowledge is built upon one's experiences. Also, both learning theories have different levels of analysis: at the individual and social. Similarly to different groupings of constructivist learning theory, three dominant conceptions of transformative learning theory have evolved – rational, social and extrarational perspectives (Cranton and Taylor, 2012).

The rational/cognitive perspective of transformative learning theory is predicated on the notion that people have an innate drive to derive meaning from their experiences. It is based on Mezirow's original 1978 study that led to the development of his theory. Assuming a relativist position where truth is not fixed and change is unremitting, it proposes that people are continually striving to improve their understanding of the world and can develop a more critical view of the world. This "psycho-critical process" of interpreting or re-interpreting one's experiences (Cranton and Taylor 2012, 196) is based on three elements: construing of meaning, critical reflection and rational discourse (Mezirow 1990, 2003).

The element of construing of meaning is central to this theory because it is seen as the construction of a new or revised interpretation of the meaning of an experience that then guides subsequent understanding, appreciation or action (Mezirow 1990). These interpretations are filtered by a set of assumptions, or habits of mind. Habits of mind are formed in childhood in an uncritical way, through cultural assimilation and socialisation. They are the habitual ways that people think, feel and act in their world and are expressed as a point of view particular to a person (Cranton and Taylor 2012). Over time, habits of mind and frames of reference, the filters we use to interpret experience, are reified and become the way that people rationalise and evaluate their world. When people encounter new ideas that present a dilemma or distortion, they either strengthen these frames of reference or else extend their boundaries. However, if the new idea or experience is so markedly dissimilar and cannot be assimilated, it is either rejected or else a new frame of reference is formed, which results in transformation of one's perspective referred to as a "paradigmatic shift" (Cranton and Taylor 2012, 196).

The second element of critical reflection plays an integral role in the construction of a new frame of reference. It is when engaging in critical reflection that people can question their frames of reference and challenge the validity of presuppositions in prior learning. Mezirow (1990) and Taylor (2007) assert that people need time to reflect on their frames of reference and, if necessary, transform them. Hence teaching to facilitate critical reflection is not about how or how to; it is about providing opportunities for learners to reflect why, the reasons for and consequences of what we do. It is about challenging frames of reference and exploring alternative perspectives, which might lead to the transformation of old ways of framing the world and perhaps action being taken based on these new perspectives.

The third element of transformative learning theory is rational discourse. It is an important element because transformative learning can be regarded as "communicative learning", a type of learning where you need to be able to understand what someone means when they are communicating with you, in other words, their frame of reference (Mezirow 2003, 59). As this type of communication or rational discourse occurs, you are assessing the authenticity, appropriateness and beliefs of others in order to arrive at a judgment of some kind. This process is referred to as "critical-dialectic discourse". and such dialogue with others is an essential part of critical reflection (Mezirow 2003, 59; Taylor 2007), grounding transformative learning in the nature of human communication.

Social transformation is the second of the dominant conceptions of transformative learning theory. In this conception the unit of analysis shifts from the individual to a transformation of society as a whole through individuals undergoing changes in their perspectives. Developed by Brookfield, this conception has parallels with social constructivism (Cranton and Taylor, 2012) and has its foundation in the philosophical roots of emancipatory learning (Romano 2018), illustrating a strong link to the work of Paulo Freire. Not only is the aim to create public knowledge but also to raise learners' awareness and consciousness of the dominant culture so that they can explore its relationship to power and control over what is and is not knowledge in a society. In this way people can continuously reflect on their experiences, and then as a result of transformation, make changes towards a more equitable society.

While this conception is similar to the rational/cognitive one in that both have a cognitive basis, a social transformation conception is concerned with societal change. Central to this conception is critical reflection as students develop the ability to critique ideology, becoming aware of how their biographies and histories are entrenched in social structures that confer privilege on some and subjugate others. Consequently, they construct their own meaning of the world (Cranton and Taylor 2012). Along with critical reflection, a dialogical approach to teaching and learning is adopted where problems are posed and students move continuously between reflecting and taking action in a critical manner. The teacher-student relationship is important as it needs to be horizontal, one of mutual trust and respect (Cranton and Taylor 2012; Romano 2018).

The third dominant conception does not rely on critical reflection to bring about a shift in one's perspective; instead, transformation occurs through a process of individuation (Cranton and Taylor 2012). The extrarational transformation conception draws on Jungian psychology and there is an emphasis on emotions, imagination, spirituality and arts-based learning rather than rationality (Romano 2018). The process at the heart of extrarational transformation is discernment, not critical reflection, where individuals work to bring the "unconscious to consciousness" (Cranton and Taylor 2012, 196). This process takes place at an individual level as people work to simultaneously resolve personal dilemmas and expand their consciousness, leading to a deeper level of integration of their personality. As such, individuation is an inner process where individuals set themselves apart from other people and in doing so, are able to see how they are both similar to and different from other people. Transformation is the emergence of "Self" (Cranton and Taylor 2012, 197).

It is proposed that in this conception, learning is a personal experience that involves emotions, imagination and intuition. Students experience emotions through unconscious issues evoked during learning, such as the learning task, its context, the teacher and other students. It is through the evoking of these emotion-laden images that individuation is mediated, enabling students to bring their unconscious into consciousness through personal intuitive and imaginative ways of knowing (Romano 2018).

These three dominant conceptions of transformative learning theory illustrate its broad-ranging notions, from having a cognitive/rational foundation to one based on emotions and intuition. The common thread running through all conceptions is one of transformative learning bringing about change in the way people view their world. The ways in which this 'change' have endeavoured to be realised in ESE will now be explored.

Realising 'transformative' learning in ESE

ESE has always had transformative ideals (Stevenson 2007). As a relative newcomer to curriculum, ESE emerged as environmental education in Britain in the 1970s from four related but distinctive movements: environmental studies, outdoor education, conservation studies and urban studies (Tilbury 1995). As the result of three international conferences held in the 1970s, a set of objectives were developed for environmental education at Belgrade in 1976 and then refined at Tblisi in 1978. These objectives were then adopted by countries around the world and are still regarded as relevant today (Marcinkowski and Reid 2019). According to *The Belgrade Charter*, these objectives, for both individuals and societies, are to:

- Acquire an awareness of and sensitivity to the environment and its problems;
- Acquire an understanding of the environment, its problems and people's presence and role in it;
- Acquire values and concern for the environment in order to motivate people to take action to protect and improve it;
- Acquire skills for solving environmental problems;
- Be able to evaluate environmental measures and education programmes in terms of ecological, political, economic, social, aesthetic and educational factors; and
- Develop a sense of responsibility and urgency about environmental problems in order to take action to solve those problems.

(The Belgrade Charter on Environmental Education 1976, 135–136)

Transformative ideals can be seen in the charter's objectives of acquiring awareness of and sensitivity to the environment, in the acquisition of values and concern for the environment and developing a sense of responsibility and urgency about environmental problems, leading to the taking of action. However, as noted by Stevenson (2007), these transformative ideals were largely ignored in the 1970s and 1980s because they clashed with the role of schools as sites for social reproduction. Furthermore, these ideals did not align with the dominant curriculum and pedagogical practices that focused on transmitting discrete, discipline-based facts and simplistic 'truths'.

The Earth Summit in 1992 called for a 're-orienting' of environmental education because of mounting concerns about the severity of environmental degradation (Tilbury 1995). This re-orientation was also a response to the perception that up to this point in time, environmental education had been seen to be "apolitical, naturalist and scientific" (Tilbury 1995, 195). It was recognition of the way that environmental problems are anchored in society in people's history, social, cultural, political and economic systems. The need for a lifelong education that resulted in people choosing a more sustainable lifestyle was also recognised. This shift resulted in the re-naming of environmental education (EE) to education for sustainable development (ESD) and education for sustainability (EfS), and it received broad support from EE practitioners, researchers and policy makers (Reid et al. 2021).

Consequently ESD and EfS were regarded as a more broad-ranging form of learning, and the role of transformative learning leading to a change in students' ideas and perceptions became more overt. Transformative learning could occur through students coming to view their world in different ways, such as how societal structures perpetuate unsustainable practices (Tilbury 1995) such as overconsumption. It could also take place through positioning learning in the context of an environmental problem that is of personal relevance for students, enabling them to examine the links between the quality of their environment, social justice and human rights. The inclusion of components such as values clarification, learning a variety of action-taking skills and developing political literacy also have potential for facilitating transformation (Fien and Tilbury 2002; Nolet 2009; Tilbury 1995).

As we moved into the 21st century, there has been increasing recognition that despite the re-orienting to ESD and EfS, sustainable lifestyle decision-making that will result in the restoration and flourishing of our planet is not occurring at the scale needed (Taylor 2017), namely societal transformation. For example, as noted by Reid et al. (2021), all of the environmental problems identified in an international document signed by 1700 scientists in 1992 have worsened, apart from ozone layer depletion. A full realisation of transformative learning in ESE has yet to take place.

There are two interrelated challenges that have been identified and debated in the ESE field since the start of the 21st century that are related to achieving ESE's transformative ideals. The first relates to the simplistic, linear relationship between knowledge, attitudes and behaviour that was incorporated into many ESE programmes of learning. The second relates to the eventual identification of the target for transformation.

The relationship between knowledge, attitudes and behaviour

As outlined in *The Belgrade Charter*, the learning goals in ESE involve students developing knowledge and understanding about the environment; acquiring values, developing awareness of, sensitivity towards, and feelings of concern about the environment (loosely grouped as attitudes); and being able to take action to solve environmental issues. These elements of knowledge, attitudes and behaviour are regarded as fundamental to ESE (UNESCO 1978), forming the basis of education policy and curriculum in many countries.

These elements were captured into what has become somewhat of a 'mantra' in ESE – 'education in, about, and for the environment'. Education 'about' the environment involves students developing knowledge and understanding about environmental issues, and learning is situated in the cognitive domain (Tilbury 1995). Education 'in' the environment is experiential in nature, with students often involved in fieldwork. These experiences aim to develop environmental awareness and concern, situating this learning in the affective domain. Regarded as a goal of education, education 'for' the environment goes further with students developing a sense of responsibility and actively participating in the mitigation and/or improvement of the environment (Tilbury 1995). This active, participatory approach often involves kinaesthetic or embodied learning. These three approaches are integrated and regarded as cyclic as learners move through each approach during their learning (Tilbury 1995).

The potential for transformative learning can be located in these approaches when students engage in fieldwork, as their environmental awareness and concern could be developed. There is also potential to develop an environmental ethic, which comprises values such as living within environmental limits, concern for other people and social responsibility (Tilbury 1995). When engaging in education for the environment activities, students could also transform their beliefs and values through a growth in their understanding of the political elements involved in the issue, as well as an examination of the structures in a society that contribute to unsustainability, giving rise to environmental degradation (Tilbury 1995).

These three approaches to ESE are probably best encapsulated in Sterling's (2010) notion of instrumental ESE. Instrumental ESE is regarded as behaviourist and prescriptive, a 'remedial vehicle' that will teach learners how to change their behaviours to those that will bring about a more sustainable lifestyle. It assumes that learning is linear in nature and by developing content knowledge and raising environmental awareness, students will be able to effect environmental and social change (Sterling 2010).

The mantra of education in, about and for the environment became known as the K-A-B model, encapsulating the view that by developing **k**nowledge about an issue and having experiences to develop pro-environmental **a**ttitudes, **b**ehaviour change would ensue (Marcinkowski and Reid 2019). This linear approach spawned multitudes of published studies that explored the effects of ESE programmes. However, the vast majority were concerned with either the characteristics of learners, such as the type of environmental knowledge or attitudes they possessed, or else the outcome of the programme (Rickinson 2006). Learners' experiences and responses to the programmes, as well as the learning processes involved, were largely ignored (Rickinson 2006).

Furthermore, this simplistic interpretation of these three approaches ignores the intent of their author. Arthur Lucas is credited with their conception in his 1972 doctoral thesis. Naming them as different 'classes' of education, he used education about, in and for the environment to illustrate the myriad types of learning programmes that could be deemed environmental education (Lucas 1972). He argues that given the various combinations of the classes of education in, about and for the environment, along with the different types of environment he defines, for example, urban, agrarian, living and cultural to name but a few, over a hundred possible programmes could be labelled as environmental education.

The lack of progress towards more sustainable societies has raised questions in the second decade of the 21st century about the benefits of ESE and if it ‘worked’. To answer this question researchers at Stanford University and the North American Association for Environmental Education carried out a systematic literature of studies (Ardoin et al. 2018). From an initial sample of 2034 studies, 119 were selected for analysis. Findings showed that engaging in environmental education programmes had many benefits that went beyond the development of environmental knowledge, attitudes, skills and behaviour. Students' knowledge in academic subjects such as science, mathematics and writing improved along with emotional and social skills like enhanced self-esteem, teamwork and leadership skills. Furthermore, skills such as critical thinking, problem solving and systems thinking were enhanced. It was concluded that engagement in ESE programmes had many benefits for students as well as positive impacts on their learning (Ardoin et al. 2018). While this plethora of positive evidence could be the result of transformative learning, there was no overt mention of its use. Furthermore, as noted by Reid et al. (2021), the effects of environmental degradation and biodiversity loss are intensifying, suggesting that transformation is not occurring at a societal scale.

Transformation of what? Identification of the ‘target’ for change

As discussed, in the first two decades of the 21st century there was a growing recognition that ESE programmes were not realising the transformative ideals that result in people making more sustainable decisions in their lives. Coupled with this was recognition that developing knowledge and understanding about environmental issues does not always lead to behaviour change. The simplistic K-A-B model just does not ‘work’. What needed to be transformed to result in sustainable behaviour on a societal scale was still an unknown.

The complexity of the relationship between knowledge, attitudes and behaviour began to be recognised in the first decade of the 21st century. One of the most recognised articles was written by Kollmuss and Agyeman (2002) who identified a range of internal (psychological) and external (social) factors that shape behaviour, ranging across gender and years of education; motivation; values and attitudes; emotional involvement; locus of control, environmental awareness and knowledge; feelings of responsibility; and the influence of social institutions. There was, however, acknowledgement of some relationships. Quantitative research suggests that there is a weak relationship between knowledge and behaviour (Kollmuss and Agyeman 2002) and that the relationship between attitudes and behaviour is of relatively moderate strength, although attitudes are not tantamount to behaviour (Marcinkowski and Reid 2019).

Further evidence of the weak relationship between knowledge and action was revealed in the second half of the first decade in the 21st century with the increasing interest in climate change education. Studies exploring students' knowledge about the causes of climate change proliferated during this time. What quickly became apparent was that knowing about the causes and effects of climate change had little impact on students making more climate-friendly lifestyle decisions (Li and Monroe 2017). Clearly transformative learning was still not happening at a societal scale.

It seems that although understanding about the causes and effects of the climate emergency is important (Monroe et al. 2017), or indeed knowledge about the many environmental issues we face, it is our perceptions of the way in which we see ourselves on our Earth and our relationships with each other and nonhuman others that are key (Stevenson

2006; Taylor 2017; Wals and Benavot 2017). Some writers propose that a transformation or paradigm shift to an eco- or bio-centric worldview is needed (Stevenson 2006), but others go further, arguing that a transformation to a relational worldview is imperative, where humans view themselves as an integral part of Earth's biosphere (Wals and Benavot 2017), learning to "become *with* the world around us" (Common Worlds Research Collective (CWRC) 2020, 2). It is this change in our view of our relationship with the Earth, with each other and with nonhuman others, which can be considered an environmental ethic, that needs to be the target for transformative learning as this view is not innate (Reid et al. 2021).

The problem with our relationship with the Earth, each other and nonhuman others is our sense of exceptionalism and the bifurcation of nature and culture (Latour 2015; Taylor 2017). Humans' sense of exceptionalism – our placing of ourselves as above and having power over every other living species on Earth (Taylor 2017) – originated with the Enlightenment. The Enlightenment was a time of separation – the state from religious institutions, the rise of individual liberty – and more importantly, the separation or bifurcation of nature from culture or humans (Latour 2015). These endeavours were supported by the rise of science, with its values of empiricism, scepticism and rational thought. It was also a shift away from relying on traditional and innate ideas. Consequently, there was an explosion of scientific knowledge, a knowing 'about', as scientists sought to explain the world using 'the' scientific method and reductionism, where a system is seen in terms of its component parts. Coupled with rampant consumerism, it is largely through our application of scientific knowledge that our ability to manipulate and transform our world that we have entered the Anthropocene (Hamilton 2015); a geologic epoch where humans are the dominant species and are shaping the Earth (Stone 2020).

It is not only students' relationships with the planet, each other and other nonhuman others that needs to be changed. The way in which ESE programmes are designed and taught is also part of the reason for the lack of large-scale societal transformation. This issue can be traced back to the initial motivation for environmental education, which was to conserve the natural environment (Smyth 1995). This perception, coupled with the environment being seen as natural, as something out there that is 'pure' and separate from humans persists today, makes it difficult to tackle the impacts of human behaviour (Smyth 1995; Taylor 2017). Because the bifurcation of nature/culture and human exceptionalism are not addressed, an anthropocentric worldview remains part of the covert curriculum in education systems (Orr 1994). Instead of playing a key role to enact change, education has become part of the problem (CWRC 2020).

Moreover, even when ESE programmes foster the ideals of protecting, caring and restoring the environment, they do not directly address the problem of the bifurcation of nature and human exceptionalism. Through fostering of these ideals of protection and care, educators are continuing to reinforce the subject/object binary, which is argued to be the fundamental divide in education (CWRC 2020). As long as educators continue to perceive their role as one of teaching their learners (the subject) about the "exteriorised world" that is out there (the object) (CWRC 2020, 7), reproduction of this divide will continue, perpetuating the belief that humans can act with impunity and at will on the environment (Taylor 2017). In addition, in such programmes, learners are being taught that they are the only living species who have agency (Taylor 2017), bolstering bifurcation and sense of human exceptionalism further. As long as our education systems continue to produce humans who practise and enact our "sense of human exceptionalism", nothing will change (Taylor 2017, 1453). We will continue to churn out subsequent generations of educated people who are "more effective vandals" of the Earth (Orr 1994, 5).

This is the challenge facing ESE researchers, educators and policy makers. It would seem that as a theory of learning that explains how deep shifts in perspective can be achieved, such as transformative learning could be fruitful for explaining how to develop this relationship. Strategies that could prove useful will now be discussed, along with areas that require further exploration.

Can the potential of transformative learning theory be harnessed in ESE?

Given that the goal of ESE programmes is to transform students' relationships with the Earth, each other and nonhuman others and that transformative learning theory has potential for elucidating such change, what will help students to shift their perspectives at a deep level and change they ways in which they view themselves in their world?

The strategy consistently mentioned by ESE researchers when discussing transformative learning is teaching students how to think critically (Reid et al. 2021; Sterling 2010; Wals and Benavot 2017; Wals and Dillon 2012). Critical thinking is a key element of Mezirow's transformative learning theory and, as argued by Wals and Dillon (2012), an essential requirement for a sustainable society. They assert that a sustainable society is a reflexive one, made up of citizens who can think critically about normative societal systems and structures, altering them as needed in the shift to a more equitable and just planet for all.

Situating learning in contexts that are familiar to students is another strategy mentioned for transformative learning (Tilbury 1995; Wals and Benavot 2017), while Sterling (2010) refers to students learning contextualised knowledge. Ensuring students study environmental issues pertinent to their local communities can help to foster connections to their 'place' through their lived experiences and could lead to the development of an environmental ethic. Educators being aware of the context in which they situate learning is also an element discussed by Cranton and Taylor (2012) that can help foster transformative learning.

Another frequently mentioned strategy when discussing transformative learning is that of ensuring learning is holistic (Tilbury 1995). Engaging in holistic learning helps students to develop understandings across a range of subject areas and directly participate in environmental stewardship actions (Wals and Dillon 2012). Thus learning is both "multidisciplinary and multimodal" (Reid et al. 2021, 786) as students learn how to bring about change and develop agency (Wals and Benavot 2017). As discussed by Cranton and Taylor (2012), utilising a holistic orientation can also foster transformative learning.

While it would seem that utilising these strategies could help to foster transformative learning where students develop an environmental ethic, seeing themselves as part of the Earth's ecosystems along with nonhuman others, why is transformation at a societal scale still not occurring? The theory elucidates how transformation takes place, the target of transformation in ESE has been identified, as have some strategies to nurture transformation. It seems that gaps remain in our understanding about transformative learning and while Mezirow's theory has some explanatory power, at present it cannot provide a full understanding. Several problems can be ascertained that need further exploration as they currently prevent such understanding and, possibly, large-scale societal transformation from occurring.

The first problem is that transformative learning theory has many conceptions that have evolved far past Mezirow's first iteration in 1978 (Romano 2018). As DeSapio (2017) argues, this theory lacks a central concept and formal organisation, and while such a lack has enabled this evolution, it also has prevented consistent description and explanation (Romano 2018). Three broad groupings of this theory were discussed at the beginning of this chapter, but there are at least seven quite different conceptions that can be found ranging from Mezirow's original psycho-critical conception to psycho-developmental, cultural-spiritual, race-centric, social emancipatory and planetary (DeSapio 2017). Although they use Mezirow's original conception as a reference point, each conception differs to some degree in their attempt to articulate a central concept and formal organisation. Hence there is space for ESE researchers to explore which conception or conceptions would best 'fit' ESE learning or even a new conception developed.

Another problem lies in the question of what is the realm or domain in a learner that needs to be engaged in order to be transformed (DeSapio 2017). The two most common learning theories have an easily identifiable domain. Behaviourist learning theory focuses on changing people's behaviours, whereas cognitive learning theories focus on cognitive processes (Wals and Dillon 2012). Because a domain cannot be pinpointed, it is impossible to separate transformative learning from non-transformative learning. This problem could possibly explain why ESE does 'work' and has many benefits for students, as identified by Ardoin et al. (2018), but has not resulted in transformation on a societal scale.

This problem of domain focus presents a challenge for ESE programme design. Since the target is developing a relationship with the Earth, each other and nonhuman others in order to make sustainable lifestyle decisions and there is a weak relationship between knowledge and behaviour, it would seem that the cognitive domain should be the focus. However, developing this relationship also requires nurturing pro-environmental beliefs, values and attitudes, which involves focusing on the affective domain. A focus on the affective domain could be more effective given the moderately strong relationship between attitude and behaviour (Marcinkowski and Reid 2019). But learning in ESE also involves the kinaesthetic domain where students learn through their participation in environmental actions; another possible domain on which to focus. Deciding upon which domain to focus is not clear and presents another gap that warrants further research.

Not only does the unknown of domain focus present challenges for ESE programme design, it also presents problems with assessment. How can teachers assess if transformation has occurred? While there are some instruments available, for example the Critical Reflection Questionnaire, these have been developed for research purposes. Instruments that could be used in educational settings have been designed for tertiary education (Romano 2018). Consequently, educators in early childhood, primary or secondary education sectors would need to use tasks such as narratives and journal writing, self-assessments, interviews and arts-based techniques such as photography and collage to collect assessment data, which have been shown to provide evidence of shifts (Romano 2018). Next teachers would need to consider what indicators of engagement in critical reflection might entail, given that critical reflection is a central element in transformative learning. Likewise for perspective transformation – what would demonstrate that a transformation had occurred? Once having made these decisions, an even more difficult assessment conundrum remains, that of how can a teacher assess if any change or perspective transformation has been integrated into a student's environmental ethic and will shape their future actions? Due to these difficulties, the different domains in which transformation could occur, and given the different dimensions in which it can occur (individual, community or society), Romano (2018) suggests that any assessment be set in its specific learning context. While this suggestion seems fruitful, the question of assessment remains fraught with difficulty and warrants further research.

A further problem has been dubbed the "inbetween problem" (DeSapio 2017, 58). This problem is one of bridging the gap between theory and practice. There is no doubt that transformative learning does exist and is observable. However, the learning process that results in transformation needs to be able to be described and replicated (DeSapio 2017). Although strategies have been identified earlier in this chapter, a consistent and replicable process for transformation in a specific context has yet to be developed or articulated and thus provides another area for further research.

Finally, it must be acknowledged that transformative learning theory is a theory of adult learning (DeSapio 2017; Romano 2018). It is regarded in this manner because critical reflection requires learners to carefully reconsider and evaluate their knowledge, experiences, beliefs and values (Romano 2018). Young children and youth do not have the depth of knowledge and experiences of adults because of their age, which could impact on their ability to critically reflect on their learning and experiences, possibly hindering perspective transformation. The degree to which this could affect transformation is yet another gap that needs exploration.

Conclusion

Throughout the first two decades of the 21st century, ESE practitioners, researchers and policy makers have been tackling the challenge of how to educate people to live more sustainable lifestyles in order to solve environmental issues such as climate change and biodiversity loss. It has been recognised that the simplistic, linear K-A-B model was not effective but that ESE learning programmes still resulted in learning that led to environmental action-taking, albeit on a limited scale. ESE researchers now consider that learning programmes need to focus on students developing an environmental ethic where they view themselves in a relationship with each other, the Earth and nonhuman others, not as separate and able to act with impunity on others. This environmental ethic is not innate and needs to be taught.

Transformative learning theory does provide explanatory power for how this environmental ethic can be developed. It can be explained through students being presented with disorienting dilemmas, engaging in rational discourse, construing of meaning and critically reflecting on these experiences in the light of their existing knowledge, beliefs and values, leading to a deep shift in perspective taking place that will affect their future actions. Using this explanatory power could enable effective programmes of learning to be designed and taught, leading to transformation at a societal scale.

However, while specific strategies can be identified that could nurture this deep shift in perspective, there are gaps in this theory's ability to provide an expansive explanation. While the target for transformation has been identified, the most effective conception or conceptions of transformative learning theory for ESE is still not apparent, nor is the domain or domains on which the focus of learning should be placed. Assessment is an issue along with having a consistent and replicable learning process. The challenge of children and youth being able to engage in critical reflection given the paucity of their life experiences also needs addressing. It is these gaps and challenges that need further exploration and research as people working in the ESE field continue to work towards an ESE that helps people to live within the limits of Earth in an equitable and just manner for all.

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6.3 PROTOTYPING IN SUSTAINABILITY EDUCATION

Mark C. Runacres

Key concepts for sustainability education

- Prototyping provides a unique opportunity for engineering students to become familiar with sustainable design.
- The requirement that Fab Labs be open to the public stimulates community engagement, which is essential for sustainability education.
- As repairability is a key element of sustainable production, it should be included in sustainability education programmes where production plays a role.
- Fab Labs are ideally suited to train people from diverse backgrounds to become the technicians of a more circular economy.
- Sustainability education in open labs, for a wide group of users, requires leveraging and managing user diversity.

Introduction

The ability for students to turn their ideas into physical prototypes has a profound effect on sustainability education. The prototyping facilities of a Fab Lab provide a place and a framework for students to test their ideas without too much effort, and thus verify the consequences of their design choices. This is important, as it is widely accepted that the environmental impact of any product is to a large extent determined in its design phase.

Sustainable design is intimately connected to repairability (see Chapter 4.4 in this volume). A product that can be repaired will almost always require fewer resources and produce less waste than a product that is difficult or impossible to repair. Repairable design, and the technical ability to repair, is therefore an important element of sustainability education in engineering.

Essentially, a Fab Lab is a lab that minimally has 3D printers, laser cutters, computer-controlled milling machines and a set of standard tools and materials. The requirement that Fab Labs should share basic capabilities serves to foster collaboration, as it guarantees, at least in principle, a commonality of tools, machines and experience, and thus allows projects to be shared over different labs. This community-building capacity of Fab Labs is further enhanced by the requirement that they are publicly accessible. This

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means that even a university Fab Lab that primarily caters to a user base of students should also provide training to, and interact with, users from outside the university. Strong community engagement enhances the societal impact of the sustainability education that our students receive and connects them with the real-world sustainability challenges and actions of the local community. Fostering a local community of makers, with the skills and confidence to locally manufacture, adapt and repair a wide range of products and devices, is also a key factor in moving towards a more circular economy.

Community engagement engages stakeholders with diverse backgrounds and perspectives. This is beneficial to any programme in higher education but is particularly crucial for sustainability education, where the inherently multidisciplinary and global nature of the challenges involved cannot be addressed effectively without a diversity of perspectives.

The goal of the present contribution is to illustrate how Fab Labs can be used to put these sustainability principles into practice, not only within engineering education but also beyond.

FABLAB Brussels

In 2010, we founded the FABLAB Brussels at the Vrije Universiteit Brussel, in Belgium. Inspired by the original Fab Lab (short for fabrication laboratory) at MIT (Gershenfeld 2005, 16) and many other great Fab Labs around the world (e.g. Kohtala and Bosqué 2013, 2–4) we set out to construct, machine by machine, a workshop for our students. To express and advertise what we had in mind, we quickly settled on the baseline *Prototypes not PowerPoints!* We made sure that students would use the Fab Lab from the very first weeks they entered our programme. In keeping with the idea of a Fab Lab, our lab is also open to the general public, although the majority of users are students. A picture of students working in the lab is shown in Figure 6.3.1.

Our students run the lab

Lab work is labour-intensive. One need not be cynical to see in this basic fact a principal explanation for the drift in education away from practical hands-on classes and towards theoretical exercises and online activities. Of course, this is not the only explanation. In particular online teaching has merits in its own right and brings undeniable added value to education (foremost the potential to reach students that may otherwise not benefit from top-class higher education). However, the enthusiasm of university administrators for online teaching is at least in part driven by economics.

So how does one operate a lab that should accommodate 400+ students for practical work? The boundary conditions of 21st-century academia don't provide the staff to do that. But we have students. Every year, more students. This as a result mainly, we hope, of our successful programmes but also, we know, of good job prospects. After graduation, these students will often lead a team comprising a number of technicians for whom they will be responsible. This is one of the many reasons why we value the practical aspects of their training so much. Even if, very often, our graduates will become technical managers who rarely hold a tool themselves (a horrifying truth we sometimes hide from our students), their practical technical expertise and insight will remain one of the pillars on which their authority within their team is based.

It thus makes complete didactic sense to have students run the lab, as running a lab is a skill they need to acquire anyway. Also, running the lab gives students a sense of ownership:

Figure 6.3.1 Students working in FABLAB Brussels at the Vrije Universiteit Brussel.

Photo credit: Lieven Standaert

the Fab Lab truly is their lab. This means that the need for maintenance, for signalling necessary repairs, does not have to be explained by staff. Of course, staff is still necessary: particularly tricky problems need expert advice, orders need to be placed, strategic decisions need to be made. This is generally not something for students to do. But compared to our other teaching activities, students in the Fab Lab operate with much greater autonomy, and as staff we can fulfil the coaching role that we can only dream of for other courses, where students often engage less fully.

The ownership of the Fab Lab by students leads to a natural peer-teaching dynamic. As students progress through the curriculum and work collaboratively on projects, those who are most committed tend to congregate and motivate one another, steadily enhancing their skills. Other students acknowledge their proficiency and often seek their guidance and counsel.

Student ownership of infrastructure and learning is not specific to engineering, and its merits in terms of a fuller engagement with the curriculum should be applicable to sustainability education in different fields.

User diversity needs to be managed

Safety is the prime concern in any workplace and certainly in labs with potentially dangerous machines. Even though the average skill level of our users is high, there is considerable diversity. First-year students are less experienced than last-year students. As a Fab Lab we do not only serve our students but are also open to the public. External users may be working in a Fab Lab for the first time. It is a challenge to manage this diversity in a flexible way that maximises safety. The way we do that is to very clearly define whether a certain user is skilled to work with a certain machine. For every machine or technique, we provide workshops or step-by-step tutorials. After the workshop is completed, the student performs a test that demonstrates to a member of staff that they are skilled to work with the machine in question.

To manage this in a flexible way, we have developed a badge system. Every student or visitor receives a badge, which contains a dynamic list of the machines with which they are skilled to work. Every machine has a badge reader and will only work after the user is identified by the reader. The system behind the badge reader then checks whether the user is skilled for that machine and will only operate in case of a positive identification.

Of course, user diversity goes further than technical skills. Also, managing user diversity is not unique to sustainability education; it is a challenge faced by educators across various fields. However, due to the inherently interdisciplinary nature of sustainability education and the need to connect with local stakeholders, user diversity is particularly important for sustainability education, and it is likely that most programmes in sustainability education will need to leverage and manage user diversity (see Chapter 6.4 in this volume).

Sustainability requires durability

Sustainability at the very least implies the ability to manufacture things that last. Making stuff that breaks is obviously not sustainable. Some of the things we manufacture are, inevitably, other machines. The idea of machine self-reproduction, as pioneered by von Neuman (von Neumann and Burks 1966, 294), is of fundamental importance, and it is popular among makers as both a theoretical framework and a fantasy. At a more practical level, a Fab Lab offers the opportunity to use the available machines to make new machines. For example, most standard 3D printers only allow for the printing of relatively small objects (e.g. 25 cm × 21 cm × 21 cm for a Prusa I3 MK3S). This is bound to become rather limiting at some point. A bigger, more expensive 3D printer can be bought, but a logical step is to use the available machines and materials such as aluminium profiles to build a larger 3D printer. This is an exercise students of ours did with the aim of printing wind-turbine blades larger than 1 m. Although the students built an impressive machine, the precision of the prints deteriorated after a few runs. One of the main issues is that in some places, the materials we had used were not sufficiently stiff, resulting in excessive play that worsened over time. Of course, the design could be improved to circumvent these issues. However, the example taught us a more general lesson: if we were to make machines that would last, we would need to use more durable materials. Among other things, this meant being able to work with metal with the same ease with which we worked with other materials.

One of the workhorses of any Fab Lab is the laser cutter. This machine allows to cut two-dimensional shapes from plates. These shapes can then, if desired, be assembled into three-dimensional objects, as illustrated in Figure 6.3.2.

The laser cutters we have in our lab only allow to cut through plywood up to 6 mm or acrylic up to 10 mm. This allows plenty of things to made, but cutting metal is out of the question. The metal we need for sturdy and durable machines can, however, be cut with a waterjet cutter. A waterjet cutter uses a high-pressure pump to create a narrow jet of water mixed with an abrasive to cut through material. A typical waterjet cutter runs at a pressure of a few thousand times the atmospheric pressure. The speed of water in the jet is around

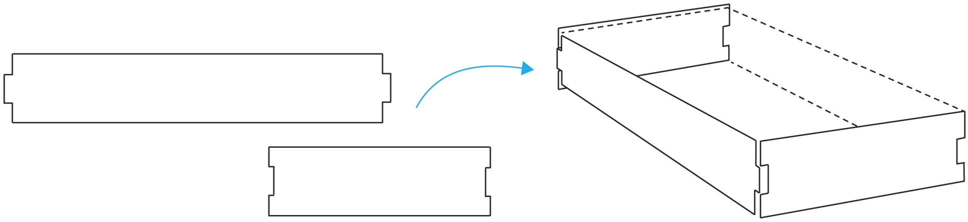

Figure 6.3.2 Shapes cut from a plate with a laser cutter or waterjet cutter can be assembled into three-dimensional objects

700 m/s, which is roughly twice the speed of sound in air, giving a new meaning to the term 'supersonic jet'. Waterjet cutters essentially cut through anything. In addition to being powerful, waterjet cutters are also precise.

Of course, machines with such capabilities are expensive. Too expensive, in fact, for our lab. The only way we were able to acquire one was because our students found a disused, disassembled, second-hand watercutter at an auction in Holland and was confident enough that they could restore it to working order. Thanks to the training and can-do attitude of our students, we can now cut through steel plates of practically any thickness we may need, as shown in Figure 6.3.3. And this at about one-tenth of the cost of a new machine. This illustrates the circularity of the training: machines are used to train the students who can then build or acquire new machines.

The effect of the Fab Lab on teaching: students are getting better

Teachers have been carping about declining standards since the Middle Ages and probably before. In the early fourteenth century, the Franciscan friar Alvarus Pelagius complained that students attend classes but make no effort to learn anything (Tierney 1992, 296–297). And everywhere you go, you hear that standards are declining. Our experience has been quite different. We have noticed that, actually, students are getting better, at least at what they do in the Fab Lab. If we compare the level of current student projects with the projects of ten or even five years ago, there is a clear increase in technical sophistication. We believe peer learning and peer pressure explain at least part of this improvement. Unfortunately, we do not have all that many projects where students of different years work closely together. This is not because we do not believe in such projects (we do), but only because these are more difficult to organise when schedules are already very full. However, students share the same lab space and see each other's work. We believe this is causing an upward drift in quality, as students learn from other students what is possible and are challenged to surpass what their peers have done. At the same time, among the staff, there has been an increase in confidence about what students are capable of. When we first started out with the Fab Lab, we would not have dared to ask second-year students to build a small wind turbine from scratch. Now we know that this, and more, is possible.

Prototyping makes you smart

The effect of the Fab Lab within the programme goes beyond the technical skills that students acquire. There has been a noticeable effect on many other courses. It is not always

Figure 6.3.3 A proud student holds a sign cut by a waterjet cutter.

Photo credit: Lieven Standaert

easy to identify precisely why the effect is so important. Part of it comes from shared experience. Students have worked together on projects that professors are familiar with. This means that concepts can be illustrated by prototyping examples pulled from a common reservoir. These examples involve machines and materials and are, by, definition concrete. This focuses the attention of students.

The ability to make things also has a profound impact on the way students think. One thing a Fab Lab does is to drastically reduce the distance between an idea and a prototype. Somehow this tends to crystallise thoughts even when the prototype is not actually built. The fact that it can be built, with relative ease, already brings things into sharper focus. This tends to prune sloppy thinking, as it is harder to make careless statements when there is such an immediate path to a practical test.

The danger of prototyping

One can have too much of any good thing, and prototyping is no exception. The ease with which prototypes can be built, and the experience that students have with building them, sometimes leads to a problem-solving approach that can be described as *build now, think later*. This is to a large extent a result of the training we give our students, as students will most readily use the tools with which they are most proficient and the materials they know well, even for problems that would be more readily solved with other tools or materials. This is akin to, but different from, Kaplan's Law of the Instrument. It is less a case of everything looking like a nail to the student who has a hammer than that students who have a hammer will use it for other tasks than pounding. This overuse of familiar tools and materials is not innocuous, as it may lead to a suboptimal trial-and-error approach.

Apart from being suboptimal, a trial-and-error approach hampers the development of important modelling skills. Modelling is an essential engineering tool. It can decrease cost and increase safety and sustainability. At a fundamental level the purpose of modelling is to visualise the relation between the intention of an activity and its outcome (Gilbert et al. 2000, 17). The important thing here is that the visualisation comes first. It precedes, and influences, the outcome of the activity. With an adequate visualisation, a positive outcome is more likely. To quote an example made famous by Sartre (1946, 2), an artisan making a paper knife starts from a conception of it, and it is hard to imagine an artisan making a good paper knife without a clear conception of its eventual use. (The central idea in existentialist philosophy, at least in its atheist form, is then that man is fundamentally different from a paper knife, in the sense that there is no conception of man that precedes the existence of man. The existence comes first. But that's a different subject).

Modern engineering provides tools to take this conception much further than Sartre no doubt imagined. We have computer-aided design, physical conservation laws (such as Newton's second law) and a wealth of data with powerful tools for data-analysis that allow us to design a paper knife under certain specifications (cost, mass, time between sharpenings, etc.). Furthermore, the model may be used to *simulate* the expected behaviour of the paper knife. Such a detailed conception of the object being manufactured, and the possibility to simulate its behaviour under different conditions, contributes to a more sustainable design: it has the ability to reduce the number of prototypes before series production, to limit faults and failures and to reduce energy and material cost. It is therefore important in engineering education to develop modelling skills as well as prototyping skills. In the paragraphs earlier, I have argued that some tension may exist between these two sets of skills.

Building wind turbines

In one of our coolest and most successful second-year projects, students were asked to design and build a working wind turbine from scratch. Requirements in terms of energy production were modest, but the turbines had to be fully functional in terms of control, safety requirements etc. The fact that essential functional components (blades, generators, yawing system, anemometers, etc.) were often made from scratch and then assembled gave students an invaluable insight into how a wind turbine works and that it is non-trivial to capture the energy available in the wind. More importantly, perhaps, students learnt that they *can* build a working wind turbine if they put in the time and the effort. The wider sustainability lesson here is that solutions are within reach, and something can be done. A can-do, solution-driven attitude to sustainability may be exactly what sustainability education needs to provide amid increasingly worrying and gloomy climate forecasts. After all, if the current generation of students stops believing that the sustainable development goals can be reached, we will truly be in trouble.

Circularity through distributed manufacturing and repair

In a way, a Fab Lab is a small factory. Its basic requirements are quite limited and within reach of many organisations in most countries. And the key added value of a Fab Lab to a local community doesn't even need the lab to be outfitted with everything that is listed by the Fab Foundation. An open workshop with some kind of training programme and access to materials can be enough to make a difference. The idea is that local communities can meet their needs by manufacturing certain things themselves. At least in principle, this allows them to better customise products, to tailor them to local needs. This in turn encourages on-demand manufacturing, where products are manufactured if and when such a product is asked for. On-demand manufacturing increases sustainability by reducing inventory waste, because there are no heaps of stuff waiting in warehouse until they find a user or are discarded because consumer demand has moved to other products. Also, local manufacturing has the potential to reduce shipping costs. Distributed manufacturing is strongly linked to circularity and the enablement of new circular business models, as replacement parts can be easily fabricated by local industry even if the parts are not standard parts. This aligns with the 'right to repair' further discussed later. Finally, distributed manufacturing is also a way of distributing knowledge and thereby empowering local communities.

To produce or to repair

A key element to responsible consumption is of course to avoid waste by thinking twice before discarding a defective product or machine (see Chapter 4.2 in this volume). If it can be repaired, repair is likely to be more sustainable than replacement. Repairability is a multifaceted issue, but central to any repair is technical expertise. Any repair beyond the trivial is likely to require a certain level of technical expertise and confidence, given the fact that the repaired article should be as trustworthy as the original. This is where Fab Labs make an important contribution: by providing technical training directly geared towards the interest of the trainee and giving the trainee the confidence to repair.

There are many other facets of repairability. Although a thorough discussion is beyond the scope of this contribution, I would like to briefly mention some aspects of repairability that go beyond technical ability.

Big tech companies often actively oppose repairability. It is not exaggerated to say that many products are specifically designed *not* to be repairable. Access to the defective component will often involve handling the housing in a way that risks breaking it. The repair may require tools that are difficult to obtain, and finding manuals is no easier. The planned obsolescence built into some products is merely the unpalatable extreme of the same logic.

Legal finesse can also erect multiple barriers to repairability. Intellectual property rights, although generally legitimate and justified by themselves, can be used to lock up a product completely. Then there are constructions by which the buyer of a product does not actually own the product, because they have in fact bought a service and legally do not have the right to repair the product. This goes further than voiding the warranty, which many makers and tinkerers will do quite happily. Sometimes repairing actually means breaking the law. This ownership model may make sense for megawatt-class wind turbines, where repair work is indeed highly specialised, but is rather perverse when it is used to prevent farmers from repairing their tractors. On the other hand, selling products as a service has the potential benefit that the manufacturer has an interest in a long-lasting repairable product. The sustainability of products as a service then depends on how dedicated the manufacturer is to preventing waste by repairing. To put it very mildly, many companies have a track record that is far from exemplary in this regard.

It is therefore no surprise that we are living in the age of waste (Wainwright 2021). The driver for these companies is to make money, preferably loads of it, not to save the planet. There is of course a business case for saving the planet, and as the planet's demise moves from a long-term consideration to an imminent threat, more and more companies will become aware of the business opportunities that sustainable production offers. But the process is painfully, and perhaps fatally, slow. Placing the stewardship of the product with the buyer will therefore often present the most sustainable option.

The greater sustainability of repair compared to production is partly due to the fact that it shifts the focus from energy and resources to labour (Stahel 2016, 435). Repair uses fewer resources than manufacturing a new product, but will invariably be more labour intensive. Furthermore, repair is generally more local than production: the cars driving around in our cities come for all over the world, but are serviced and repaired locally.

The substitution of manpower for energy and resources must have appeared like a no-brainer in the 1980s when it was first proposed (Stahel and Reday-Mulvey 1981, xviii). Over recent years, the substitution has become more problematic, as skilled labour is no less in short supply than energy or resources. This again points to the need of practical training that Fab Labs can provide. The workforce is there, and is likely to be swelled by new waves of migration. Fab Labs can contribute to better matching the skills of the workforce with changing demands and new societal challenges. In this way, Fab Labs with the right training programmes can make our society more sustainable through a shift towards a circular economy, while at the same time contributing to a more equal and more connected society.

Supply lines and the bicycle crisis

Beyond the human suffering and the medical achievements and heroism, the COVID pandemic was also a stress test of our existing models of education, transport and production. This stress test has brought our dangerous dependence on fragile global supply chains into stark focus.

One of the many examples of this dependence is what one may call the current global bicycle crisis. In the interest of full disclosure, I should first confess here my passion for cycling as a sport and a means of transport and my belief that bicycles are the finest machines ever invented, with the possible exception of wind turbines. Often, as is the case here, bicycles are the most natural way for me to illustrate a point.

As being near other people came to feel risky during the pandemic, public transport became less appealing. Many people of course took to their cars, but especially in cities, the bike became an option also for people who were not yet active cyclists. Rising fuel prices were another factor, as was, hopefully, increased awareness of man-made climate change. Furthermore, cycling outdoors was allowed in many countries when fitness centres were closed. So cycling for fitness and recreation also took up.

While more and more people, many of whom did not own a bike or at least not one they believed was suitable, started to bike, production of bicycles and bicycle components slowed down because of reduced production capacities. It became very hard to get a new bike. (When one of my daughters recently wanted to buy a mid-range racing bike from a major company, waiting times for the different models were all in excess of 12 months.) This situation lasted for almost two years and is still not completely solved.

In terms of production, two reasons explain why it is taking so long to solve the bicycle crisis. First, the dominant model for production is linear rather than circular: bicycles are made from base materials such as carbon or aluminium tubing. Secondly, production is not very flexible: bicycles can only be made in bicycle factories, and production volumes are hard to ramp up. A more circular economy, combined with flexible production, provides a way out.

The first thing to note is that there is a stock of bicycles locally available. Many people buy a bike and stop using it after the initial enthusiasm has waned, often rather quickly. The bike then sits in a cellar or a shed. After a few years, some maintenance will be needed to restore the bicycle to working order. Some new cheap bicycles sold outside bike shops are so shoddily assembled that they develop a problem within the first weeks of use. In most of these cases, a moderately skilled mechanic can repair the bike. Insightfully, the French government, between May 2020 and March 2021, granted a 50 EUR bonus for every bike restored to working order, with the explicit ambition of getting the bike out of the cellar (Razemon 2021). Local workshops and networks are of course essential. To meet a large-scale challenge, small solutions will not suffice, and we need more mechanics. Training, of the kind that can be done in a Fab Lab or a local workshop, is key. Our Fab Lab in Brussels has the advantage of sharing a site with the aptly named *Hors Catégorie*, who offer repair services but also repair training and a workshop for cyclists who cannot work on their bicycles at home. As building and strengthening local communities is an import aspect of sustainable development (SDG 11), coffee and group rides are also a part of the service. It is this combination of a network, an available stock and the training of skilled mechanics that shows that the circular economy is doable and viable and is a robust way of meeting a challenge.

For the sake of completeness, I should mention here the rapid growth of bicycle rental in cities. Although beyond the scope of a contribution focused on technical training and local production and repair, these rental services make it much easier to use a bike occasionally and provide a platform for new cyclists to test whether they like cycling.

Rising to the challenge: the Breathney ventilator project

At the start of the pandemic, there was a fear of a shortage of mechanical ventilators. The question was put to us whether we would be able to build ventilators. We did not know, because we had no medical training, but we knew that we were willing to try. Even though, eventually, there never was a shortage of mechanical ventilators in Europe, the lessons learnt from the project are worth sharing.

One of the many advantages of being an academic Fab Lab is that we had direct access to a university hospital. We could therefore discuss the medical specifications of a mechanical ventilator with them, build on their network and interact with previous similar initiatives.

From the start, we decided to view our ventilator as a toolbox with open-source hardware and software, so that we could share our designs and prototypes with other groups. We were, however, deliberately cautious about sharing our design indiscriminately before it had been thoroughly tested. Also, we made the design as modular as possible, so that parts of our design could be integrated in other designs. A second important design choice was to avoid the use of medical components as much as possible. A major health crisis was happening and we did not want to further stress already overburdened medical supply lines. Partly because many of our students had been involved in the Formula Student race car competition and were often car enthusiasts, the automotive industry was a natural sector to turn to. This is not the place to discuss the design in detail (those interested can find more information on https://breathney.vub.be) but we used, for instance, truck windscreen wipers for mechanical actuation and automotive sensors for monitoring and control. With these guiding principles and starting from an MIT design (Al Husseini et al. 2010), a team consisting mostly of engineering students, built a first prototype of a mechanical ventilator in four days (and nights). The team grew to more than 50 members and over the course of April 2020 developed a fully functional ventilator.

Upscaling and flexible production

It is fair to say that most of us were surprised at how rapidly we made progress. The Fab Lab is always a dynamic place, but the energy during those first six weeks was very special. Students were sleeping in the offices of their professors, with full support of those professors and the university administrators, to be able to get back to work as soon as possible. It took me a while to realise that, while developing our Fab Lab, we had prepared ourselves for exactly a challenge like this. Over the years, we had acquired the right machines and learnt how to organise the lab. We had students who were used to working on projects together and could afford to be blunt without falling out. We were known within our university as people who got things done, so support did not need to be negotiated. It was immediate. Although it may sound arrogant, we were not only ready but also very much suited for the challenge.

The challenge in the example was not directly related to sustainability. However, I would argue that the skill set, the can-do attitude and the local network that enabled our students to build a mechanical ventilator also make them suitable to address technical challenges related to sustainability. Hopefully, they also acquired the confidence that they can rise to the occasion and propose working solutions to big real-life challenges. Building such confidence is a valuable outcome of any programme in sustainability education.

Conclusion

In this contribution, I have argued that Fab Labs provide a unique platform to train better engineers and that the skills acquired are key to building a more sustainable future. The way in which Fab Labs can be used in sustainability education has a relevance that goes beyond engineering. First, it is important to realise that making and prototyping are as important in fields such as art, fashion and architecture as they are in engineering. With some exceptions, such as the emphasis on students being able to build their own machines, the illustrations given earlier apply almost directly to education in those fields. The Fab Lab model also shows a way for universities to break down the proverbial ivory tower and engage with local communities. The transfer of knowledge between universities and their local communities is important in its own right but given the multidisciplinary nature of sustainability, the increased diversity that comes with community engagement is of crucial importance for sustainability education.

I have argued that the education model provided by a Fab Lab gives students a sense of ownership of infrastructure and learning. This deepens understanding and confidence and may foster a positive can-do attitude that is necessary for successful sustainability education.

Fab Labs are part of a broader trend towards smart decentralised production, often called distributed manufacturing, which is potentially a more sustainable form of production. I hope to have demonstrated that the combination of the prototyping capability of a Fab Lab with the production capability of a flexible industrial plant makes a society more robust against major challenges that may require products to be manufactured rapidly at considerable volumes.

As Fab Labs are by definition open to the public, they provide technical skills to a broad group of users, enabling them to contribute to a more sustainable future, in which the ability and the right to repair are crucial. The training opportunities that a Fab Lab provides thus give a diverse workforce the ability to adapt to changing demands, and remain or become active contributors to a more circular, sustainable economy.

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6.4

LIVING LABS AS A CONCEPT AND PLACE FOR HOLISTIC SUSTAINABILITY EDUCATION

Torsten Masseck

Key concepts for sustainability education

- Living labs are real-life test and experimentation environments where users and producers solve problems and co-create innovations.
- Higher education institutions (HEIs) need to redefine their learning environments allowing for real-world, collective and experience-based approaches to problem solving and ideation.
- Living labs and education for sustainable development (ESD) benefit from a common conceptual approach.
- Living labs at universities can create ecosystems for sustainable transition between university and public or private societal stakeholders.
- The architecture living labs at UPC empower students to be creators of their own teaching and learning processes in interaction with societal stakeholders.
- HEIs could strengthen their role as societal game changers for sustainable development through living labs as places for collective learning, knowledge generation and value discussion.

Introduction

With the aim of maintaining and fostering the many positive energies generated by the LOW3 project, the author proposed, designed and implemented LOW3 as *Living Lab for Sustainable Architecture and Lifestyle* at the ETSAV (UPC) campus at Sant Cugat del Vallès (Barcelona) from 2010 until today. Nevertheless, the term living lab, its concepts, its application in the field of architecture and its relation to sustainability education were not clear right from the start. This lack of an established conceptual framework motivated 5 years of theory and action research activities, leading to the author's doctoral thesis on living labs in architecture for sustainability education (Masseck 2016). This article summarizes some of the main findings, extends the discussion to other living lab projects at UPC and will hopefully be useful and inspiring for similar projects and initiatives.

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Education for sustainable development (ESD) in higher education

Many international commitments and declarations have been generated since the 1990's, with the aim of fostering and further developing ESD in general and ESD in higher education in particular. The Talloires Declaration (ULSF 1990) and the COPERNICUS University Charter for Sustainable Development (COPERNICUS Alliance 2011) have been the main documents through which several hundred universities committed themselves to promoting education for sustainability. Many subsequent declarations like the Rio +20 treaty on Higher Education (COPERNICUS Alliance 2012), regarding the introduction of ESD into the curriculum and the institutional frameworks of higher education institutions, show the continuous work in progress among universities and institutions in order to make ESD an essential part of the HE system. Based on the United Nations Agenda 2030 (United Nations 2015), the Sustainable Development Goals (SDGs) are now intended for integration into HE curricula, learning objectives are defined for integrating SDGs into education (UNESCO 2017) and a roadmap for this integration has been elaborated (UNESCO 2020).

Higher education institutions (HEIs) are identified as important stakeholders in the process of sustainable transformation of society on three levels:

- through their academic activities in the field of teaching, research and innovation: educating professionals, which will also be the future societal leaders and so-called game changers
- on the organizational level as communities with a specific practice, infrastructure and impact: the institutional performance as an example for the transition of society, e.g. campus operation and impact reduction
- and through outreach to society, as a stakeholder in learning and transformation processes: contributing through knowledge for action and influencing the societal practices of production and consumption

This holistic view of HE embedded in an organizational structure, which gets transformed to a higher level of sustainability by its members at all three levels, strongly connected to society and its real challenges, opens the opportunity for universities to become effective agents of change (Svanström et al. 2008). The underlying holistic transformation process of HEIs includes a necessary redefinition of learning outcomes of academic educational programs, new methodologies of teaching and learning and the overall redefinition of HE learning environments, giving answers to the following questions:

- Which are the places, tools, methodologies and strategies for the creation of efficient synergies between education, research and innovation for transition towards sustainability, including institutional transformation and outreach to society?
- Where and how can these multistakeholder processes be initiated, fostered and managed?
- What are the related desirable learning outcomes, skills and competences and values that should be promoted?

Real-world, collective and experience-based approaches have been shown to be powerful in this context, as learning on sustainability is not limited to the acquisition of specific knowledge, but rather needs a radical shift of focus, which can be achieved through interdisciplinary collaboration and exchange, value discussion, as well as real experiences of behavioural change. Concepts like "unlearning" are linked to the need to get out of routines to experience new habits and new ways of doing things. All of these processes need time and places to be implemented, experienced and optimized in order to be fully integrated into educational environments.

In this holistic transformation, the concept of living labs at universities can have a major impact, as it connects people, disciplines and physical places and has the potential to create ecosystems of transition between university and any kind of public or private societal stakeholders (see Chapter 6.3 in this volume).

History of living labs

Living labs are platforms which involve users in the innovation process by designing, developing and validating new technologies, products or services within real-life environments. The detected gap between research and innovation in Europe, the inability of European nations to transform their leadership in research into commercial successes in the marketplace (Almirall 2009), is in the origins of the emerging concept of living labs. Though innovation has formally been a task of individuals as entrepreneurs, a collaborative approach to innovation with multiple stakeholders seems to be a valid and useful option in a world of increasing complexity (Almirall 2009). In extremis, open innovation is defined as an open process where multiple stakeholders collaborate in the process of jointly developing new products or services (Chesbrough 2006). On the other hand, user participation in innovation processes has been identified as a valuable contribution for market readiness of products and services. According to these developments, living labs emerged to organize and structure user-centred research and participation in innovation, creating a framework for the corresponding activities and interaction among stakeholders.

Within the EU policy framework for information, society and media, focused on "Strengthening innovation and investment in ICT research", and embedded in co-operation and policy support programs for competitiveness and innovation, living labs have been fostered in their quality as interoperable collaboration environments supporting user-driven open innovation processes (European Commission 2009). With several pilot experiences operating, at the end of 2006 the European Network of Living Labs (ENoLL) was founded under the Finnish presidency to give support and structure further development of living labs as a methodology and mechanism to strengthen innovation in Europe. In 2021, more than 480 living lab projects were declared as registered members of the ENoLL network.

According to ENoLL, a living lab is a real-life test and experimentation environment where users and producers co-create innovations in a trusted, open ecosystem that enables business and societal innovation.

Architecture living labs

Architecture living labs emerge where a living lab approach is implemented within the context of buildings (e.g. existing buildings, homes of people, but also a housing complex or a city quarter) or where prototype architecture or architecture laboratories are opened up to the users, involving them in testing and innovation activities within a societal context (prototype buildings for real clients and users) or research context (prototypes or laboratories simulating real-life contexts).

Schuurman et al. (2013) differentiate living labs as extensions to test beds and living labs that support context research and co-creation, which are both focused on innovation through user involvement, including "American-style" living labs and living labs focused on knowledge exchange which are considered to be focused on exploration and not on co-creation. In the field of architecture, and taking as an example a prototype home, this could mean the following differentiation of the project as a living lab according to its focus:

- A prototype home tested under real-life and context-related conditions with real occupants for a certain period (living lab as extended test bed)
- A prototype home used as an environment to carry out context related co-creation activities with users and other stakeholders (living lab as supporting infrastructure)

Both forms of living labs are understood as innovation platforms for user co-creation. Alternatively, according to the differentiation of Schuurman et al. (2013), a living lab can be focused on exploration and not on co-creation, resulting in the following definitions:

- A prototype home as a show room and exhibition of technology and innovations (living lab as showroom or "American-style" living lab)
- A living lab as place to explore and learn (living lab for knowledge exchange)

Nevertheless, a review of case studies of living lab–like projects in the field of architecture show a huge diversity of concepts and denominations, e.g. applied research centre, showcase home, research laboratory, demonstration building, experimental platform, community lab, prototype home and observational research facility, among others. This reflects the persisting lack of clear definition of categories and shows that a corresponding conceptual framework is still to be developed. (Masseck 2016)

Living labs and education for sustainability

Education in the field of sustainability and specifically ESD requires the definition of a whole set of new learning outcomes, which can be best achieved through specific learning environments, tools and methods, fostering ESD-related knowledge, skills and competences and offering space for individual and collective reflection and redefinition of values. Living labs related to HEIs might match this demand for new learning environments and methods, due to their specific qualities, and might be forerunners for a new and innovative way of sustainability related teaching and learning at universities, strongly linked to collaboration, co-creation and innovation in real-life contexts.

Approaching a common framework of ESD and living labs, four ESD characteristic paradigms can be identified and related to corresponding living lab concepts as discussed next (Masseck 2016).

Multidisciplinary systemic approach

ESD is based on a critical, transdisciplinary and systemic view on sustainability related to our production and consumption systems, lifestyles and their environmental and social impact. Sustainable development is a multistakeholder process that must integrate all relevant actors of society.

Living labs correspond to this paradigm as they are focused on multistakeholder processes, are multi-disciplinary and are transversal, often constituted through public-private-people partnerships (PPPPs).

Participatory co-creative action

Sustainable development (SD) is an open-ended process, dealing with uncertainty and adaptation according to new knowledge and with changing paradigms as part of the process. Pathways for changes towards SD must be generated, negotiated and agreed upon by society and are related to the generation of new values, which must be defined and adopted collectively by participants in the process in order to make related transformation processes effective and long lasting.

Living labs correspond to this paradigm as they are based on user involvement, fostering user co-creation and participatory processes among diverse stakeholders.

Open collaborative environment

ESD is about exploration, insight, understanding, co-creation, adoption and implementation of more sustainable solutions as answers to societal SD challenges. The process of ESD itself is transformative and should be based on the free availability and exchange of knowledge (knowledge as common good, not an economic value), as well as collaboration and trust among people (e.g. in the discussion of values).

Living labs correspond to this paradigm as they foster collaboration and open innovation among entities, offer networking opportunities and allow the exchange of knowledge among partners, including value discussions.

Real-life context-related settings

ESD must be related to real problems in its real contexts in order to search for systemic solutions, considering all relevant social, environmental and economic aspects, not limited to disciplinary short-term changes. Knowledge for action, a paradigm of sustainability science, is a key element of ESD and requires relation to real-world challenges.

Living lab concepts concepts correspond to this paradigm as they focus on real-life environments – people in their everyday life – and are context related and multifaceted.

This correspondence of four principal paradigms allows understanding that living labs and ESD benefit from a common conceptual approach and therefore offer many synergies for the implementation of activities and generation of meaningful outcomes in sustainability education.

Living labs at UPC: BarcelonaTech

UPC works on so-called campus living labs by activating university buildings and their communities of users (students, faculties, administration) to experience, analyse and improve their buildings and the activities which take part in them with the goal of optimizing the environmental performance of the whole ecosystem (buildings, infrastructures, people, processes).

This approach creates communities taking over responsibility for the environmental impact of their workplace. Campus lab activities encourage all members of the academic community to collaborate beyond disciplines and backgrounds, empowering them as actors in the transition process of their institutions at all levels.

At the Valles School of Architecture (ETSAV), living labs play a major role specifically as instruments allowing the introduction of new pedagogical approaches in the education of architecture students through designing, building and operating experimental sustainable housing prototypes.

The development of these living labs has been linked to the Solar Decathlon Europe (SDE) Competition, an international competition of universities for energy self-sufficient solar houses. Originally from the United States, this competition has taken place since 2010 in four editions in Europe, and UPC participated in all four events.

In this competition, large student groups of 50–100 members across all levels of studies, with interdisciplinary collaborations between architecture students and engineering students and collaboration of companies, consultants and faculties, plan, build and operate 1:1 scale prototype homes. Focused on innovation in sustainable housing concepts and energy self-sufficiency through active and passive use of solar energy, Solar Decathlon projects generate knowledge, experience and tangible outcomes in a limited time, usually 2 years between start of the competition and delivery of the prototype.

Thus, this process of co-creation through a large number of stakeholders in a transdisciplinary and collective process is a singular, intense, enriching and successful pedagogical process for the education of students in the field of holistic sustainability transition. One unique quality is the holistic approach to housing, not only from a technical, material and systemic point of view regarding energy, carbon emissions or lifecycle but also from a sufficiency related discussion regarding our needs for habitation, the transition to a sharing economy, the definition of a good life and the relation between consumption and happiness. All this is related to the exploration of new concepts of housing such as co-housing, tiny-house concepts, collective neighbourhood infrastructures, habitability of urban space and others, which can be experienced and tested through real, operational prototypes.

The competition format of SDE allows also connecting on an international level to other groups of students with different cultural and sometimes also economic backgrounds, learning how they faced and solved the underlying challenges of the competition itself and in relation to the specific societal challenges in their home countries. This leads to a holistic learning experience which for many students means the personal transition from a student who expects input through teaching lessons to a young professional positioning himself in a changing world, who has designed, constructed and operated a highly advanced sustainable building in a collective process of creation and who is able and willing to defend environmental concerns and positions within his future professional practice.

Finally, these prototypes are not made solely with the purpose of competition. They are planned, at least in the case of UPC, in advance for a specific after-competition use, which allows generating real impact in society, reconstructing and operating prototypes as living labs in different locations, e.g., a campus site or embedded in a specific societal context. All four UPC prototypes have been operated as living labs during the last 10 years, with individual teams of students as main drivers of the projects (Masseck 2016).

LOW3 2010

The LOW3 living lab is based on the SDE 2010 prototype LOW3 of UPC, developed by a student team of its School of Architecture ETSAV under direction of the author. The project started in 2010 with the reconstruction of the solar house at the ETSAV campus at Sant Cugat del Vallès (Barcelona). The ETSAV School of Architecture is the main stakeholder of the project, with many administrative and industry partners collaborating and funding the project.

The main objectives of the project are:

- To convert the LOW3 prototype into a living lab as an experimental platform for teaching and learning about sustainable architecture, sustainable lifestyle and ESD
- To foster technological research and education on sustainable architecture, energy efficiency and renewable energies through designing, testing and evaluating the prototype solar house
- To generate educational research based on innovative experience-based, participatory learning methodologies, strategies and tools for ESD
- To use the fully functional solar house for real living experiences including monitoring and performance evaluation and exploring more sustainable lifestyles
- To create space and equipment for explorative and experimental educational activities with exhibition space for materials and technologies.

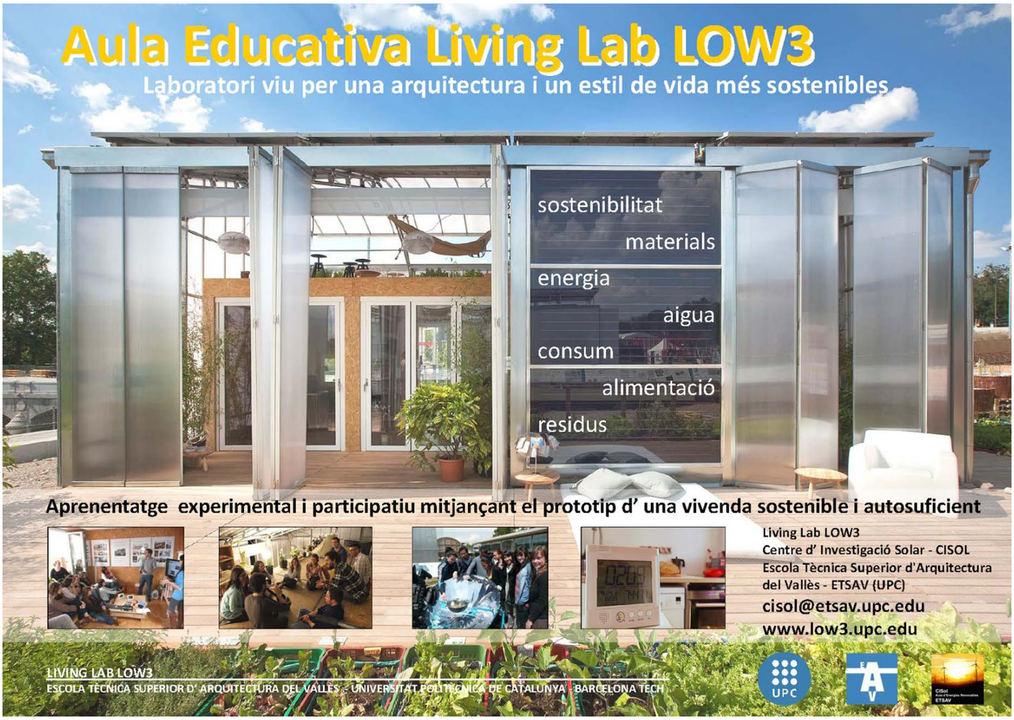

Figure 6.4.1 LOW3 living lab (UPC).

(*Picture*: Torsten Masseck)

The projects and activities of LOW3 are focused on educational research and innovation, especially through the living lab approach, which gave rise to a hybrid in-person and online course on sustainable housing and lifestyle.

Teaching activities have been carried out on all levels, from elective undergraduate and master's courses, guided educational visits and explorative activities up to regular co-creation and innovation seminars on the master's and PhD level. The house occupation experiment "Live at LOW3" allowed the evaluation of the prototype under real conditions of use as student housing for two people. The experiment was designed and carried out by students at the master's level with a holistic monitoring and evaluation of sustainable lifestyle parameters. Several master's and PhD thesis projects have been linked to the project. Industry research has been carried out in the field of concentrated solar photovoltaic (PV) systems. European research projects related to energy transition and sustainable lifestyles benefitted from LOW3 as a meeting room and inspiring place for networking. The huge diversity of uses and outcomes over the last 10 years validate the concept of LOW3 as an educational living lab with a transdisciplinary approach to teaching, research and innovation on sustainability.

Pas a Pas 2012

Pas a Pas is a project based on the SDE 2012 prototype e(co) of UPC. After the competition, the solar house was stored at the ETSAV campus with some modules used as temporary working space for the e(co) student collective, developing the concept for future use. Since 2015, the project has been located at the Les Planes neighbourhood of Sant Cugat del Vallès, near the ETSAV campus, as a community living lab and place for meeting and organizing neighbourhood initiatives. The main stakeholder is the city of Sant Cugat del Vallés (Barcelona), together with Les Planes Neighbourhood Association, the Arqbag cooperative (former e(co) student collective) and ETSAV (UPC) as university and author of the project.

The main objectives of the project are:

- To establish and support neighbourhood initiatives in the field of energy refurbishment, sustainable consumption and social innovation
- To adapt the prototype solar house e(co) through a new layout to the local site and its new program as community meeting and working space
- To create a neighbourhood building workshop and platform for social innovation regarding energy efficiency, use of collective space and sustainable lifestyle.

Projects and activities are focused on the analysis and evaluation of building standards of neighbourhood buildings through monitoring, collective development of solutions and execution of refurbishment concepts for housing and public spaces and the coordination of neighbourhood participatory processes and workshops.

Important outcomes are specific neighbourhood refurbishment projects such as the energy refurbishment of the roof construction of several houses or the refurbishment of the local sports facility. Pas a Pas has successfully implemented a program against energy poverty, improving the housing conditions of several elderly neighbours with very low incomes, while simultaneously activating the workforce of unemployed neighbours through a corresponding program together with the local administration. This allowed generating unique synergies between neighbours, administration, university and private companies through a

Figure 6.4.2 Pas a Pas living lab (UPC).
(*Picture*: Torsten Masseck)

PPPP, collectively improving the quality of life of citizens. User-centred research through user surveys, observation and monitoring formed part of the process and considerable outcomes could be generated in a relatively short time. The former UPC students and drivers of the project are currently successfully running the Arqbag Cooperative as young professionals, and some members evolved as professors at the faculty, transmitting their knowledge, attitude and experience gained in the last years to following generations of students.

RESSÓ 2014

Ressò is the 2014 SDE prototype of UPC. After the competition, the solar house was stored with the Ressó student collective developing and managing the concept and necessary agreements for its future use. Since 2016, the project has been located at the Sant Muç neighbourhood in Rubí (Barcelona) as a neighbourhood living lab and co-housing facility for meeting and organizing neighbourhood initiatives. The main stakeholders are the city of Rubí (Barcelona), together with the Sant Muç Neighbourhood Association, the Ressò student collective of ETSAV and ETSAV (UPC) as university and author of the project.

The main objectives of the project are:

- To create a neighbourhood facility for a low-density neighbourhood
- To foster knowledge generation and neighbourhood actions in the field of energy efficiency, renewable energies and sustainable lifestyles

Figure 6.4.3 RESSÒ living lab (UPC).
(Picture: Torsten Masseck)

- To offer a place where social innovation and networking among citizens can take place
- To develop and apply low impact technologies and new constructive solutions for the refurbishment of the existing building stock of the neighbourhood.

Users of the infrastructure are mainly the members of the local community who, together with other stakeholders, initiate processes of improving sustainability parameters of the neighbourhood (mobility, energy, social innovation). Educational initiatives allowed knowledge dissemination regarding energy efficiency and renewable energies using the prototype as a show case. Several local refurbishment projects have been carried out with the support of UPC students and faculties.

Ressò is a unique neighbourhood co-housing facility for meeting and organizing neighbourhood initiatives, which activates synergies among neighbours, administration, university and private companies through a PPPP in order to collectively improve the sustainability of the community. UPC students have been the drivers of the project from design and implementation to operation and maintenance. After graduating, the former UPC students have founded the Accio-Ressó cooperative, starting their professional life linked to the project.

TO 2019

TO is the 2019 SDE prototype of UPC. It is the newest project at UPC and has been rebuilt at the UPC Campus South Diagonal in Barcelona at the beginning of 2020, with the aim to start activities as a living lab that allows guided visits and educational initiatives for UPC

Figure 6.4.4 TO living lab (UPC).
(Picture: Torsten Masseck)

students and the general public. The project has received support for this post-competition use by the city council of Barcelona and the Barcelona Energy Agency.

The main objectives of the project are:

- To create a living lab which offers guided visits, exploration and activities related to sustainable housing and lifestyles
- To foster knowledge generation in the field of energy efficiency, renewable energies and sustainable lifestyles through seminars together with local energy agencies
- To offer an inspiring place to UPC students and faculties, but also to the general public, where innovation and networking can take place.

Due to the pandemic outbreak in 2020, no specific activity could be implemented up to date, but the operational infrastructure of the living lab is fully functional and ready to create a major societal impact regarding sustainability knowledge and education.

Outcomes of the UPC living lab experiences

The specific impact of UPC living labs can be quantified through the number of initiatives carried out and the involvement and participation of students and visitors. For the LOW3 living lab of UPC, this means as a result after 10 years of operation: 10 regular living lab LOW3 courses, 8 innovation and co-creation seminars on the master's level (InnoEnergy), 2 international summer schools, 1 house occupation experiment "Live-at-LOW3", 5 open doors days, 30 educational visits in collaboration with different secondary schools and HE programs and more than 40 special events which took place at LOW3, with overall around 600 student participants and more than 2000 visitors (Masseck 2017).

Nevertheless, many of the outcomes of the project cannot be quantified easily, as they refer to the creation of networks and educational outcomes in a non-formal learning environment, e.g. in the field of value discussion and interpersonal competences.

Living lab experiences at UPC showed that the generation of networks among the huge diversity of participants is one of the most valuable outcomes which benefit all stakeholders of a living lab project. HEIs build up or improve their university-industry relationships and their collaboration with public institutions; students build up interdisciplinary networks that often allow generating a core group for a start-up initiative or any other type of cooperative enterprise linked to the project; and companies get into touch with potential future collaborators among the participating students.

Regarding educational outcomes, four generations of students have been educated through this new concept of architecture living labs at UPC, generating a high amount of environmentally sensitive young professionals. These young professionals are trained on sustainable construction, with the ability to collaborate with professionals from other disciplines in the optimization of energy and environmental concepts, but also understand the wider societal impact and social meaning of architecture, e.g. regarding energy poverty, inclusion, immigration, mental health and similar aspects.

Finally, some of these UPC students created environmentally focused cooperative associations, leading light house projects on sustainable co-housing and sustainable refurbishment in Barcelona, besides maintaining their link to teaching and research at UPC. This allows them sharing their experience with new generations of students and contributing to the ongoing sustainable transformation of education at ETSAV.

Critical view on living labs as educational infrastructures in HE

Living labs are in HE are complex projects with a huge variety of stakeholders to coordinate and several challenges to overcome regarding infrastructure, financing, management, operation and related issues. Based on the experience of 10 years of operation of the LOW3 prototype as a living lab at the ETSAV School of Architecture and the experience of three more living lab projects of UPC, some critical aspects of living labs in HE can be mentioned (Masseck 2017):

- **Lack of institutional integration:** We stated a lack of institutional support mechanisms and a missing teaching and research framework which would make integrating living labs with their special dynamics easier in higher education, existing curricula and the operational structures of a campus.
- **Missing culture of collaboration:** There is still a lack of collaboration culture between university, companies and administration when it comes to teaching, research and innovation through living labs and the use of real-life environments. PPPPs are difficult to establish and to maintain over time, as the diversity of stakeholders requires constant negotiation regarding individual interests, expectations and contributions.
- **Complexity of the living lab approach**: The complexity of living labs in educational environments is challenging due to the number of stakeholders involved and the need to create, operate and maintain a physical infrastructure. This requires a physical place for

implementation, an operational plan for exploitation and a business plan for its financial viability, as well as collaboration agreements among stakeholders.

- **Recent appearance:** Due to the relatively recent appearance of living lab activities integrated into HE environments, there is only limited experience and a lack of knowledge about successful operational and business models.

Some of these aspects could be improved over time through the increasing experience with living labs at UPC. Progress could be made, for example, in the integration of living lab activities into curricula by linking the projects to specific subjects and recognizing the competences acquired through the participation in a living lab project. Many other challenges still must be addressed by HEIs and the related stakeholders to fully integrate living lab projects as tools and platforms for holistic sustainability education.

Conclusion

Living labs were originally defined as a systemic innovation approach, where multiple stakeholders collaboratively participate in the development process of a new product or service. The experience at UPC shows that this market-oriented and technology-based living lab concept can be transferred into the academic world of teaching, research and innovation in HE.

ESD-related competences and strategies have been associated with the four main characteristics of the living lab approach: the multistakeholder approach, the user involvement approach, the open innovation approach and the real-life setting approach, showing that living labs can be valuable instruments for ESD and serve as transformational tools for HEIs' transition towards SD.

HEIs are expected to be societal game changers contributing to progress through the generation of new knowledge, the contribution to societal well-being and the implication in societal challenges and value discussions. In this context, academic living labs for teaching, research and innovation could serve as shared activities platforms for all HEI stakeholders, offering teaching and learning services to students, research and innovation environments to researchers and collaboration and outreach activities to society.

UPC's experiences with four living labs allowed a transition from student-centred teaching to participatory teaching and learning through the projects, with students as creators of their own teaching and learning processes in interaction with many other relevant societal stakeholders. Living lab projects at UPC show the diversity of possible approaches and their potential to create impact, but also allow identifying a series of challenges of the concept regarding organization and management, integration into the established academic settings and sustainability of projects over time, which must be addressed for broader integration of living labs as educational tools for sustainability education in HE.

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6.5
LEARNING TO COLLABORATE

Didac Ferrer-Balas and Gemma Tejedor Papell

Key concepts for sustainability education

- Collaborative approaches are at the very nature of sustainability processes. The ability to collaborate successfully in interdisciplinary and professional teams and to involve diverse stakeholders in meaningful and effective ways is essential.
- Project-based sustainability courses and collaborative learning are useful but can fail if not enough attention is paid to the quality of the collaboration.
- Collaborative competencies are part of sustainability competencies and require a reflexive approach.
- The transdisciplinary approach brings collaboration between society and academia as a core element to traditional research. It is based on the integration of knowledge between different disciplinary knowledge and practice.
- Collaboration involves working together towards a common goal that combines the rational and the emotional. It involves respecting and encouraging diversity, aligning expectations, planning, reducing uncertainty and building strong relationships.

Introduction

Most sustainability challenges are complex and require solutions that come from cooperation and collaboration between different groups, sectors, or institutions. The UN Agenda 2030 (United Nations, 2015) recognizes that the Sustainable Development Goals (SDGs) "can only be realized with a strong commitment to global partnership and cooperation". This means that the people who have to develop this commitment through "partnerships between governments, the private sector and civil society" must be able to collaborate. International experts in sustainability education agreed upon a framework stating eight competencies that students should be trained in for advancing transformations towards sustainability (Brundiers et al., 2021,). The eight competences gather five "key competences" (Wiek et al., 2011) namely, systems-thinking, anticipatory, normative, strategic, and interpersonal competence, and three emerging competences, namely intrapersonal, implementation, and integration competence. This framework points to the importance of collaboration in advancing sustainability

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transformations. An essential part of interpersonal competence is the ability to collaborate successfully in interdisciplinary and professional teams and to involve diverse stakeholders in meaningful and effective ways. These competencies can be developed through listening, compassionate communication, negotiation, and conflict resolution. In addition, integration competence is necessary for a coherent combination of collaborative and self-caring planning and implementation efforts, using established procedures for sustainability problem-solving, and achieving SDGs (Redman & Wiek, 2021).

However, to date, not enough attention has been paid to training people to collaborate. One possible explanation is given by Keast and Mandell (2013) when they affirm that

> people with collaborative skills are not currently highly rewarded nor valued for these skills. This needs to be changed if collaborations are to become more effective. Working in collaborations will require trying out new skills and expanding current competencies, often in new settings, all of which will involve risk taking, but the reward will be the ability to achieve innovative and sustainable solutions to complex problems.

It is generally thought that collaborative attitudes should have been acquired in previous educational stages, but higher education has a great potential to increase the capacity of learners to develop skills, knowledge, and attitudes. Nevertheless, collaborative learning (CL) has been applied increasingly in teaching. It can be defined as a set of teaching and learning strategies promoting student collaboration in small groups (two to five students) in order to optimize their own and each other's learning (Johnson & Johnson, 1999). To achieve this purpose, teachers have made attempts to organize different types of collaborative activities in their classroom teaching. The literature refers to several obstacles affecting the effectiveness of CL, including students who participate in such learning activities expressing their lack of collaborative skills (Le et al., 2018). Another barrier to take into account is "the dominant pattern at universities to put more emphasis on research than on teaching, which "leads to or consolidates the practice of utilizing project-based sustainability courses for generating more research outputs, at the expense of facilitating deep learning experiences for students and participants overall" (Le et al., 2018).

More recently the transdisciplinary approach brings to traditional research, as a core element, the collaboration between society and academia. Transdisciplinarity has been considered "the methodology" of sustainable transition (Scholz & Marks, 2001), strongly overlapping and interchangeable with sustainability science (Kates et al., 2001). It is based on the integration of knowledge between different disciplinary knowledge and practice (Scholz & Marks, 2001), through processes of co-design, co-production, or co-creation (Gibbons et al., 1994) to achieve new, socially robust knowledge (Nowotny et al., 2001). Society adds a real-world standard of quality, which cannot be achieved by disciplinarians (Bergmann et al., 2005). In some universities, "experiential knowledge" and "scientific knowledge" were integrated into case study–based research and education as a reality of transdisciplinary collaboration (Scholz & Steiner, 2015), which is still considered essential to achieve the UN SDGs (Fuso Nerini et al., 2018).

Collaboration in sustainability key competencies

It is important to understand the relationship between competencies for sustainability and collaboration. Wiek and colleagues (Wiek et al., 2011) identified five key competencies for sustainability: systems-thinking competency, futures thinking (or anticipatory) competency, values thinking (or normative) competency, strategic thinking (or action oriented) competency, and collaboration (or interpersonal) competency. The ability to collaborate fits in the "collaboration competency", which they define as "the ability to motivate, enable, and facilitate collaborative and participatory sustainability research and problem solving. This capacity includes advanced skills in communicating, deliberating, and negotiating, collaborating, leadership, pluralistic and trans-cultural thinking, and empathy". All these skills are particularly important for successful stakeholder collaboration with stakeholders and a necessity for most of the methods assigned to the previous competencies. The ability to understand, embrace, and facilitate diversity across cultures, social groups, communities, and individuals is recognized as a key component of this competence (Wiek et al., 2011). Later on, based on the work of the earlier cited studies and other authors (de Haan, 2010; Rieckmann, 2012) a set of cross-cutting key competencies for achieving all the SDGs was compiled by the UNESCO in order to sustainability citizens "to be able to collaborate, speak up and act for positive change" allowing people "to engage constructively and responsibly with today's world". Three more competencies were added, shaping the eight key cross-cutting competencies for sustainability: critical thinking, self-awareness, and integrated problem-solving competencies. In this report "collaboration competency" is defined as "the abilities to learn from others; to understand and respect the needs, perspectives and actions of others (empathy); to understand, relate to and be sensitive to others (empathic leadership); to deal with conflicts in a group; and to facilitate collaborative and participatory problem solving" (UNESCO, 2017), adding the emphasis in empathy, learning from others, and problem solving.

In addition, collaboration is also related to the rest of the five competences mentioned. For example, the famous proverb "if you want to go fast, go alone; if you want to go far, go together" illustrates its long-term thinking nature (anticipatory competence), and sharing the sense of purpose in a group connects to the strategic competence. Collaboration also implies agreeing on standards (normative competence) or looking at interconnected relationships through the lens of different perspectives (systems thinking).

Collaborative approaches are at the very nature of sustainability approaches for governing the commons (Ostrom, 1990), setting self-limitation (Princen, 2005), and finding new ways to organize sustainable companies (Laloux, 2014), just to cite some. In that sense, education for sustainability should provide a basic toolbox for understanding the fundamentals of what constitutes good collaborative work. Since most collaborations are team-based, this chapter focuses on a minimal toolbox for learning the collaborative competence.

Learning to collaborate

Collaboration skills can be learnt. Daniel Goleman (Goleman, 2004) states that "the skills and characteristics of collaborators are different to the norm. While some people inherently possess collaborative competencies and characteristics, they can be learnt if members are willing to step outside the comfort zones of usual practice". It is also important to note that collaboration capacities are not correlated to level of education, so the fact that an individual progresses academically does not mean he or she will collaborate better. For example, studies have shown that the presence of experts on a topic might be a handicap for the performance of a group to find solutions on this topic, as they can get blocked on the lack of skills to cooperate (Gratton & Erickson, 2007).

Collaborative practices can range from few individuals to large crowds. Although there are some major collaboration experiences, most collaborations happen in small groups. New large collaborative organizations (Laloux, 2014; Pflaeging, 2014) take the form of aggregated self-organized cells which share a general purpose but are autonomous. Therefore, the most appropriate learning context to practicing and reflecting on collaborative competences is a small group in a project or initiative, as proposed by project-based learning and other CL methods. These learning activities might range from simple learning contexts to much more complex situations. Brundiers and colleagues (Brundiers et al., 2010) refer to the importance of using a "progressive model": suggesting, first, to bring the world into the classroom (e.g., through guest visits); second, to visit the world; third to simulate the world (practice interactions in a safe space); and fourth, to enter the world and address real-world challenges.

This is also mentioned by Theres Konrad et al. (Konrad et al., 2021), who state that "professional interactions need to be carefully developed and monitored by the instructor, for instance, through a sequencing approach to stakeholder engagement".

In a recent study, these authors put the focus on four types of interactions of project-based learning related to three sustainability educational programs at the master's level and study how they can contribute to learning collaboration skills:

- Peer interactions (student-student interactions)
- Student-stakeholder(s) interactions (professional interactions)
- Student-instructor(s) interactions (deliberate interactions)
- Student-mentor(s) interactions (supportive interactions)

These interactions offer students different, authentic, and potentially new perspectives in how to work together. The authors conclude that "project-based sustainability courses are uniquely suited to develop students' interpersonal competence; even more so, if the various interactions inherent in such courses are used deliberatively, beyond just learning-by-doing". For example, they state that "observing peers is not sufficient alone; it requires processing the observations (reflecting), e.g., in conversations with peers, which allows students to compare and contrast their own perspectives, preferences, and style of working with those of others". Therefore, this indicates that instructors need to offer opportunities for reflection.

However, one difficulty for this process is the competence of the instructors. Freeth and Caniglia (2020) point out the often-held assumption that researchers already know how to collaborate when entering interdisciplinary research teams and argue that, if we want to enhance interdisciplinary sustainability research, we need to take collaboration and its challenges seriously. They outline a strategy for learning to collaborate while collaborating, which implies (1) creating conditions for learning to take place, which includes paying attention to discomfort as a trigger for learning and (2) engaging in collaborations in ways that strengthen researchers' collaborative capacities by cultivating particular orientations, knowledge, and skills. In that sense, Bickford and Wright (Bickford & Wright, 2006) suggest that "the most effective way faculty can appreciate the possibilities of a learning community is [. . .] to experience being a student again". Konrad and colleagues (Konrad et al., 2021) suggest for instructors "not to take on the role of the learning facilitator for students but to join the learning community and utilize the interactions to develop *their* interpersonal competences themselves".

Collaboration in practice: the case of Nexus24

In order to contribute with a structured introductory method to integrate the reflection on collaboration while learning in academic activities, this chapter centers on the experience of the Nexus24 Program set up at the Universitat Politècnica de Catalunya (UPC) in 2014 (Ferrer-Balas, 2017). The aim of the program is to "make collaboration normal by 2024" in the management of the university. In that sense, the particularity of this educational program – which has been led by the first author of this chapter – is not an academic initiative but a professional development one and was launched by the UPC management to train the administrative staff. Especially among this staff category, the working culture is bureaucratic and the organization highly compartmentalized. Legal framework and other restrictions have brought it to operate traditionally in a hierarchic mode. Resources are more and more limited, while needs are always growing, provoking the frustration of many of the staff and bringing low levels of motivation. This was the fundamental reason why the manager of the university (head of the 1900 administrative staff) launched in 2014 the Nexus24 collaborative work program. A crisis generally stimulates two types of opposed responses: on one hand, fear related as competition, fragmentation, control through strong hierarchy, etc.; on the other, collaboration, flexibility, openness, sharing power and resources, etc. The Nexus24 program is an example of the "second type" of responses to crisis suggested earlier (collaborative not competitive) and aims to change the working culture at the university in ten years. Beside that general purpose mentioned, there are five specific goals:

- Motivate and empower people.
- Develop talent that is wasted in the university.
- Open and share this knowledge at the university.
- Gain flexibility as an organization.
- Improve the university through concrete projects.

The core of the Nexus24 program is the collaborative team. As Nexus24 is a culture change program based on CL, the program aims to offer the UPC staff an experience of genuine collaborative work of "learning by doing" and reflective practice. It is only through that experience that learning can be achieved, because collaborative work is such of those competences that cannot be learnt "in theory", but "by doing" as mentioned before. The people involved in collaborative teams have the opportunity to experience a different way of working and reflect on it, having the feeling of being suddenly in a new system with a new culture.

After more than five years of the program and the experience of more than 50 real collaborative teams, an operating model to run it has been consolidated. This consists of six elements around the core element of the collaborative team: the principles, a network, the building blocks, teams and roles, process for collaborative projects, and energy and resources. The description of these elements can be found elsewhere (Ferrer-Balas, 2017), though some of the fundamental aspects are described in the next sections.

Although Nexus24 is not a program designed for undergraduate or master's students, it aims to influence the collaborative culture of the university as a whole, and so should ultimately benefit them. In that sense, some experiences of training the students of the UPC master's of sustainability on Nexus24 collaboration practices have shown the potential and interest expressed by students to integrate the collaborative learning activities in the programs. Their typical reaction was "if you had taught this before to us we would have avoided many problems in collaborative group assignments".

Initiating the collaboration

Before starting any type of collaborative project, there is the need to see together the whole picture and plan the collaborative effort with the team, aligning expectations, sharing motivations, and reducing uncertainties. Le et al. (Le et al., 2018) describe the typical problems students encounter when collaborating in groups. In their own study, they report that all students agreed that, when they started to work in groups, they did not know how to collaborate effectively. Their lack of collaborative skills such as accepting opposing viewpoints, giving elaborate explanations, providing and receiving help, and negotiating prevented them from working productively in groups. This experience is rather representative and coincides with the one experienced with UPC master's students.

From the Nexus24 experience, a recommended practice to start the work is to spend a minimum time in the group on what we call "the collaboration building blocks" (Figure 6.5.1). This scheme aims to give importance to different aspects that will be fundamental during all the process. Using this scheme from the beginning, basic errors can be avoided, like starting without a shared purpose, misunderstanding the use of collaborative tools, or not paying attention to the diverse personalities of the collaborators. The depth of the reflection will

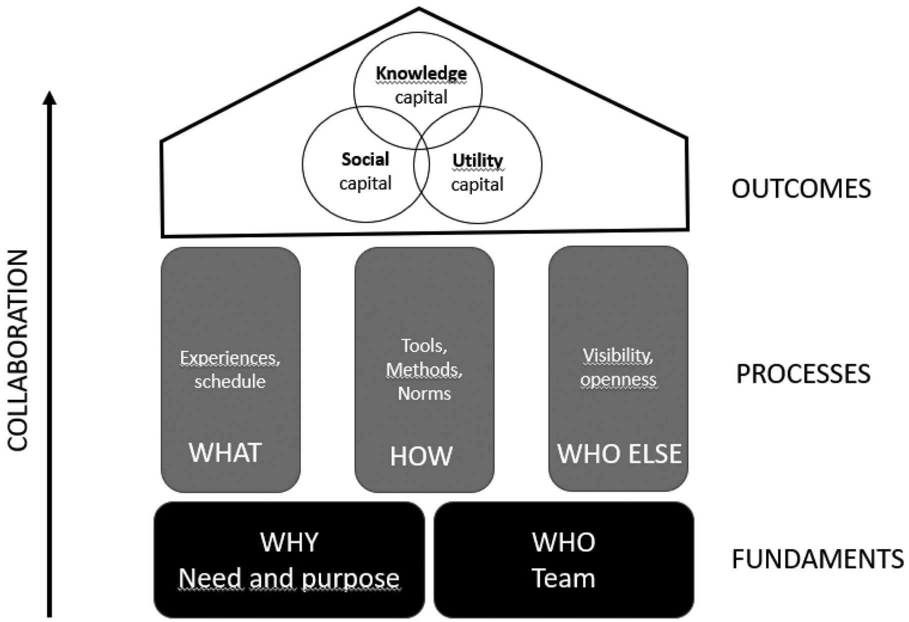

Figure 6.5.1 The collaboration building blocks, created by the authors.

be chosen by the instructor and the group, according to the time available and the level expected for the students, e.g. according to Brundiers's "progressive model" cited earlier.

As can be seen in Figure 6.5.1, there are three different levels: fundamentals, process, and outcomes. *Fundamentals* have to do with the reason for the collaboration and the nature of the team. *Processes* deal with organizational issues where the practical collaborative skills are developed. And finally, on the roof, the three capitals represent what the collaborative effort will produce as *Outcomes*. Regardless of the endeavor, all collaborations have the potential to increase the social capital related to the quality of the relations between collaborators, the knowledge capital, meaning what is known individually and as a group, and the utility capital, in the form of solutions or useful ideas to address the need and solve problems. In collaboration settings, too much attention is usually paid to the latter, whereas paying attention to this triad of "benefits" can help to focus not only on the results but also on valuing the process, enhancing the importance of learning.

The following sections deploy the five aspects of the collaboration building blocks in order to help the teacher to orient students in their collaboration efforts. A first activity proposed is to think about the different building blocks from the start. This can be done collectively with adhesive notes on a blank canvas (or remotely in a digital board) with those different blocks and will give a mental model to the team members that enhance the importance of the reflective practice. On different moments of the project course, visiting this model will be helpful to reflect on the collaborative process.

WHY: need and purpose

A shared purpose drives collaboration. "If you want to build a ship, don't drum up people to collect wood and don't assign them tasks and work but rather, teach them to long for the endless immensity of the sea," pointed out Antoine de Saint-Exupéry (Nayar, 2014). The concept of purpose goes beyond the "goal" or "outcome", as it includes the personal will of the individuals involved in the project. Defining a joint purpose is an extremely interesting moment, as the team must integrate the external needs as well as the internal aspirations. It also connects to the concept of "mission" (who we are and what we want to do together). And it cannot be imposed; it must be desired. Authors such as Laloux (Laloux, 2014) have given a fundamental value to the concept of "evolving purpose" for designing new Teal organizations. In that vision, the purpose is not rigid and might evolve as the members of the group also evolve. A purpose must connect with our both rational and emotional dimensions. In general, students are not creating organizations, but learning to think about how to share and connect their interests, passions, and abilities in the project, which is already a valuable experience.

In order to work with students, the idea is to ask them to build and make explicit the joint purpose when they start a project, obviously within a framework which will depend on the curricular activity. It is important that they identify the individual aspirations which can move them. On the other hand, the collaboration will have to start from or connect with a need. Correctly identifying the needs addressed by the project will be an ongoing discussion throughout the collaborative process, but it is critical that it is not forgotten or left to the end.

WHO: team and roles

The members of a collaborative group can be volunteer or appointed. In the first case, things are easier: a genuine desire for joining a collaboration is key, as a true collaboration cannot be imposed. However, we might find situations where one "has" to collaborate with other people who have not chosen to be there. It is fundamental to build confidence between the members and help to build strong relationships. Collaboration needs generosity and empathy, and these are not necessarily spontaneous.

What are we good at? What are our values? A crucial aspect of collaboration is diversity. Diverse points of view, skills, disciplines, values, etc., build the collective competence of the group and justify that the effort is not better to be done individually.

Recent studies present overwhelming evidence that teams that include different kinds of thinkers outperform homogenous groups on complex tasks, producing what the authors call "diversity bonuses". These bonuses include improved problem solving, increased innovation, and more accurate predictions – all of which lead to better performance and results (Page, 2017). Page shows that various types of cognitive diversity – differences in how people perceive, encode, analyze, and organize the same information and experiences – are linked to better outcomes. However, too much diversity or a badly managed diversity can bring the collaboration to failure, especially if the limitation of time does not allow to integrate the diversity potential.

Practices for team-building like those described in the Action research workshop for transdisciplinary sustainability science at UPC (Tejedor et al., 2019a) are useful, especially when starting the venture, but not only. It is necessary to reserve time to talk about the personal and emotional dimension of the collaboration.

One relevant practice for team building is that each member shares with the rest his or her profile. Techniques which identify one's principal personality like the DISC test (Rohm, 2010) have been shown to be helpful for the self-knowledge and understanding the diversity of perspectives, which instead of being a source of conflict, can become the source of creativity. It is strongly recommended to educators to spend time on self- and peer assessment of skills, abilities, and personalities. This can be done at the beginning of a course or degree, as students will need to organize in different teams later on. It is obviously not necessary to pass the test every time, just once.

General roles in a collaboration

Using a simplified scheme, in Nexus24 we describe three fundamental roles in a collaboration: member (or participant), facilitator, and sponsor. The member (or participant) is part of the collaborative team. He or she can either be an initiator of the initiative or a follower, but at one stage is considered a full member of the collaboration team. The facilitator is not a member; he or she lies outside the team and observes the group, introducing methodologies to help the group improve its performance. The facilitating role is not indispensable in collaboration, and mature groups might not need it, but in general it is very helpful. The task includes organizing regular reflections on the teamwork and the quality of the collaboration, and therefore it has a fundamental role for the acquisition of collaborative competences. With students, it is interesting to have a facilitator role model at the beginning, which can be the instructor (in that sense, it is important that he or she is familiar with facilitation practices). In a next stage, it is possible to ask one of the members of the team to be the facilitator and step out of the collaboration to observe the group and practice the facilitation skills. This experience gives a deeper level of competence in collaboration as it is a meta-reflection.

The third role is the sponsor. This figure has two facets. On one hand, it opens the space for collaboration and gives importance to the task. On the other hand, it follows the outcomes and is committed to implement the outcomes of the effort if, for example, the team is designing a prototype. If the effort is done within an organization, the sponsor tends to be in an important hierarchical position. Real-life collaborative projects tend to have those sponsors. In general, collaborative teams present the developments at the end of each development period (e.g. "sprints" when using agile methods). In academic contexts, it is rather normal that the instructor takes this role when no external sponsors exist.

Specific roles in a collaborative team

A different angle on the roles is to understand them within the collaborative team. While the personalities of the members are somewhat constant and will vary little in a life span, the roles can be different for the same person in different teams. In fact, they are an emergent property that depends on the rest of the members. They usually are related to the personalities, so the predominant roles fit with the personal profile, and a good recommendation for any collaborator is to know about his or her preferred roles when joining a team. For example, the *Tejeredes* approach (Figueroa, 2016) defines six typical roles in form of animals: leader (lion), articulator (spider), executor (ant), reflexive and fraternal (bear), pollinizer (bee), and caretaker and crafty (fox). Each of those roles has some typical and indispensable functions in any team, pointing out that there are not better or worse roles. In that approach, each role has a collaborative (positive), as well as hierarchic (and negative) side.

In a learning situation of a collaborative team, it is highly recommended to help the team to analyze before and after their work the role distribution and carry out a group reflection on potential or existing conflicts due to the overlapping or lack of roles, for instance. The degree of depth the team will take on them will vary from just commenting in five minutes to devoting a full session on sharing personalities, etc. And this can be iterative and repeated in different moments. The context of the collaboration will justify this depth, and in general is decided by the facilitator (or instructor).

HOW: tools and methods

Experimenting and co-creating

It is fundamental for any collaboration to "do things together". If the group only discusses, their endeavor hardly progresses. Experimenting and failing as early as possible is the best way to learn as a group, while defining what to do cannot be obvious and can lead to never-ending discussions. Often, a way to solve it is to think from the users' perspective and their needs. Then, if the purpose is clear, collaboration can take the form of some first developments, experiments, or prototypes. Those can have several shapes and infinite materializations possible but will help the group to progress and have meaningful conversations. While the traditional way of reasoning in a team has been to split the final work in parts, distribute the full work, and sum the parts at the end, the collaborative approach is rather the opposite, allowing the team to benefit from the potential of the whole-group diversity for the full work. In fact, before dividing the work, it is highly recommended to apply an iterative process and to start with easy questions leading to very basic developments in prototype form. If the expected result users' are accessible, it is very fruitful for the group to show the first prototypes to a selection of them to get a rapid feedback (they can be represented by the sponsor). This iterative process can save hours of discussion in the group. In summary, our recommendation is to work in "sprints" with iterative processes and to conduct presentations and feedback on the output product as well as internal conversations (retrospectives) on the process experienced at the end of each phase, to reflect on the experience's gains and failures.

There are multiple methods to co-creating. For example, agile methods (Cobb, 2015) help to understand the dynamics of prototyping and iterating with the user at the center. Design thinking (Brown, 2009) is a user-centered methodology, strongly focused on co-creation. Looking for a deeper level of consciousness in the process, Theory U (Scharmer, 2016) aims to connect people on a journey through their profound purposes with a method explained as "learning from the future", which strongly relies on intuitive practices instead of fully rational ones. In any case, understanding and sharing the purpose is key to deciding what type of method to apply in the collaborative effort.

Collaborative tools

Communicating with each other within the team and sharing information and knowledge are key aspects of the collaborative process. Today, digital technology advances make it easier, and there are multiple tools available and new ones appearing every year, which allow both synchronous and asynchronous work.

The team will have to discuss and agree from the beginning on the communication tools (channels), how often they will interact (frequency), and where the information and knowledge generated are going to be kept. Too often, this is given for granted: teams start with a large degree of informality and everything seems easy at the beginning. After some weeks chaos and inefficiency appear. Some people take all the load or do the work without informing, generating inefficient redundancies. Others disappear or do not give enough priority to the tasks. Saturation of team meetings or ineffective ones are other typical issues. By spending some time to think about it and agreeing on the right practices and group norms, as well as identifying the most skilled and interested people to keep order in the team, this can be well organized. In an iterative process, the tasks will be divided in phases or sprints, thus giving a rhythm to reflect on the quality of the collaboration process at the end of each sprint.

The fundamental set of collaborative tools in a team is the following (Figure 6.5.2):

- A messaging system (instant or email group).
- A digital store for the information generated.
- In it, a logbook, which is a shared collaborative file with a register of all meetings and other relevant information with the links to the full documentation. This allows the team to create transparency and keep track of the project or initiative, without the need of a hierarchic organization. Alternatively, a more sophisticated form is a digital collaboration board which allows dividing a project into tasks with different levels of information and assigning the tasks to the members. Those boards allow you to see who's doing what and the current tasks' progress.
- Retrospective procedure. At the end of each phase, a simple board (e.g. with four quadrants: What has worked well? What has not worked? Ideas for improving? and How did

Figure 6.5.2 The basic collaborative toolbox, created by the authors.

I feel?) is used to align the team and allow difficulties and ideas to emerge. It is recommended to draw a simple action plan to address the problems that have been detected in the previous phase.
- Meeting and co-creation space. Digital or physical, the team needs a space to share ideas, images, references, or other emotional connections (birthdays, celebrations, etc.).

Equipped with those five basic tools, a collaborative team becomes very powerful.

Sometimes, the goal is not to solve a problem, but to initiate some collaborative momentum or create a community. Imagine a group of students who want to create an association at their school. Their goal is to set up a collaborative community, and they might benefit from the "community canvas", which is "a framework that helps build stronger communities and make our society a bit more connected". The canvas is structured in three sections for any collaborative community (identity, experience, and structure) and has a "minimum viable community" version to start.

Who else? (Outreach)

When collaboration is in the core values of a group, there are some questions linked to external communication which cannot be ignored: Is the collaborative work going to be kept private or will it be made public? At what stage? For the team's purpose, is it desirable to attract other collaborators? These questions can help the team decide where to spend efforts in external communication, setting a social network account and spending efforts to keep it updated, answer and manage interactions, etc. Communicating teamwork to the world outside may activate new collaborations. But it can be very distracting from the goal. However, it can be valuable for some student projects that have a certain duration and are intended to have some impact. Instead of or in addition to the use of social networks, organizing a final presentation of the collaborative project (beyond the strictly academic purposes of evaluation) is a good way to leverage and get some reward and feedback on the work done. Being able to attract the audience to such a presentation is part of the collaborative skills.

In the same way, it is interesting to ask the team to reflect on the openness of the information and knowledge generated. For example, the team might publish its work under a Creative Commons license, in which case it can decide under what conditions the information is shared.

Impact of collaboration

In any collaborative process, there are fundamentally three outcomes: knowledge, solutions, and connections (social capital). Solutions might arise (or not) during the process, but knowledge will be generated and thus learning will occur in the interactive process of a diverse group which collaborates and in general, this will be positive for sustainability. As knowledge is an unlimited resource, the unsustainability of the process can fundamentally come from a bad use of time (or other non-renewable resources used) in the process. In general, excessive attention is paid to the usefulness of the solution instead of the learning process. But sharing knowledge can be fundamental in future developments. Documenting this learning in open and shareable formats should be as important as having solved the challenge itself.

Additionally, a good collaborative process creates new social relations and builds a sense of community. Giving visibility to these intangible realities is important and can be done easily using graphs and networks visualization software. Since networks and local communities are fundamental to sustainable solutions, we can conclude that collaboration generally helps to move in the right direction towards sustainability.

Conclusion

The UN Agenda 2030 recognizes that the SDGs need a collaborative approach. However, to date, not enough attention has been paid to training people to collaborate. The transition to sustainability requires people who act as change agents, capable of driving transformations. As a competence for sustainability, collaboration implies understanding, participation, cooperation, and action. And in the same way it is central to the transdisciplinary approach for the co-production of co-owned knowledge.

Introducing collaboration learning into higher education is fundamental for sustainability education. It has been traditionally undervalued or taken for granted and yet it is imperative that it is planned. Collaborative learning as pedagogy to improve learning has been applied increasingly, and it is effective when students are competent in collaborative skills. As they progress in their studies, education for sustainability requires that students have opportunities to practice interdisciplinary and transdisciplinary forms of collaboration and engagement with stakeholders (Whitmer et al., 2010; Yarime et al., 2012), which are limited in the traditional academic model (Hart et al., 2016).

This calls for an emphasis on collaborative, communication, and interpersonal skills (Roy et al., 2020) which are essential for dealing with complexity, along with critical thinking, systems thinking, and values. Some pedagogical strategies row in that direction, rooted in the constructivism of Piaget and the social constructivism of Vygotsky (Olmedo Torre & Farrerons Vidal, 2017; Tejedor et al., 2019b). In general, small-group learning methods allow collaborative work using communicative, interpersonal, and interactive skills to promote critical thinking, as actively constructing knowledge, which interacts with previous knowledge, experiences, beliefs, and perceptions (Kalaian, 2017). Good examples of collaborative learning can be found in didactic strategies such as jigsaw strategy, simulation games, case study implementation, problem-based learning, project-oriented learning, service learning, and challenge-based learning, which promote experiences that lead to deeper learning. These strategies have in common that they are:

- active, pulled by the interaction with the social
- contextual, facing real-world problems
- engaging with stakeholders and community, handling different perspectives
- student-owned, developing self-esteem, self-management, and preparation for professional life

Students should practice collaboration in project teams and get some time and support to reflect on the quality of their collaboration. It is recommended to introduce some fundamental reflections and practices at some early stage and keep them in the different stages of the project development through a facilitation process. Instructors should be familiar with the basic concepts of collaborative work and see those projects as an opportunity to improve their own collaborative competence and become learners themselves. This chapter presents a model based on the five collaboration building blocks aimed at orienting teacher and student in setting collaborative practices. It also presents a fundamental set of generic collaborative tools which empower any collaborative effort.

Just as we learn to swim by swimming, we learn to collaborate by collaborating, and doing so while learning about other topics. Just as external help is critical to learning to swim, we can benefit significantly in learning collaboration practices by introducing external help in the form of meta-practices to reflect on the experience. What went wrong? What was helpful? How can we improve our collaboration next time?

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6.6
TRANSDISCIPLINARY LEARNING COMMUNITIES

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Key concepts for sustainability education

- Transdisciplinary learning communities are an important pedagogical tool for sustainability education.
- Transdisciplinary learning communities can be instrumental in assisting students to understand complex sustainability problems.
- Transdisciplinary learning communities activities are engaging for students, as they are eager to help resolve difficult sustainability issues.
- Transdisciplinary learning communities stimulate the creativity of students for finding solutions to sustainability issues.
- Transdisciplinary learning communities in higher education are not only beneficial to students but also to scholars and to all partners involved.

Introduction

Education is seen as an essential driver for sustainable development (Kubisch et al. 2021). In the classical sense, education typically refers to the opportunities for a radical transformation that can lead to positive changes at the local and global levels in terms of sustainability (Biberhofer and Rammel 2017). In other words, education is preparing the younger generations to the necessary changes for a sustainable development of our planet. Since younger generations nowadays usually have unlimited access to information through the internet, universities need to go beyond informing towards incentivizing attitude changes and fostering a deeper understanding into how and why sustainable challenges are occurring in each specific context. Moreover, new concepts such as 'smart cities' or 'circular cities' stand for sustainable urban areas. These also emphasize the role of education and related aspects as knowledge and innovation (Biberhofer and Rammel 2017). Therefore, sustainable development education should use tools that not only promote acquiring knowledge through education but also develop and transfer it.

Knowledge development and transfer play a central role in the process of understanding and resolving sustainability issues. Due to the complexity of sustainability issues such

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as climate change, poverty, or inequality – to mention just a few, a collaborative approach between practitioners and experts from various disciplines and backgrounds is recommended to generate knowledge. Knowledge transfer, on the other hand, requires the active involvement of students in the interaction with these experts and practitioners (Kubisch et al. 2021). This makes sustainability education quite challenging (see Chapter 1D "Challenges for sustainability Education"). Therefore students working with practitioners is a useful pedagogical method that helps to resolve challenging problems, develops competencies of responsibility, and improves the well-being of the community (Kubisch et al. 2021). When approaching problems of sustainability in a community and involvement of expertise from different fields, a multidisciplinary approach is required (Lüdeke-Freund et al. 2021; Domik and Fischer 2011), as knowledge from single disciplines (e.g. economics, law, sociology, psychology, medicine, engineering) often proves insufficient. Furthermore, we should also include stakeholders working on the practical solution of sustainability problems, as well as those who are directly affected by these problems (Kubisch et al. 2021). Therefore, using a transdisciplinary learning community (TLC) seems adequate to study challenging sustainability problems (Pohl and Hadorn 2008; Brandt et al. 2013).

Transdisciplinary learning communities

Transdisciplinarity refers to a collaboration between different scientific disciplines and non-academics to integrate two different kinds of knowledge and know-how (Lüdeke-Freund et al. 2021; see Chapter 3.4 in this volume). Like other collaborative approaches, transdisciplinarity contributes to sustainability by approaching complex sustainability issues from different perspectives, which is considered a stimulant for creativity in finding solutions to sustainability issues (Schauppenlehner-Kloyber and Penker 2015). Using TLCs allows students to apply their theoretical knowledge to real-life situations (Diaz Gonzalez et al. 2020), using multiple scientific disciplines and the practical insights from non-academic stakeholders. In this sense, TLCs are quite valuable for sustainability education, as they provide students with the multidisciplinary and practical insights needed to understand complex sustainability issues, and more importantly, to find workable solutions for them. The purpose of TLCs is to challenge students to find solutions for everyday problems (Lozoya-Santos et al. 2019). The interaction between multiple scientific disciplines and various stakeholders from a specific community within a TLC opens doors for students to find actionable solutions (Schauppenlehner-Kloyber and Penker 2015).

Moreover, students experience the TLC activities as engaging. By collaborating in real-world problems, students develop competencies in responsible citizenship while simultaneously contributing to find solutions to the sustainability challenges of their own community and thereby improving the life quality of their families and themselves (Kubisch et al. 2021). Students take ownership of the learning, as they immediately see how it can have an impact in their daily lives. According to Lawthom (2011), taking students to the communities allows them to contextualize their learning. The competencies gained in a TLC approach are different from the ones learned in the classroom (Lawthom 2011). The difference stems from the fact that a TLC approach helps students to gather knowledge about a specific sustainability issue from a variety of scientific and non-scientific sources in conjunction with their own experiences of that issue (Lawthom 2011). In addition to learning and competence development, a TLC approach gives students the opportunity to develop various soft skills, stretching beyond the scientific knowledge gathered at universities. They also cultivate a sensitivity to non-technical dimensions of the sustainability problem into the proposed solutions. It also requires working in community-based design projects where the students must be aware of the needs of the various stakeholders (Payne and Jesiek 2018). According to Lozoya-Santos et al. (2019), using the transdisciplinary approach in education develops four domains of transversal competences: critical and innovative thinking, interpersonal skills, intrapersonal skills, and global citizenship. Critical and innovative thinking includes creativity, entrepreneurial skills, and a reasoned process of decision making. The domain of interpersonal skills refers to communication, leadership, teamwork, organizational skills, and sociability. Intrapersonal skills denotes self-discipline, self-motivation, enthusiasm, perseverance, and commitment. Lastly, the domain of global citizenship refers to a mentality of awareness; tolerance, respect, and openness to diversity; intercultural understanding; the ability to resolve conflicts; and respect for the environment. Overall, a transdisciplinary learning approaches resonate with the UN focus on global citizenship education, where students are engaged in finding solutions of global societal issues (Guadelli 2016).

The use of TLC in higher education is not only beneficial for students but also for all partners involved in the process, as there is mutual learning (Bracken et al. 2015). TLCs help faculty and university staff to build networks within the community in which they are located. It opens a space for exchanges between the inhabitants, the university, the government, and any other relevant stakeholders that are located there (Agramont et al. 2019). All of these constituents engage in pondering together about challenging issues and looking for workable solutions. This resembles a lot the idea of blue sky thinking, where people look for novel ideas without boundaries. Due the transdisciplinary approach, the community members of the TLC are the ones that help the scientists involved to define the research problems and questions (Wickson et al. 2006). They are also key in the interpretation of the data, as they are the ones that better understand their own problems and context (Alba and Dentchev 2021). All stakeholders involved in the TLC should in fact contribute towards defining research problems, analyzing data, and formulating conclusions. Through the research process, the involvement of community members and relevant stakeholders makes the knowledge generation more engaging for the students, as they learn how to approach real-life problems and how to propose workable solutions (Lozoya-Santos et al. 2019). The non-academic actors involved in the TLC provide essential input that contributes to solving complex sustainability problems (Polk 2015; Mangkhang 2021). When universities start a TLC process, they can relatively easily include specialists from different scientific disciplines. Good contacts with a specific community and relevant stakeholders contribute to the development of a TLC that performs well. Thus, successful TLCs involve key members of the community and engage any and all stakeholders that can constitute solid partners for resolving sustainability issues (Polk 2015). The involvement of local governments and opinion makers is, moreover, quite beneficial to creating a dynamic TLC (Jost et al. 2021).

Using a TLC approach requires time to engage the community members with the academics and other stakeholders (Alba and Dentchev 2021). As they originate from different contexts, it takes time for them to get acquainted, to understand the specific challenges of the context, to align interests and create trust. As we will see later, TLC interventions have six stages, each of which takes time to achieve the specific objectives of that stage in order to progress to the next one. As students' interventions might only be for a short period of time (e.g. one semester), it is well conceivable that a community does not trust or engage with the students. It is equally probable that students lack time to fully grasp the context of the learning community. Therefore, students should intervene in the framework of projects that have a closer contact with a community, that allows for short interventions or for specific problems previously identified.

The six stages of TLC interventions

Using TLCs as a pedagogical tool requires universities to follow a process that includes six stages, as Lozoya-Santos et al. (2019) would argue: (i) organization, (ii) matching, (iii) training, (iv) research and development + innovation, (v) filtering, and (vi) acknowledgement (Lozoya-Santos et al. 2019). The *organizational* stage starts when the university establishes the areas and protocols of working. This first stage involves university faculty and staff inviting community members and stakeholders to share their problems and needs. The organization stage needs to finish with clear objectives, common interests, and the division of the work being defined. This stage creates interlinkages between theory and practice and connects the research interests of the universities with the practical problems of the communities (Biberhofer and Rammel 2017). During the *matching* stage, it is necessary to have the right experts to achieve the objectives selected. Experts and extra organizations that may be required are added to the TLC team. At this stage, the stakeholders of the community also get involved. Once all experts and organizations that have relevance for the TLC are identified, the training stage starts. *Training* is important, as it will guarantee the next steps. In it, collaborative and innovative thinking is promoted in a safe learning environment. Basically, it is important here to find a common language between all the participants that will help to avoid misunderstandings or ambiguity (Domik and Fischer 2011). Participants of the TLC receive training in innovation and creative thinking that will help them reach their objectives as they learn how to communicate from their different backgrounds and profiles in a constructive manner. When students participate in any of the stages of the TLC intervention, it is paramount that they also receive training to foster their involvement and develop communicational skills to deal with the different profiles that are part of the TLC. The *Research & Development + Innovation* stage is the core of the TLC where all the collaboration is performed with extensive interaction between all the participants of the TLC including the students. In this stage, the research objectives decided at the organizational stage should be reached. The necessary experimentation or data gathering occurs as well as the innovation to resolve the challenges the community faces. At this stage, more than one solution can be tested, and the stage lasts until the optimal solution is picked. The community should be pleased with the solution provided and be willing to implement it to solve their sustainability issue. The TLC intervention would not exist without this stage as it is the hands-on moment. The *filtering* stage involves a review of the intervention, the objectives that were achieved, possible publications, and technology development. In this stage, organizations and the community are welcome to participate, but usually researchers take the lead as filtering is providing a written record of all the work done and the results obtained. The underlying data have been already collected in the previous stage. In the *acknowledgement* stage, the selected information from the filtering stage goes public. This stage includes the socialization of the work and results to encourage other communities to take action to solve their own sustainability issues. After the acknowledgement stage, the TLC loop may start again, this time taking into account what has been learned, in search of new problems and new members for a TLC to help resolve them.

VLIR-UOS Bolivia: a case in illustration

We would like to illustrate the involvement of students in TLCs by means of the transdisciplinary research program named VLIR-UOS Bolivia, a collaboration between Universidad Catholica Boliviana (UCB) and four Flemish Universities in Belgium (Vrije Universiteit Brussel, Ghent University, KU Leuven, and Antwerp University). It is a 10-year program financed by the Flemish Interuniversity Council (VLIR) that aims to contribute to the development of Bolivian society (VLIRUOS 2019). It started in 2017 to help disadvantaged communities with transdisciplinary interventions in six projects: social vulnerability, integrated water management, food security, indigenous rights, productive development, and transversal. Each of these projects contributes to the program from a specific discipline, as shown in Table 6.6.1.

Four vulnerable communities in Bolivia were selected, all in close proximity of the four campuses of UCB, i.e. in La Paz, Cochabamba, Santa Cruz, and Tarija. Team members from each of the six projects go to the different communities and involve students, the local population, local governments, non-governmental organizations (NGOs), and any other stakeholders present. So, for each of the four TLCs, there is a team formed by experts from the six projects of the program and the six disciplines need to work together to solve the sustainable issues of the community.

Examples of student involvement in TLCs

During the TLC interventions in the previously mentioned projects, students have been involved in the process through various interventions: (i) events, (ii) intensive immersion, (iii) field visits, (iv) research, and (v) course students.

1. Events: Student participation in short interventions (events organized for one day or one weekend) can create beneficial results for the community.

Throughout the TLC programs, various events have been developed with the communities, such as sales fairs, startup weekends, or hackathons. People from the community, stakeholders, university representatives, and students of all disciplines are invited to find

Table 6.6.1 Projects and corresponding disciplines of the transdisciplinary research program VLIR-UOS Bolivia

VLIR-UOS Bolivia	
Project	*Discipline*
Social vulnerability	Psychology
Integrated water management	Water engineering
Food security	Agriculture
Indigenous rights	Law
Productive development	Entrepreneurship
Transversal	Research methods

Source: Own creation based in (VLIRUOS 2019) solutions for the sustainability challenges. In these events, students needed to connect with people, understand their problems, and create a team to develop a solution. As this involvement of students is limited, they might not be able to identify the problems and develop solutions within such a short timeframe. Sometimes the researchers or other participants of the TLCs have already identified some problems or challenges in advance and bring in students from diverse disciplines to brainstorm and find a solution (Feld 2012). This kind of intervention can occur at the 'research and development + innovation' stage.

2. Intensive immersion: We connected business students from Belgium and Bolivia with Bolivian entrepreneurs for a full week. We had activities to break the ice and stimulate the exchange of ideas. The first two days, the students were requested to talk as much as possible with the entrepreneurs and get a thorough understanding of their lives, their context, their challenges, and their opportunities. For the next three days, the students gave different workshops to teach specific skills that could help the entrepreneurs to overcome these challenges. Topics included marketing, finances, and Excel. The content was delivered in the simplest most practical manner in small groups (four students to six entrepreneurs), so they could guide them step by step and stop whenever there were doubts. The entrepreneurs were more than happy with the knowledge, but the students also realized that many variables influence an enterprise, including the ones that are not necessarily business related such as family factors or absence of resources. This intervention is suited to the 'research and development +innovation' stage as the students have specific goals and tasks and little time to connect with the learning community.
3. Field visits: Students visit the TLC for one day to see the results of some other interventions. For example, they go at the closure of the hackathons or to the fairs that the vulnerable entrepreneurs organize. This gives the students a glimpse into the community and is often used to motivate them to participate more actively in a longer intervention with the TLC. This intervention occurs at the 'acknowledgement' stage, and students' involvement is crucial so they can understand how their future intervention will lead to genuine concrete results that improve the lives of people in their own community.
4. Research: Students developing research for their bachelor or master theses got involved with the TLC over around one year. They visit the community and get as much immersion as possible. Students connect with people and understand their problems in order to develop their research. Finalizing this research, students publish in edited journals and give presentations at the university to share their results with the full TLC teams as well as other students and the community concerned. This happens at the 'research and development + innovation' stage.

Similarly, PhD students also intervene in the TLC with specific research. As their involvement lasts at least four years, they can intervene at any stage of the intervention loop. This wider timeframe allows them to understand the context and get to know the community better, so that the communication and trust improve (Alba and Dentchev 2021). The student can get more in-depth information on the inhabitants' problem, then develop the research, and work out a feasible solution in collaboration. The time is often long enough for the student to see the proposed solution being acted upon in real life. The PhD students come from Belgium as well as from Bolivia. Their varying backgrounds and knowledge of the context further enrich this process. Based on the research from the TLC, two PhD students have already graduated, one has submitted and is currently awaiting the defense procedure, and three are in the final phase before submission.

5. Course students: Professors involved in the program can identify specific situations in which students can intervene in the community to solve a specific need. For example, in the VLIR-UOS program, communication students went to the community to see the local radio station and teach the community how to prepare radio communications. They understood that the community preferred a local person to be in charge of their communications as they needed to take ownership and be able to communicate the topics they found relevant. Students felt highly engaged as they realized the extent of the problem and had the tools to solve it. They even put in extra time by providing additional support in terms of elocution and pronunciation refinement and were on standby in case of problems.

Another course went to develop informational videos with locals about the consumption of water and the public policies being developed around this topic. Students needed to understand the problem, talk to the experts in water management and law, and engage with the community to understand how to communicate the message. Later, they connected with language students to provide two versions of the video, one in Quechua, the native language of the region, and one in English to show at international events. The students' commitment was high as they knew it was not only about getting a grade, but especially about helping the community to protect their water resources.

The above-mentioned five interventions of students's involvement in TLCs are summarized in Table 6.6.2.

Through all these different interventions, students become aware of the sustainability challenges that are present in their surroundings. Students cannot evaluate the severity of extreme poverty before being engaging with TLCs in communities that live in extreme poverty. Similar is the difficulty assessing the impact of other sustainability issues on these communities. For example, students were astonished at the effect that the lack of rain and global warming has on agricultural communities and how, further down the line, this affects the produce of fruits and vegetables that they consume. Moreover, students do not only become aware of the sustainability issues and their impact on the involved communities, but they also start to better understand how those problems were created. Most importantly, students start to reflect upon their own non-sustainable actions and the impact these have on their environment.

During these interventions, students find sustainable solutions, often under adverse conditions and with limited resources. Their contribution can vary from merely giving their

Table 6.6.2 Students' involvement in TLCs

Intervention	*TLC stage*
Events	Research and development + innovation
Intensive immersion	Research and development + innovation
Field visits	Acknowledgement
Research	Full loop
Course students	Research and development + innovation

opinion about a particular case to proposing a well-elaborated solution. Members of the community show appreciation for both the expertise and the novel ideas that students provide. But most of all, they appreciate the attention to the challenges of their community, as they typically think that no one cares about their situation.

Conclusion

In summary, we pinpoint four key guidelines to consider when planning the use of TLCs as a pedagogical tool in higher education. In the first place, each TLCs is unique and different, with different objectives involving different participants. Each transdisciplinary intervention needs to consider the specific characteristics of the community concerned. Each TLC is different, with different objectives and with different participants. Here we have presented examples of interventions that worked in a specific project and context. However, as no two TLCs are the same, such interventions should be tailored to each specific one based in their own needs. A copy-paste approach might not lead to success (Verbeke 2013), as the resources and the people involved will always be different.

Second TLCs interventions need to carefully consider the right timing for each of the relevant actors (Casado-Caneque and Hart 2015). For example, if working with an agricultural community, harvesting times are not ideal to start or work on a TLC, because in those months, the community likely has different priorities. Similarly, farmers generally work on their land from early in the morning until mid-afternoon, so activities need to be scheduled around this. When planning student interventions, the convenience of the community is paramount and not such factors as, for example, the timing of the academic calendar.

Third, the involvement of students in TLCs requires additional explanation of how transdisciplinary interventions work. Conventional higher education departs in the first place from a monodisciplinary approach. Although efforts are being made to stimulate multidisciplinarity in sustainability, a transdisciplinary approach to resolving sustainability issues is still rather scarce (Lüdeke-Freund et al. 2021). In this context, student involvement in a TLC can create confusion. For this reason, training students in innovation and creative thinking before the intervention can help them improve their impact and connection with the different participants of the TLC. As most students are only involved for a short time span, they are not usually part of the training stage, although providing them with a short training session in transdisciplinary thinking before their intervention could help them avoid tunnel vision (Lozoya-Santos et al. 2019).

Fourth, the TLC core team should be kept stable at university level. The same professors and researchers should be present during the six stages of the TLC intervention. They provide guidance and context for diverse student interventions that can vary in time, from one day (for some field visits by graduate students) to four years (for some PhD students). As different students will come and go from the TLC, is important to have a central team of academics that remains constant and supports students trying to connect with the inhabitants, as they are the ones that will have the trust of the community when other actors come and go.

In conclusion, TLCs are invaluable pedagogical tools in sustainability education. Sustainability educators need careful planning and a pragmatic approach to transdisciplinarity, as the four guidelines suggest, to embrace TLCs in their curricula.

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6.7
SERVICE-LEARNING AS A TEACHING STRATEGY FOR THE PROMOTION OF SUSTAINABILITY

Pilar Aramburuzabala

Key concepts for sustainability education

- Sustainable development calls for teaching methodologies that provide interactive, experiential and transformative learning that is focused on the real world.
- Service-learning is an experiential teaching-learning method that integrates community service and critical reflection with academic learning, personal growth and civic responsibility.
- Service-learning covers many sustainability principles in higher education: ethical behavior, holistic and complex systems perspectives, glocalization, transversality and social responsibility.
- The use of service-learning as a tool for sustainability education presents a few challenges such as institutionalization, tools and quality indicators for evaluating the impact, adapting the service-learning model to diverse cultural contexts and knowledge of the methodology.

Introduction

Curricular sustainability implies the integration of the principles, values and practices of sustainable development in all aspects of education and learning, with a view to addressing the social, cultural, economic and environmental problems of the 21st century (UNESCO 2005). The literature on education for sustainable development calls for pedagogical innovations that provide interactive, experiential and transformative learning that is aligned with the real world (Sipos, Bryce and Kurt 2008). The UNESCO Bonn Declaration (2009) was a call to turn knowledge into action for sustainable development and to reorient curricula to meet this goal (Brundiers et al. 2010).

The concept of sustainable development is a great challenge and, at the same time, a great opportunity for higher education, since education for sustainable development is related to the ultimate goal of education: to prepare students for their future and to assume their responsibility for it. In this sense, higher education can play a key leadership role, if it provides the means so that the millions of university students in the world graduate with the

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necessary knowledge, competencies and commitment to contribute to the more sustainable development of societies. Therefore, if we want to create the conditions that ensure a more sustainable future, higher education has to make an effort to educate university students with the skills, knowledge, attitudes and values that allow them to face many sustainability challenges including climate change, loss of biodiversity, global overpopulation, global health problems, poverty and extreme social inequality.

Sustainability education does not only imply including sustainability content in the syllabus of the different subjects. It also entails other global changes in the very conception of the educational process (Vilches and Gil 2012). For this reason, the challenge of integrating sustainability into university studies is great. Curricular change depends less on regulations and more on the experience and capacity of teachers, who are the ones who design teaching guides, participate in study committees and create academic programs to allow sustainability to be integrated into teaching. Secondly, due to the organization of the university by departments and subjects, which does not always favor the interdisciplinary curricular innovation that is required in sustainability education.

Furthermore, most university curricula does not take into account the goal of educating for a sustainable society. Subjects tend to focus on specific competencies, and transversal competencies are often forgotten. This is why a large and well-orchestrated effort is required by universities to integrate sustainability competencies into curricula, so that they prepare students to live and work sustainably and that facilitate students' explicit understanding of the interactions and consequences of their actions and decisions. Regardless of the curriculum subject, students should learn and practice holistic systems thinking and be able to apply this type of thinking to real-world situations. In addition, students must understand how the systems of which they are a part (social, cultural, economic, political and ecological) function and are integrated (AASHE 2010). This task requires significant changes, not only in the curriculum but also in teaching (Azcárate, Navarrete and García 2012). In this sense, the role of teachers is a key component in sustainability education development. For changes to occur in what and how to teach, teachers must have adequate knowledge, skills, attitudes, incentives and resources.

The work of teachers is also importantly part of a larger network that includes students themselves, administrative staff, accreditation agencies, government agencies, companies, foundations and non-profit organizations. For this reason, the best opportunity for curricular change is through collaboration between these actors. In these groups there are people committed to sustainability who can form the basis for establishing alliances and collaborations that support sustainability education. Education for sustainability in higher education is a profound transformation process that requires time for reflection, questioning and debate of ideas and values and the use of pedagogical methods in accordance with the principles of sustainable development (Selby 2007). Higher education is responding to these challenges in different ways: prioritizing campus sustainability practices, supporting research related to more socially and environmentally engaged sustainability, with increasing intention and frequent involvement in sustainability issues by non-academic partners, and the adaptation of study and pedagogical approaches to integrate sustainability into teaching programs.

As universities emerge from their ivory tower and commit to sustainable development and the changing needs of the local and global community, the importance of having new approaches, such as service-learning, to guide these tasks is becoming more important.

What is service-learning?

Service-learning in higher education is an experiential educational method in which students engage in community service, reflect critically on this experience and learn from it personally, socially and academically. The activities address human, social and environmental needs from the perspective of social justice and sustainable development and are focused on enriching learning in higher education, fostering civic responsibility and strengthening community engagement. Service-learning is recognized with academic credits (EASLHE 2021)

This methodology can be used in all undergraduate and postgraduate degrees. Its integration in the curriculum can take different formats: integrated in the teaching syllabus, external internships and final bachelor and master's thesis. All teachers previously trained in this methodology can supervise a service-learning project, which must be linked to the content of the subjects they teach and to social organizations (associations, non-governmental organizations [NGOs], foundations, public institutions, etc.). Key elements of service-learning include (Furco and Norvell 2019):

- Integration in the curriculum
- Student voice
- Partnership with the community
- Reciprocity
- Reflection
- Moral values

Therefore, service-learning is an innovative, active and collaborative teaching-learning method that integrates community service and critical reflection within academic learning, personal growth and civic responsibility. It is a powerful tool for learning and social transformation, which responds to the ultimate goal of education: to educate competent citizens capable of transforming society. Service-learning is an important and very necessary response to a global educational system that remains largely oblivious to increasing world environmental and social needs. (Aramburuzabala 2014).

The following are some examples of recent service-learning projects:

1. Post-fire reconstruction
    a. Community service: In an urbanism course, urban and architectural proposals were prepared for the reconstruction of a neighborhood that was destroyed by a fire.
    b. Learning: Territorial-social diagnosis with the community, identification of spatial and environmental variables, social and cultural norms of a habitat with high vulnerability.
2. From the countryside to the campus
    a. Community service: Setting up a coffee shop and a store of agroecological products on campus. Preparation of the business plan, marketing studies and the psychographic profile of the consumer. Workshops on packaging improvement. Development of the brand design and the identity manual.
    b. Learning: Marketing course in business administration: Group work, use of procedures and research methods, planning and implementation of strategies and solutions, assessment of popular knowledge.

3. A life path
    a. Community service: Construction of an ecological trail for community use; construction of a collective memory demonstration for the community.
    b. Learning: Knowledge and skills of the professional profiles of visual communication, psychology, architecture, communication, civil engineering and biology.
4. Better vision
    a. Community service: Students of optics and optometry provide glasses for free or at a very low cost to patients without resources derived from social services and community organizations. They carry out dissemination and collection campaigns for disused glasses, which they then repair.
    b. Learning: Knowledge of ophthalmic optics, optical surfaces, applied technology, economics and management, equipment maintenance and operation, human relations, communication skills, knowledge of the social environment.
5. Right to law
    a. Community service: Law students and professors offer legal services to individuals and groups at risk of exclusion, collaborating with public, social and professional entities.
    b. Learning: Knowledge of various subjects: Penitentiary, international, social, minors, gender and immigration law; human rights and communication skills through the media.
6. Adam's Project
    a. Community service: Medicine and nursing students act as clowns in pediatric oncology units to compensate for the severe impact that hospital stays have on children with cancer.
    b. Learning: Direct contact with the patient, their family and the professionals who care for them, understanding of living conditions in hospitals, empathy, communication skills, playing resources, responsibility and professional skills.
7. Lights and . . . action!
    a. Community service: Students from the School of Mining and Energy Engineering carry out assessments of electrical systems in old buildings in order to improve energy efficiency and prevent possible electrical risks.
    b. Learning: Applying knowledge and skills on electrical installations, communication with clients, organization and teamwork, responsibility.

This service-learning pedagogical approach is rapidly growing in popularity in many areas of higher education, in part, because millennials are more interested in helping to change the world than previous generations.

There are two main mechanisms that make service-learning an effective educational tool: the process and the results. In the first place, service-learning provokes a mental process that improves learning. Research shows that complex facts and ideas are better retained when knowledge is linked to experience and transfer of skills and knowledge to real situations is facilitated (Billig 2006; Tijsma et al. 2020). Therefore, when teachers create a reflective service-learning environment, understanding and recall of complex material are likely to improve.

Secondly, service-learning produces results of great interest to higher education. Research on service-learning shows the positive effects of this methodology (Aramburuzabala and García-Peinado 2012; Moely and Ilustre 2014; Rutti et al. 2016):

- Facilitates learning through active participation in service experiences
- Contributes to developing critical thinking and problem-solving skills
- Provides students with structured time to reflect by analyzing, discussing and writing about their experience
- Provides students with the opportunity to transfer skills and knowledge to real situations
- Extends learning beyond the classroom, into the community
- Develops values and a sense of helping others
- Develops a sense of self-efficacy and self-confidence
- Teaches students to critically question society
- Raises awareness of social justice
- Emphasizes social change rather than charity

Service-learning actions are aimed at the environment and at people and groups living in scenarios of social disadvantage, exclusion and/or risk of exclusion, focusing their actions on situations of injustice related to the environment, equity, respect for diversity, interculturality, functional diversity, learning difficulties, educational inclusion and human rights. Students reflect in a structured way, analyzing, debating and writing about these realities; their origin; how to prevent and deal with them; and the impact of the service on improving the environment, sustainable development, injustices and social change (Cayuela et al. 2020).

This critical service-learning approach assumes the political nature of service and promotes sustainable development and social justice over more traditional perspectives of citizenship (Wang and Rodgers 2006). In this way, service-learning becomes a transformative instrument of environmental, social and political reform.

The role of service-learning in sustainability education

In 2005, the Conference of Rectors of Spanish Universities approved a document, revised in 2012, the annex of which contains a description of the basic principles of education for sustainability in the Spanish university framework. But does service-learning comply with the principles of sustainability education in the university environment? Next, service-learning is contrasted with these principles in order to analyze the suitability of this methodology for promoting the practice of sustainability in the university environment, and the corollaries between them and critical elements of service-learning are shown.

1. Ethical principle: The university must strive to educate citizens recognizing the intrinsic value of each person, placing freedom and the protection of life as objectives of public policies and individual behavior. The search for this objective must be carried out in harmony with the environment and be conditioned by the need for fairness, respect for the rights of future generations and the stimulation of communicative and participatory rationality procedures in decision-making.

Service-learning recognizes the implicit controversy in the different aspects of the problem that it addresses and encourages analysis and debate on the values involved in each project, so that students recognize the ethical and controversial nature of the problem that is the object of the action.

Numerous authors have referred to the importance of service-learning in the development of values such as citizen participation, respect for diversity and social commitment (Bringle 2020; Bringle and Clayton 2021; Johnson 2017, Lester et al. 2005), although to obtain the maximum benefit from service-learning experiences, it is necessary for teachers to explicitly talk about civic and democratic participation or other values that are expected to be developed through service-learning (Lebovits and Bharath 2019; Millican 2019). And when the service-learning course is over, teachers need to assess whether student values and understanding have changed so that career choices and commitment to sustainable development last.

Teachers who use service-learning recognize that every decision they make about content, methodology and evaluation is imbued with values. That is why they welcome controversial topics linked to the curriculum. Teachers encourage students to arrive at reasoned opinions and to explain how they justify their ideas about the problems they are working on and social justice issues related to them.

Giving students a voice in service-learning activities facilitates the development of tolerance of differences, but also self-esteem, and political commitment. "Voice" (student voice) means that students assume real responsibilities from the very moment of identifying the needs in the community, facing challenging tasks, collaborating in the design of the project and making decisions. Additionally, students learn to give voice to members of the community.

2. Holistic principle: The university, in all its facets, must act from an integral and interdependent conception of the components of the social, economic and environmental reality. Ethical, ecological, social and economic approaches to address problems related to environmental imbalances, poverty, injustice, inequality, armed conflicts, access to health and consumerism, among others. This implies a relational understanding of processes, regardless of their various manifestations.

Service-learning projects cover diverse topics from a holistic and inclusive perspective. This pedagogical orientation requires educators to focus on social responsibility and critical issues for the community. Service activities can be related to the environmental, cultural, social and economic realms and deal with issues such as the natural environment (e.g., restoration of degraded areas, analysis and monitoring of water, flora and fauna, research on endangered species, campaigns awareness raising, energy consumption audits), health promotion (e.g., drug prevention, nutrition, hospital accompaniment), educational support (e.g., literacy, violence prevention, adult education, disability), citizenship, homeless and elderly care, immigration and other human rights issues.

This methodology uses a holistic approach that facilitates the understanding of issues from different perspectives. It teaches students to critically question society and emphasizes sustainable development and social change (Baldwin et al. 2007). Service-learning projects allow critical debates to develop on issues related to ecology, power, privileges and social inequalities and critically examine issues such as environmental imbalances, racism and equal opportunities, favoring sustainable development and the social commitment of the participants from a transformative perspective. The students reflect in a structured way on these realities, their origin, how to prevent and deal with them and the impact of the service in improving the situation and in environmental and social change.

3. Complexity principle: The adoption of systemic and transdisciplinary approaches that allow a better understanding of the complexity of social, economic and environmental problems, as well as their involvement in all situations we can encounter as citizens and professionals.

Service-learning works with real and complex problems, which facilitates the development of systemic thinking and understanding of related problems and the connections between social, cultural, economic, political and environmental systems.

This is possible thanks to the fact that in service-learning projects, the participants carry out different actions (National Youth Leadership Council 2020):

a. Investigate, analyzing problematic situations and identifying needs. They identify the forces that influence the problem and the relationships and patterns between the phenomena. A need in the community is identified through a visit, a debate, the Web, newspapers, interviews, information, data, the history of the group within which they work, etc.
b. Plan and prepare the project with service activities linked to learning objectives based on the needs detected. With the information collected, decisions are made to start the project, in which the curriculum is combined with the needs of the community and the interest and motivation of the students.
c. Act. Students carry out service actions by collaborating with each other and with community partners. They act through a service that involves different types of action: direct or indirect, punctual or continuous, short or long term.
d. Reflect. They do it throughout the entire process and in a structured way to analyze, evaluate, improve the project and integrate the experiences. Students write, discuss, evaluate, make decisions to improve the project, plan, etc.
e. Demonstrate and disseminate. Students record what they have learned and the service that has been provided and extend it by exposing, teaching or representing it: They may make brochures, put up advertisements, design web pages, make videos, organize support campaigns, etc.
f. Evaluate. Students evaluate the phases and results of the project with the participation of the different actors. They obtain information from community partners and final service beneficiaries in order to assess how the project has impacted the identified need. They also evaluate their own experience, as well as the fulfillment of the learning and service objectives.
g. Celebrate. The lessons learned and the achievements of students.

This intellectual, analytical, critical, activist, multicultural and inclusive, experiential, value-based and student-centered character of service-learning projects (Wade 2001) favors the understanding of the complexity of environmental, social, economic, political and cultural aspects.

4. Glocalization principle: The adoption of approaches that establish relationships between curricular content and local and global realities.

As has been said before, service-learning is an experiential learning methodology. Research indicates that learning by doing produces effective results (Kolb 1984). When students integrate the content of a subject or area within real-world activities, they better retain what they have learned. In the case of this methodology, the activities must combine clearly identified curricular content with solidarity actions that must be meaningful both for the students and for the members of the community (Kenworthy-U'Ren and Peterson 2005). This means that service-learning activities not only offer services to the community but also that students carry out important academic and professional learning while identifying the needs of the local and global community, analyzing problematic situations, making decisions, acting, reflecting and evaluating and understanding best how to create sustainable community change. (Brower 2017)

Reflection is probably the most mentioned element of service-learning and the essential one to generate learning (Eyler 2002; Kenworthy-U'Ren and Peterson 2005; Steiner and Watson 2006). In fact, Eyler (2002) goes so far as to say that through reflection academic study is linked to deep understanding of social problems, and students can develop the cognitive capacity to identify, frame and solve unstructured social problems. For this reason, structured reflection is essential to obtain the maximum benefit from service-learning.

5. Transversality principle: Integration of content aimed at educating in competencies for sustainability in the various areas of knowledge, courses and degrees. They will be applied to the different levels of management, research and knowledge transfer at the university.

Service-learning is applied in courses of different disciplines and across all university degrees. Basic elements of this methodology, such as learning through experience and community service action, are known in active pedagogies. Nor is the connection between the university and community service new. However, it is the intentional combination between academic learning and solidarity service which acts in such a way that learning enables service action and service action facilitates meaningful learning. Service-learning is also novel in that this combination contributes to sustainable development, the improvement of communities and the development of civic skills, in addition to the improvement of learning and the development of professional skills.

In any subject, knowledge can be transferred to solve problems related to a sustainable future and social justice, and through projects aimed at natural and social sustainability, significant learning can be achieved in all areas of knowledge. In fact, there are multiple published examples of service-learning projects connected to different areas of knowledge. This methodology can be used in undergraduate and postgraduate degrees associated with specific subjects, but also in specific service-learning courses for one or all degrees or within the framework of external internships.

In relation to this issue, there are two current challenges: to explicitly integrate transversal skills for sustainability in the different university degrees and to promote the institutionalization of service-learning in universities.

6. Principle of university social responsibility: Contribution of the university to the sustainability of the community. This will be reflected in the internal management and in the collaboration with entities and organizations in research projects and actions that contribute to improving the quality of university education and progress in solving social, economic and environmental problems.

Service-learning is a tool that makes the social commitment of the university a reality. It is consistent with the United Nations General Assembly of 2002, which promotes the contribution of universities to natural, human and social sustainable development and the inclusion of teaching-learning methodologies that develop not only professional but also civic competencies and social responsibility. Service-learning responds to the university's commitment to sustainability in the search for environmental quality and social justice; it contributes to generating a culture that promotes comprehensive and environmentally sustainable human development, as proposed by the United Nations General Assembly in 2002. In fact, the number of universities that define service-learning projects with an explicit focus on sustainable development is increasing, albeit slowly (Pearce 2009).

Therefore, it is necessary that higher education assumes a leading role in environmental and human development processes, exploring and putting into practice new strategies aimed at building a fairer and more participatory society.

Service-learning is based on the fact that in order to make the university's principle of social responsibility a reality, collaboration with other social and educational organizations is necessary. Any service-learning project, no matter how small, requires the participation of other entities: associations, NGOs, foundations, municipalities or public institutions. In fact, the generation of networks is one of the characteristics of this methodological approach, which breaks down the walls of the university to contribute to social progress and sustainable development.

Service-learning projects must involve reciprocity. This means that both the student and the agents of the organization benefit from the relationship. This reciprocal benefit is critical to the initial and sustained success of the experience (Kenworthy-U'Ren and Peterson 2005). Faculty must be engaged with the organization and understand their needs and the appropriateness of student involvement in the organization. When the match is effective, faculty gain the trust and understanding of the organization and coach students to create a reciprocal arrangement that benefits both (Cushman 2002). Trust and understanding must be developed so that no one is misperceived as an outsider coming in with prescriptive, preconceived solutions that may not fit the context. (Brower 2017)

Finally, the principle of social responsibility also means taking into account the sustainability of the community capacity building when the service-learning project finishes. The aim is that the community members who have been empowered will sustain and continue the development efforts, but if that does not occur and the community needs persist, it is necessary to reflect on the need to sustain the project (Aramburuzabala et al. 2019).

The use of service-learning pedagogy

Throughout this chapter, service-learning has been presented as a pedagogical strategy that engages students in service to improve understanding of sustainability concepts through hands-on learning and as an instrument of environmental, social and political reform that promotes sustainable development and social justice. Not only does it facilitate the acquisition of knowledge about sustainability and contribute to improving communities, but the methodology itself is also a model of sustainable development for students, since it is inherently sustainable. Through service-learning students and teachers do not limit themselves to reflecting on sustainability, but rather carry out, in practice, work for social and environmental sustainability in a specific field in which, in an effective and applied way, they improve the state of what they work towards as well as promote sustainable development. It is, therefore, a means of education about, for and from sustainability that complies with the principles of sustainable development.

From the perspective of sustainability, service-learning would be a more powerful tool if it worked from an explicit focus on sustainable development, which would guide the entire process, from the detection of needs to the evaluation, including the reflection activities that would have to include sustainable development as an element of criticism and debate.

Service-learning projects of any degree and subject must explicitly integrate within their objectives – and not only de facto – the development of transversal competencies for sustainability (CRUE 2012): (1) Competence in the critical contextualization of the knowledge establishing interrelationships with local and/or global social, economic and environmental problems; (2) competence in the sustainable use of resources and in the prevention of negative impacts on the natural and social environment; (3) competence in participating in community processes that promote sustainability; and (4) competence in the application of ethical principles related to the values of sustainability in personal and professional behavior.

Much has been done regarding the practice and institutionalization of this methodology; however, the use of a service-learning approach that is explicitly based on sustainability and aimed at promoting a higher education that promotes sustainable development in a real and efficient way still needs to be further developed.

Some of these challenges refer to accommodating the model of service-learning within the various socio-political models by:

- adjusting it to the diverse cultural and natural contexts in which it occurs;
- having infrastructure for project coordination at the level of each higher education institution;
- knowledge of the methodology as a means for sustainability education, for which courses, seminars and other training actions are valuable;
- curricular time for teachers, since designing, implementing, and evaluating service-learning projects for educating for sustainable development requires extra effort and time;
- tools and indicators for evaluating the impact of the service-learning experiences on the environment and on the various actors;
- research that allows obtaining evidence of the impact of this methodology on students, teachers, the university, the community, the natural environment, and participating social entities from the sustainability perspective;
- financing that facilitates its use and impact;
- internal and external recognition, both for teachers through promotion mechanisms and accreditation systems, and for students, who must obtain recognition of their participation in these experiences;
- sustainability of the service-learning projects, but also of the institutional programs that support this methodology;
- quality standards that improve the practice and research of service-learning as a tool for education for sustainability;
- involvement of students, academic staff and community partners based on motivation, reciprocity and collaboration;
- and the analysis of the benefits or possible disadvantages of making service-learning mandatory or voluntary for students.

Conclusion

If service-learning is an ideal methodology to promote sustainable development and build significant learning based on real projects, it seems reasonable to promote its use in university education. This requires implementing strategies for the institutionalization of service-learning, so that all students have access to projects of this type throughout their studies. In addition, it is necessary to carry out longitudinal studies on the effects of this methodology from the perspective of sustainability.

The ultimate goal of institutionalization is to promote and facilitate the use of this methodology within higher education so that students perform a service to the community linked to their disciplines learning objectives. It is therefore timely to develop actions that promote the institutionalization of service-learning as a key strategy for sustainability education that complies with the principles of a university committed to sustainable development.

Much has been done regarding the practice and institutionalization of this methodology; however, the use of a service-learning approach that is explicitly based on sustainability and aimed at promoting a higher education that promotes sustainable development in a real, applied and efficient way still needs to be further developed.

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SECTION 7

Environmental stewardship and climate change management as foundational learnings in sustainability education

"We have forgotten how to be good guests, how to walk lightly on the earth as its other creatures do."

(Barbara Ward, 'Only One Earth', 1972)

In this section we highlight the role and value of environmental systems and climate change knowledge and understanding in providing foundational learning and perspective transformation in sustainability education.

Environmental impact management and climate change are often noted within broad education programs but are rarely covered with sufficient depth to assist the student in understanding the challenges that mid-century global climate change will present. Many concepts are not discussed or are only superficially covered. These include sea level rise, changes in agricultural food productivity with warming climates, increased storm activity resulting in millions of people becoming displaced and/or homeless, and mass migration of people from flood-prone countries. Additional important topics include food security and trade risks as dominant crop-growing areas are subject to extended periods of drought, competing efforts for food production versus carbon sequestration, and the significant potential biodiversity loss associated with climate change. Both environmental and climate change education are touchstones in sustainability education and have been given significant focus in this Handbook.

Environmental issues are also a critical part of socio-economic development with the cumulative effects of human activities on global ecosystems. Tyler (see Chapter 7.1 in this volume) notes that understanding and addressing these environmental problems, which are not discipline specific, require both transdisciplinary and transformational learning approaches to understand the systems and feedback loops involved.

Environmental education also provides an important framework for sustainability education development and is an important part of the United Nations Agenda for 2030. Gough (see Chapter 7.2 in this volume) notes that environmental education was reoriented toward education for sustainable development (ESD) at the Earth Summit some 30 years ago, with the ongoing threat of climate change impacts re-emphasising the importance of

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environmental education framing sustainability education. In 2021, the UNESCO Conference on Education for Sustainable Development re-prioritised the environment and our relationships with nature in their sustainable development education agenda (see Chapter 7.2 in this volume).

Climate change is the most complex global commons issue of the 21st century and is a critical component of sustainability education. Alcaraz and Sureda (see Chapter 7.3 in this volume) suggest that climate change governance is a critical component of sustainable human development. A stable global climate system is essential, and a concomitant reduction in greenhouse gas emissions is critical to climate stability. International agreements on carbon reduction have been a part of our global discourse since the 1992 adoption of the UN Framework Convention on Climate Change (UNFCC). However, achieving binding agreements and obligations in policy making for specific numerical targets for CO_2 reduction has been fraught with problems. Climate change policy development has evolved since the first Conference of Parties (COP) in Berlin in 1995, COP 3 in Kyoto in 1997 (Kyoto Protocol), and COP 27 in Sharm el-Sheikh, Egypt in 2022, where leaders were urged to accelerate actions to mitigate and adapt to climate change, more than 30 years after the establishment of the Intergovernmental Panel on Climate Change in 1988.

Alcaraz and Sureda suggest that the Global Carbon Budget is a useful tool with which to both teach and monitor our emission targets. Climate governance ranges from the local level to a global multilateral scale and must consider the important equity challenges of common but differentiated responsibilities and respective country capacities.

McDiarmid *et al.* (see Chapter 7.4 in this volume) suggest that sustainable forest management values, principles, and practices offer valuable lessons in sustainability education. They note the importance of natural resource governance thinking and the role of institutional responsibility in managing natural resources, using sustainable development principles as guiding norms for sustainable production. Forests also play a critical role in global ecosystem health including CO_2 sequestration, climate change mitigation, and biodiversity conservation.

Ohta (see Chapter 7.5 in this volume) examines the role of climate change policy, mitigation, adaptation, and resilience. Climate change challenges are also framed within the important area of governance: How can we influence the management of climate change pressures, like fossil fuel consumption and renewable energy investment, without the role of government and governance frameworks in guiding and enforcing essential levels of carbon management?

Wooltorton *et al.* (see Chapter 7.6 in this volume) highlight the importance of First Nations perspectives on the environment, their sense of country heritage, and their stewardship responsibilities for country in sustainability education development.

The concepts of risk and resilience are important in both sustainability management and sustainability education, as are anticipatory thinking and the precautionary principle. Thomas (see Chapter 7.7 in this volume) contends that understanding risk, anticipatory thinking, and the precautionary principle are all important elements of sustainability management. Whilst risk management may mean choosing a different course of action given uncertainties or unknown threats or challenges, the precautionary principle suggests that 'prevention is better than cure' and advises caution in the face of unknown risks and certainties. These are important strategies particularly in relation to environmental impact risk management.

7.1
THE ENVIRONMENTAL EDUCATION IMPERATIVE 2024

Mary-Ellen Tyler

Key concepts for sustainability education

- Environmental thinking, problems, and issues do not exist within the domain of any one discipline.
- Environmental issues can never escape the sociocultural context in which they exist.
- Environmental problem-solving and sustainability education need both transdisciplinary and transformational learning.
- It is imperative to understand human activities as part of integrated social ecological systems structural and functional feedback loops.
- The cumulative effects of human activities have become a cross-scalar threat to biological life support systems, and there is no economic substitution.

Introduction: environmental déjà vu

The contemporary roots of environment issues have been identified by various authors in a variety of contexts. In a North American context, the 'conservation' movement of the 1940s, 1950s, and early 1960s (highlighted by books such as Aldo Leopold's *Sand County Almanac* and Rachel Carson's *Silent Spring*) was identified by Crosby (1995) as the foundation of contemporary environmental thinking. Alternatively, McGrail (2011) identified the late 1960s and early 1970s as the 'first wave' of environmentalism, characterized by growing public awareness of industry-related environmental impacts and concerns about the availability of natural resources relative to unlimited population and economic growth (Meadows et al., 1972). McGrail (2011) also identified a 'second wave' of environmentalism in the 1980s characterized by the concept of sustainable development. Sustainable development emerged from the World Commission on Environment and Development's report "Our Common Future" in 1987 (Brundtland report). Sustainable development quickly became the dominant framework for attempting to resolve the conflicts among economic, social, and ecological priorities. A decade later, the United Nation's Intergovernmental Panel on Climate Change (IPCC) began the first of six cycles to assess climate change at a global level (IPCC, 1990, 1995, 2001, 2021). These IPCC assessment reports

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shifted international focus to understanding human contributions to global climate change and its negative economic, social, and ecological consequences.

Despite the goals of preservation and protection of special landscapes and species advocated by the conservation movement, habitat and species loss have continued to increase at a global scale (IUCN, 2013, 2020). Similarly, sustainable development's goal of incorporating long-term social and ecological consequences into short-term economic decision-making has been subject to resistance and difficult to operationalize in pluralistic and politically polarized times. Similarly, climate change's focus on rethinking our economic and social dependency on fossil fuels has been just as contentious. Sneddon et al. (2006: 254) refer to this contentious sociopolitical context as the "post-Brundtland quagmire" and attribute it to the presence of "ideological and epistemological straight jackets" which have made collaboration, communication, and structural change extremely difficult. Awareness of environmental issues has become a significant part of mainstream popular culture, public discourse, institutional policy, and political debate over the last 60 years. However, environmental issues remain largely unresolved and continue to rapidly evolve in both scale, complexity, and potential consequence.

Environmental thinking

The stars appear small and our planet big only because of our perspective. Worldviews are part of our cultural history and context and dominate the way we organize the world around us. If we conceptualize the world as a giant machine, then we treat it in mechanistic ways. Conceptual frameworks shape cultural and social thinking. A worldview expresses 'the right order of things' that guides thinking and behaviour. Dominant conceptual frameworks have changed over time in both the sciences and humanities. Contemporary environmental thinking has come a long way from the "Cartesian Division" of the early 17th century which conceptually separated humanity and the natural world (O'sullivan, 1986). It is now generally acknowledged that culture and nature are inextricably linked and co-created. American poet Joyce Kilmer's 1914 poetic expression "only God can make a tree" continues to be seriously challenged by advances in bio-genetic engineering. The modernist belief that all problems could be solved through rational deduction and all social needs satisfied by science through causal analysis has been seriously eroded by its limited effectiveness in dealing with major public policy issues. The Cartesian tradition of separating the 'humanities' from the 'sciences' continued into modernist thinking and is still common (Gaukroger, 2006).

The re-framing of the human world as a 'social construct' began as a theory of social learning with Vygotsky and Piaget's work in the 1900s which reinforced the critical inter-relationship between culture and social learning in shaping worldviews and drew on philosophy from the 16th century (Staver, 1986; Eder, 1996; Rolston III in Chappell, 1997). The emergence of the term 'social construct' with Berger and Luckmann's (1966) seminal book *The Social Construction of Reality* was radical for its time and ranked as the fifth most important book of the 20th century by the International Sociological Association in 1998. Nature in this context became less a physical object to be 'discovered' and more of a culturally mediated worldview. Environmental issues can never escape the sociocultural context in which they exist. The value of sociocultural context in understanding environmental issues was described by Williams (2002: 20): "a socio-cultural view of meaning formation causes us to examine not just what values people hold, but where these values and meanings come from . . . how they are negotiated in society, how they are used in conflict situations,. . . and how they influence policy decisions".

There has been a 'gap' between science and public policy recognized in the academic and professional literature since the 1970s (Rittel and Webber, 1973; Bradshaw et al., 2000; Sébastien et al., 2014). A similar gap has also been identified between science and society (Wiek et al., 2012), science and media (Peters, 2013), and science and decision-making (Kiem et al., 2014). In all cases, this gap appears to refer to the difficulty of understanding science in the context of its social meaning. While scientific literacy is critical and necessary in environmental thinking, social and cultural literacy is equally critical and necessary. Applying only deterministic quantitative methods to issues where there are multiple possible outcomes and multiple social stakeholders is both scientifically and socially limited. All data needs to be validated, appropriately manipulated in a disciplinary or multidisciplinary context, and interpreted for meaning and significance before it can be used in making value-based choices. This is rarely easy in policy contexts with a variety of social, cultural, and political value systems and socioeconomic expectations. Even with low complexity 'measurements' cannot always identify the most appropriate social policy, decision, or management action to be taken as they are still subject to human interpretation. Even in highly technical situations, quantitative data still requires interpretation in decision-making. For example, it is likely that human error contributed to the Chernobyl nuclear accident in 1986. Sadly, plant operators' interpretation of available data appears to have resulted in bad decision-making (Dorner, 1996; Mullner, 2019).

Perhaps the best current example of the need to marry science and humanities in environmental thinking is climate change policy. The IPCC has been releasing technical reports since 1990 which provide 'numbers' validated by at least 196 international peer-reviewed scientific sources. These numbers show the planet warming and they have been subject to over 30 years of political and scientific debate about their 'reality'. In the meantime, there has been very little advancement in comprehensive climate change policies in national and local contexts. While science is necessary in environmental thinking, beyond very simplistic causal relationships, quantitative data may be necessary, but alone it is insufficient. Environmental policy making needs to incorporate and orchestrate the sciences and the humanities to forge socially sanctioned ways of thinking and acting.

'Environment' is different

Part of the challenge of environmental thinking is coming to grips with what is meant by the term 'environment'. Environment has historically been thought of as the human-constructed physical and social environment and the 'natural' environment. Environment also refers to the social, spatial, technological, or bio-geo-climatic contexts we actively or passively inhabit. As such, environment is a socially mediated construct involving both human and non-human components. The common reference to 'the' environment reflects the Cartesian division that the natural world is separate from human beings. This is at best a misconception and at worst a major barrier in environmental thinking. The human species is a biological species and dependent on biological life support systems. It is this reality that underlies the importance of environmental thinking. Technology is used to mediate human interactions, but technology cannot replace air, water, and soil. The environmental imperative of 2024 is the cumulative effects of human activities which have become a threat to biological life support systems for which there is no economic substitution.

Rittel and Webber (1973) challenged the accepted belief that 'scientific' approaches were the best way to deal to with public policy and planning problems. Their radical proposition stated "that scientific and technical approaches would not 'work' for complex social issues" (Head, 2019). Zellner et al. (2015: 1) re-phrased this to suggest "conventional scientific approaches failed to solve problems of pluralistic urban societies". Essentially, the limitations of conventional scientific and technical approaches in dealing with complex social and public policy issues has been recognized for the last 49 years. However, successful alternative approaches remain elusive. The reason may be, in part, because public policy and planning issues are 'normative' in so far as they focus on what 'should' happen in an uncertain future. Rittel and Webber's (1973) proposition that scientific and technical approaches have significant limitations was specific to a type of problem which they termed "wicked". These wicked problems have a high degree of complexity and uncertainty and have ten identifying characteristics summarized by Head and Alford, 2015: 714) as:

1. There is no definitive formulation of a wicked problem.
2. Wicked problems have no "stopping rule" (i.e., no definitive solution).
3. Solutions to wicked problems are not true or false, but good or bad.
4. There is no immediate and no ultimate test of a solution to a wicked problem.
5. Every (attempted) solution to a wicked problem is a "one-shot operation"; the results cannot be to learn by trial and error.
6. Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
7. Every wicked problem is essentially unique.
8. Every wicked problem can be considered to be a symptom of another problem.
9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways.
10. The planner has no "right to be wrong" (i.e., there is no public tolerance of experiments that fail).

Environmental problems are wicked problems and tend to exhibit these ten characteristics. For example, Thompson (Castree et al., 2018: 258) has described environmental problems and specifically anthropogenic climate change as a wicked problem "whose very definition is debated and disputed, so that different interpretations of causes and solutions compete to define 'the problem' in question". As such, environmental problems cannot be solved by conventional scientific and technical approaches because they involve complex social ecological systems behaviour which is not well understood in either the context of conventional scientific or public policy thinking. The hallmark of environmental issues is their complexity and sociocultural dimensions.

Complex systems and ecosystems

Complexity is a key characteristic of environmental problems and wicked problems. The most common meaning of complexity is multiple components connected and interacting in multiple ways. The greater the number of components and the more ways in which they can interact increases complexity. In 1928, Von Bertalanffy (translated by Woodger, 1933: 64) identified complexity in biological organisms and introduced systems theory in biology: “Since the fundamental character of the living thing is its organization, the customary investigation of the single parts and processes cannot provide a complete explanation of the vital phenomena”. In other words, the organism is more than the sum of its parts. Previously, reductionist approaches assumed understanding parts would result in understanding the whole. While this type of mechanistic and deterministic thinking may apply to objects with limited sets of components and connections such as clocks, it is not sufficient for understanding the dynamic behaviour of living organisms. Von Bertalanffy (1950) formally presented a ‘general systems theory’ and over the next 20 years complex systems thinking continued to develop (Dror, 1969; Chadwick, 1971; Iberall, 1972).

Tansley used the term ‘ecosystem’ in 1935 to describe dynamic biotic and abiotic collectives of interacting components and processes (Willis, 1997). In 1942, Lindeman applied the ecosystem concept in his aquatic biology research and viewed a lake as an integrated whole system. As a result, Lindeman was the first to identify trophic (feeding) webs, energy flow and transfer and nutrient cycling inter-relationships (Cousins, 1996). This work resulted in a radical shift in ecology from a descriptive and taxonomic focus to a trophic systems approach (Salomon, 2008; Schowalter, 2016). This ‘new’ ecology was described by Odum (1964: 14) as “a shift from the descriptive to the functional”. In this new ‘functional’ systems framework, ecological systems were viewed as self-organizing energy systems and much of the subsequent research in systems ecology focused on system thermodynamics (Odum, 1968, 1973; Kay, 2000; Schneider and Kay, 1994).

The fallacy of command and control and stability

Despite the emerging dominance of ecosystem thinking, its initial application to natural resource management practices was not enthusiastically reviewed. Specifically, Slobodkin (1988) expressed concerns that systems ecology was too theoretical for pragmatic problem-solving. However, this was less about ecological systems thinking and more about the expectations and assumption of a specific sociocultural view that the role of science is to provide the rules for quantitative prediction. However, ecosystems are complex dynamic, self-organizing and open systems and far from simple, deterministic, or stable. The challenge this presents to conventional applied science and policy approaches is: “We will have to learn that we don’t manage ecosystems, we manage our interaction with them” (Schneider and Kay 1994, 49).

Natural resource management has been historically focused on the social economic harvesting of populations of plants and animals in the context of fishing, forestry, and game animals. Similarly, applied ecology has focused on the control of insect pests or the management of specific landscapes or habitats of social, economic, and ecological value. The historical role of management has been to control specific functional and structural relationships and processes to achieve specific and desirable socioeconomic goals. Management for economic targets usually involves the increasing harvest or capture of more fish or trees or animals by increasing control. This ‘command and control’ approach to managing ecosystems and ecosystem components was described by Holling et al. (1996) as one of the reasons for environmental degradation and unanticipated negative effects. This ‘pathology’ of natural resource management as described by Holling et al. (1996) is the loss of resilience to human-induced or natural disturbances or stresses resulting from reducing the complexity and variation in ecological systems. This is problematic because ecological systems as dynamic complex systems are self-organizing systems that change over time in response to variability in both internal and external processes. Human control activities essentially limit and reduce the capacity and information available to the system to self-organize and respond to disturbance or perturbation. The assumption of stability in natural systems is again a sociocultural worldview. Complex systems have multiple states of equilibrium they can occupy, but over time display equilibrium punctuated by dis-equilibrium. Disturbance can be buffered up to a point, but if these buffering thresholds are surpassed, the system will move into a different domain or range of conditions. The popular belief that natural systems were 'stable' and would go back to 'normal' once the human activities causing stress or perturbation were stopped or significantly reduced was challenged by Holling in 1973. Holling introduced the concept of ecological 'resilience' in which systems manage change by transforming into different systems and behaving in different ways. As such, systems persist, not because they remain unchanged but because they are capable of change. As described by Holling and Gunderson (2002: 28), 'resilience' refers to "the magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behavior." For example, the planetary climate system has transformed over millions of years but continues to be the global climate system. As a result of anthropogenic effects, it appears to be in the process of transforming again. It is becoming a different system, but it remains the global climate system. Whether or not it is a system favourable to specific plant and animal species, including *Homo sapiens*, remains to be seen, but the historical fossil record and paleoecology record show that the global climate system has transformed over millions of years. As systems transform the 'old' normal becomes a 'new' 'normal'. This is a stark contrast with the popular belief that 'resilience' means 'resisting' or preventing change. However, complex systems adapt to change and manage change by changing over time.

Social ecological complexity and post-normal science

Complex systems includes social cultural systems as well as ecological systems. Social cultural systems also exhibit characteristic self-organizing, 'emergent', and 'adaptive' behaviours. They are also unpredictable and full of surprise and defy conventional methods of prediction. As such, environmental issues involve two types of complex systems interacting with each other. Complexity is a defining characteristic of wicked problems because of the indefinite number of possibilities involved in system behaviour. This is further complicated by the emergent and adaptive characteristics of complex systems. Emergent behaviour 'appears' at certain levels of organizational complexity that cannot be predicted by or explained by lower levels of organization. As such, emergent phenomena are 'surprises', with the biggest surprise being "complexity lurks even within simple systems" (Lansing, 2003: 183). Emergence or surprise refers to something happening that was not expected. As in the previous example of command-and-control, natural resource managers have assumed a predictable linear response and were surprised when this did not occur because the resources systems in which they were intervening were complex systems. Systems behaviour becomes increasingly unpredictable with increasing complexity which increases the likelihood of surprise or emergent phenomena. Adaptive or transformative systems behaviour also increases surprise because the system's complex interactions can have a range of possible behaviours, dependent on changing circumstances.

The ability to make accurate predictions about future states is low when uncertainty is high, and conversely, uncertainty is high when dealing with emergent adaptive complex systems. The gap between policy and science when it comes to environmental and social environmental issues is in large part the expectation that policy making will result in certainty for issues that are highly uncertain. Funtowicz and Ravetz (1990, 1991) introduced the concept of "post-normal science" in recognition of the difficulties of problem-solving and decision-making in situations with high complexity and uncertainty. As illustrated in Figure 7.1.1, the terms "applied science", "professional consultancy", and "post-normal science" are used to refer to three types of "problem-solving strategies" (Funtowicz et al., 1994: 1882).

Each type of problem-solving strategy requires different ways of thinking and different methods of dealing with each type of complexity and uncertainty. Given the high levels of uncertainty and complexity involved in global environmental risk, a post-normal science approach and the ongoing development of new methods are required. As Schlüter et al. (2019: Abstract) state: "Analyses of SES phenomena thus require approaches that can account for (1) the intertwinedness of social and ecological processes and (2) the ways they jointly give rise to emergent social-ecological patterns, structures, and dynamics that feedback on the entities and processes that generated them". Developing the breadth and depth of knowledge necessary to understand and manage emergent and adaptive complex social ecological systems at large scales is foundational to addressing the environmental imperative of 2024. It is necessary to understand how environmental thinking has evolved in order to understand the roots of current thinking and possibilities for future directions. Environmental thinking and problem-solving have moved beyond disciplinary reductionism and the artificial separation of the sciences, arts, and humanities over the last 50 years. However, an operational understanding of the behaviour of social ecological systems (SESs) is still in its early stages, and the body of knowledge necessary for addressing global scale environmental issues is still evolving

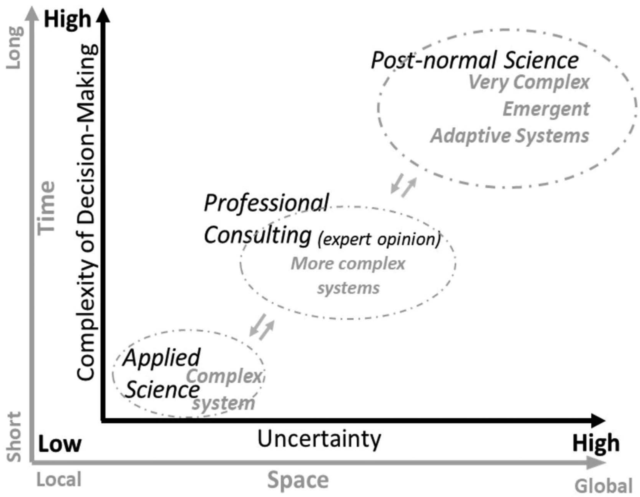

Figure 7.1.1 Post-normal science and complexity.

Source: Adapted from Funtowicz et al. (1994) and Sitte (2009)

Seven key learning concepts for sustainability education

The level of environmental literacy in popular culture needs to move beyond simple narratives of environmentally 'friendly' and 'sustainable' ways of endlessly increasing consumption. The complexity, timeframe, and global scale of environmental issues require equally complex and large-scale thinking and strategic action. The ongoing and artificial divisions between the disciplines in the sciences, arts, and humanities, together with short-term and narrowly focussed political and public policy decision-making, continues to be driven by economic growth targets. The idea that environmental science should be "based on unpredictability, incomplete control, and a plurality of legitimate perspectives" remains as unpopular and misunderstood as it was 30 years ago (Funtowicz et al., 1994: 1881). However, like all radical and counter to the mainstream ideas, Jansoff (2010: 237) suggests: "we should not be surprised if it takes decades, even centuries, to accommodate to such a revolutionary reframing of human-nature relationships".

The key learning concepts for sustainability education may at first seem less than 'heroic measures' in a media-driven popular culture that thrives on human drama, big science, and technology. The key learning concepts for sustainability are not mathematical equations, computer models, or economic assumptions. In contrast, the key concept, is how we think about things. The idea of how we think is as ancient as humanity and will be the basis for our future. The conceptual frameworks and cultural worldviews we use are inherent in how we view the 'right order of things' and underlie the values that drive institutional decision-making. Just as climate change and social justice will increasingly create moral and ethical choices, how we conceive of complex social ecological systems will also determine our future choices. Therefore, the following seven key concepts are being proposed for sustainability education in order to move environmental problem-solving forward and make sustainability more operational than aspirational. A brief overview is provided for each key concept, as there is an evolving and abundant body of research publications available online for each one to enable further and more detailed exploration.

Transformational learning

Transformational learning is key to both environmental thinking and sustainability education. It involves recognizing the complexity of social ecological issues and that environment is not 'other', but as much human as ecological. If environmental problems are 'wicked' problems involving emergent and adaptive complex SES behaviour, then a conceptual framework for understanding SES dynamics is an important place to start. Mezirow and Rose (1978) first used the term 'transformation' in the context of adult education. Transformation learning theory has evolved over time, but critical self-reflection and critical discourse are two major aspects that focus learners on assumptions and the "epistemic nature of problems and the truth value of alternative solutions" (King and Strohm Kitchener, 1994: 12). A transformational learning process enables the learner to re-examine their personal beliefs and perspectives. Mezirow (1985: 21) identifies two terms, "meaning perspective" and "meaning scheme", which become the focus of the learners' critical reflection and critical discourse process. Meaning perspective refers to "the structure of cultural and psychological assumptions within which our past experiences assimilate and transform new experiences". Meaning scheme refers to "the constellation of concepts, beliefs, judgments, and feelings which shapes" the learners' interpretation of information. For example, it is critical that old assumptions and concepts about environment and humanity as separate entities quite independent from each be subjected to critical reflection and critical discourse in order to create new meaning perspectives and new meaning schemes in sustainability education.

Transdisciplinary problem-solving

A integrated transdisciplinary approach has been described as a "key component of sustainability science" and defined as "a research approach that includes multiple scientific disciplines (interdisciplinarity) focusing on shared problems and the active input of practitioners from outside academia" (Brandt et al., 2013: 1). It has been promoted as offering an integrated knowledge framework for engaging wicked SES problems and is seen as a way of knowledge creation and understanding without disciplinary boundaries. But as Serrao-Neumann et al. (2015) and Klenk et al. (2015: 160) report, it is not free from "the 'messy' politics of achieving consensus among radically different, and sometimes irreconcilable, ways of knowing" and "the friction, antagonism, and power inherent in knowledge co-production, which in turn can exclude innovative and experimental ways of understanding". This critique of integrative approaches is essentially the same critique that has dogged the history of science, including the humanities, since antiquity. Because social behaviour is involved in the creation of knowledge, knowledge creation is not disconnected from power, authority, and control in a variety of contexts. To date it has been the outcomes of knowledge creation (theories and methods) rather than the process of knowledge creation that has been seen as valuable. However, to deal with environmental problem-solving involving SES it will require focusing on the process of integrative knowledge creation and how to enable the process. Conventional education has emphasized technical and intellectual knowledge and not social and interpersonal competencies. Collaborative and integrative approaches to knowledge creation and problem-solving require the ability to work in groups or teams which is too often assumed to occur. It is seldom taught and rarely viewed as an important area of research and scholarship. A significant barrier in trying to deal with complex wicked environmental problems is a lack of knowledge and understanding about how to effectively organize and work together across disciplinary lines. As American cartoonist Walt Kelly's character Pogo famously stated: "We Have Met the Enemy and He is Us" (Kelly, 1982).

Scenario building

Scenarios have emerged as an alternative method of knowledge co-production in the sciences, social sciences, and the arts. However, the term can mean different things in different fields. For this discussion, scenarios represent "structured conceptual systems of equally plausible future contexts" (Ramirez et al., 2015: 70). Scenarios have been used as a research tool in exploring potential future effects of climate change on Australia's Great Barrier Reef. In this application, the use of scenarios helped "elicit a diversity of responses from multiple stakeholders . . . that contributed to new and interesting insights into how adaptation is perceived" (Evans et al., 2013: 854). Similarly, scenarios have been used to explore responses to surprise and system discontinuity in environmental change research (Schweizer and Kriegler, 2012) and new research questions in long-term ecological research (Thompson et al., 2012). Research on climate adaptation policy alternatives has also been done by

Füssel et al. (2006) using a regional analysis methodology based on impact scenarios (Füssel et al., 2006). There is a myriad of examples of scenario building, scenario development, and scenario applications in the research literature that support the benefits of scenarios as a tool for gaining insight into different stakeholder perspectives and values as well as alternative futures in uncertain situations at different geographic scales and timescales.

Cumulative effects

The Canadian Council of Ministers of Environment (CCME) provides an intergovernmental forum for the discussion of environmental issues and establishing priorities for collective action (Noble et al., 2019). The CCME describes a cumulative effect as "a change in the environment caused by multiple interactions among human activities and natural processes that accumulate across space and time" and CEA as "a systematic process of identifying, analyzing, and evaluating cumulative effects." This definition is consistent with the general understanding of cumulative effects in a Canadian context going back to Hegmann et al. (1999) and restated by Dube (2003: 723) as "an effect on the environment that results from the incremental, accumulating and interacting impacts of an action when added to other past, present, and reasonably foreseeable future actions". Cumulative effects assessment (CEA) and regional-scale strategic environmental assessment (R-SEA) frameworks involve alternative future scenarios involving multiple stressors on valued ecosystem components to provide strategic and situational insight into possible changes over time in social ecological terrestrial and aquatic systems. The uncertainty and complexity involved in understanding multiple stressors and valued ecological component thresholds is highly contextual and cannot be easily measured or 'summed up'. Both CEA and R-SEA often have limited historical baseline data and monitoring of change over time as well as a lack of established methods for establishing valued ecological components and thresholds. However, cumulative effects approaches encompass social and ecological systems at large regional scales and have been effective in supporting planning and policy making in a variety of contexts. For example, the Beaufort Regional Environmental Assessment study was conducted over four years to identify cumulative effects and risks to terrestrial and marine land use from energy development. A working partnership involving the Government of Canada, the Inuvialuit people of the western Canadian Arctic region, and other key stakeholders collaborated in undertaking the study (Canada, 2016). A cumulative effects approach can enable collaborative co-creation of knowledge in a transdisciplinary framework that acknowledges SES complexity and surprise and focuses on providing decision support across jurisdictional scales. Cumulative effects assessment also involves scenarios and integrated learning and is a valuable area of competency for environmental education.

Network theory

Network theory and analysis is mathematical in nature and part of complexity theory. It has been applied to social systems and ecological systems. Examples of networks include trophic webs in ecosystems, social networks in human populations, and the internet. Networks, like system constructs, consist of "a set of actors or nodes along with a set of ties of a specified type that link them. The distinguishing feature of networks is that ties interconnect through shared end points to form paths that indirectly link nodes that are not directly tied. Network structure is defined by the pattern of these ties and nodes" (Borgatti and Halgin, 2011: 1169). For example, the 'centrality' of a network is determined by node positions and disconnected networks have ties that cannot be linked to nodes. The idea of "small worlds" emerged in the 1960s from Milgram's (1967) letter-mailing experiments which showed there was a minimum of five connections between a random sample of people in New York City. Watts and Strogatz (1998), developed mathematical methods (including graph theory) to explain these small world connections. As a result, small world network theory has been shown to occur in both social and ecological systems. The value of network theory to the study of emergent and adaptive SES is its potential to identify the number of nodes that connect extremely large systems. Buchanan (2003) cites an example of the application of small world network theory to a portion of the food web in the North Atlantic Ocean ecosystem to study predator-prey relationships affecting Canada's east coast fisheries. Similarly, Williams et al. (2002) used small world techniques on seven complex food webs and found that more than >95% of species in these food webs were connected by three network links or three degrees of separation. As such, network analysis can identify critical interconnections affecting the structure and function of the whole system.

Feedback loops

Feedback in nonlinear (complex) systems helps regulate system states and processes within a range of preferred operational states to maintain homeostasis. The term 'loops' refer to combinations of one or more system components that function together to provide either positive or negative information (Thomas et al., 1995). Positive feedback loops "are associated with exponential growth or collapse. . . . Negative feedback loops are associated with oscillatory trends or dampening" and associated with system stability (Abram et al., 2018: 335). Feedback loops are critical drivers of system behaviour. Feedback loops are not static, but can be stronger or weaker depending upon external drivers, different scales, and connections with other loops. The effect of feedback loops can be magnified and create a 'cascade' effect. Cascade theory has focused on trophic web perturbations at the ecological community level caused by the addition of a new species or loss of an existing species. However, cascade theory has expanded to include social systems as well as SES feedback loops (Lawrence et al., 2020). As described by Kinzig et al. (2006: 1): "Over time, socio-ecological systems can change states when system variables of different spatial and temporal scales and in different domains cross system-critical thresholds. This results in a cascading effect that induces or accelerates the crossing of other thresholds in connected domains and sub-systems". Understanding feedback loops is key to understanding social ecological systems and environmental issues like climate change. Specifically, feedback loops interconnect SES and human activities that generate greenhouse gases (GHGs) are subject to both positive and negative feedback responses, which can amplify or dampen the effects of change over time.

Vulnerability and resilience

Similar to sustainability, 'resilience' also has different meanings and interpretations. Specifically, resilience can be used to describe both the ability to resist change and the ability to adapt to change. Multiple authors have defined resilience in an SES context (Carpenter et al., 2001; Walker et al., 2004; Folke et al., 2010). The general definition of resilience is provided by Sommerkorn et al. (2013: 15) as: "Resilience is a property of social-ecological systems. It relates to their capacity to cope with disturbances and recover in such a way that they maintain their core function and identity. It also relates to the capacity to learn from and adapt to changing conditions, and when necessary, transform". Resilience involves feedback loops, cross-scalar interrelationships, and thresholds over time. To date, there is little agreement on how to measure resilience or if resilience can be measured. As such, the concept of vulnerability in SES has emerged in tandem with resilience (Adger, 2006). Vulnerability and resilience are related concepts, although the specific nature of this connection is not entirely clear. Vulnerability is considered as a function of sensitivity to change, adaptive capacity, and degree of exposure. Resilience has been viewed as the "flip side" of vulnerability and vulnerability as an indicator of system resilience (McCarthy et al., 2001: 89). Vulnerability assessment has consistently been used as an indicator of system resilience by IPCC working groups and appears to be a more productive tool than resilience assessment so far.

Conclusion

The historical evolution of environmental understanding will continue to be an increasingly critical endeavour with the ever greater awareness of the dependency of social well-being on ecological support systems Working toward culturally appropriate, cross-scalar, and adaptive action to address increasingly important but wicked environmental problems will require transformational learning and transdisciplinary approaches involving the social sciences, information sciences, technology, design, classical sciences, and natural sciences. Developing transdisciplinary environmental and sustainability education to support this critical challenge is only in its early stages. The path forward has been poetically described as "learning to think like a planet" (Haigh, 2014: 50). But the hard work lies in learning to think about human social systems as complex dynamic systems which are intricately coupled with equally complex and probabilistic ecological systems. Environmental problem-solving and sustainability education needs both transdisciplinary and transformational learning. Sustainability education is critical in moving historical and current narrowly defined disciplinary bodies of knowledge towards a more integrative and inclusive framework for learning from and understanding place-based complex social ecological systems which are full of surprises!

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7.2
THE TRANSITION FROM ENVIRONMENTAL EDUCATION TO SUSTAINABILITY EDUCATION

Annette Gough

Key concepts for sustainability education

- Environmental education has its origins in calls from scientists.
- Environmental education was a key starting point for sustainability education.
- Environmental education provides a framework for sustainability education.
- Environmental education was reoriented to be education for sustainable development in the 1990s.
- The environment almost disappeared from education for sustainable development in the 2000s.
- Environmental education should not be equated with education for sustainability.
- Naming the Anthropocene refocussed attention on environmental education.
- Education for environmental sustainability is part of the United Nations agenda towards 2030.
- Climate change education has become an important component of the international education for a sustainable development agenda.

Introduction: origins of environmental education

According to William Scott and Paul Vare (2018, 226), "In the beginning . . . all education was environmental, because it was a matter of survival: a response to questions of food, shelter and safety". Thus, it is not surprising that recognition of the need to protect the natural environment from human exploitation and for the sustainable management of resources has been dated to the eighteenth century, if not earlier in Europe (Blewitt 2015). Such recognition "existed in the conservation philosophy of the Theodore Roosevelt administration in the United States (1901–1909) and its concern for the rational uses of natural resources" (McCormick 1986, 178), and it is an essential component of indigenous fishing and hunting practices.

The field of environmental education, which has more recently been called sustainability education, arose out of the growing awareness of the threat of environmental degradation in the 1960s. Throughout the decade of the 1960s, scientists increasingly drew attention to

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the growing scientific and ecological problems of the environment and the need for greater public awareness of these problems (see, for example, Carson 1962; Ehrlich 1968; Goldsmith et al. 1972; Hardin 1968). The problems were seen as the increasing contamination of land, air and water; the growth in world population; and the continuing depletion of natural resources. These problems were formally recognized in the 1972 United Nations Declaration on the Human Environment (United Nations 1973, 3):

> We see around us growing evidence of man-made [sic][1] harm in many regions of the earth; dangerous levels of pollution in water, air, earth and living things; major and undesirable disturbances to the ecological balance of the biosphere; destruction and depletion of irreplaceable resources; and gross deficiencies in the man-made [sic] environment of human settlement.

The scientists were calling for more information about the state of the environment, and for education, albeit from a Western (and male)[2] perspective (see Gough 1994, 1999). For example, Rachel Carson (1962, 30) argued that "The public must decide whether it wishes to continue on the present road, and it can do so only when in full possession of the facts".

Environmental problems were often seen as scientific problems which science and technology could solve, but increasingly even the scientists themselves were arguing that science and technology were not enough. For example, urban biologist Stephen Boyden (1970, 18) argued that:

> The suggestion that all our problems will be solved through further scientific research is not only foolish, but in fact dangerous . . . the environmental changes of our time have arisen out of the tremendous intensification of the interaction between cultural and natural processes. They can neither be considered as problems to be left to the natural scientists, nor as problems to be left to those concerned professionally with the phenomena of culture . . . all sections of the community have a role to play, certain key groups have, at the present time, a special responsibility.

Boyden saw educational institutions as being at the top of the list of key groups and charged them with providing students with an awareness of the threats to the human species and stimulating thinking and discussion on the social and biological problems facing humanity while avoiding "the implication in teaching that all the answers to any problems that man [sic] may have lie simply in further intensification of scientific and technological effort" (Boyden 1970, 19).

Scientists were strong in their calls for education as a necessary component of any solution to the environmental crisis. Schoenfeld (1975, 45) states the position succinctly: "it is a cadre of scientific leaders that sets the environmental agenda in this country [USA]", and elsewhere and, as previously mentioned, Western scientists such as Carson, Ehrlich, Goldsmith and Hardin were putting education on the environmental agenda. However, they were not the only ones putting pressure "towards using education to help restore and maintain a viable life-support system. . . . The pressures come from government and from advocates of a variety of disparate positions concerning environmental needs" (Lucas 1979, 3).

These calls led to a global imperative to educate people to protect and enhance their environment. For example, at a conference held at the University of Keele in 1965, it was agreed that environmental education "should become an essential part of the education of all citizens, not only because of the importance of their understanding something of their environment but because of its immense educational potential in assisting the emergence of a scientifically literate nation" (Wheeler 1975, 8). The United States Congress passed an Environmental Education Act in 1970 (McCrea 2006, 4). The 1972 *United Nations Declaration on the Human Environment* reinforced the importance of environmental education in one of its principles:

> Education in environmental matters, for the younger generation as well as adults, giving due consideration to the underprivileged, is essential in order to broaden the basis for an enlightened opinion and responsible conduct by individuals, enterprises and communities in protecting and improving the environment in its full human dimension.
>
> *(United Nations 1973, 5)*

Framing environmental education

The descriptions of the requirements of environmental education which emerged in the late 1960s and early 1970s were concerned with introducing ecological (environmental) content into educational curricula at all levels, promoting technical training and stimulating general awareness of environmental problems. The recommendations were similar whether they came from a 1968 UNESCO Biosphere Conference (Goodson 1983) or from the 1970 Australian Academy of Science Conference (Evans and Boyden 1970). However, the statements were more exhortations than specifications.

Around this time there were many individuals, groups and organizations proposing definitions of environmental education in attempts to clarify their intents. Bill Stapp and a group of colleagues in the School of Natural Resources at the University of Michigan developed a definition for a new educational approach "that effectively educates man [sic] regarding his relationship to the total environment" which they called 'environmental education': "*Environmental education* is aimed at producing a citizenry that is *knowledgeable* concerning the biophysical environment and its associated problems, aware of *how* to help solve these problems and *motivated* to work toward their solution" (Stapp et al. 1969, 30–31, emphasis in the original). This definition, together with four objectives for environmental education, was published in the first issue of *The Journal of Environmental Education*. The four objectives were to help individuals acquire (Stapp et al. 1969, 31)[3]:

1. A clear understanding that man [sic] is an inseparable part of a system, consisting of man [sic], culture, and the biophysical environment, and that man [sic] has the ability to alter the interrelationships of this system.
2. A broad understanding of the biophysical environment, both natural and man-made [sic], and its role in contemporary society.
3. A fundamental understanding of the biophysical environmental problems confronting man [sic], how these problems can be solved, and the responsibility of citizens and government to work toward their solution.

4. Attitudes of concern for the quality of the biophysical environment which will motivate citizens to participate in biophysical environmental problem-solving.

Stapp et al. argued that this educational approach was different from conservation education, which was seen as being oriented primarily to basic resources, not focused on the human environment and its associated problems, and not emphasizing "the role of the citizen in working, both individually and collectively, toward the solution of problems that affect our well being" (1969, 30). He proposed a curriculum development model which he brought to Australia in 1970 when he spoke at the Australian Academy of Science conference (Evans and Boyden 1970). This model focuses on curriculum development procedures, "with a consequent emphasis on administrative strategies rather than philosophical analysis" (Linke 1980, 34–35), an orientation which has dominated much of the environmental education discourse.

The Stapp et al. (1969) definition and objectives for environmental education formed the basis for a number of other conceptions of the field. For example, in September 1970 the International Union for the Conservation of Nature and Natural Resources (IUCN) held an International Working Meeting on Environmental Education in the School Curriculum, in Nevada, USA, which accepted a definition of environmental education which was to become widely used in subsequent years (IUCN 1970, 11):

> Environmental education is the process of recognizing values and clarifying concepts in order to develop skills and attitudes necessary to understand and appreciate the interrelatedness among man [sic], his [sic] culture and his [sic] biophysical surroundings. Environmental education also entails practice in decision-making and self-formulating of a code of behavior about issues concerning environmental quality.

Given the types of definitions of environmental education that were emerging around this time, using terms such as 'man', 'biophysical', 'ecosystems' and 'ecological principles', it is perhaps not surprising that science education was frequently seen as the place for environmental education, generally in the form of ecological concepts, to be incorporated in the school curriculum. However environmental education was not seen as an educational priority by education departments in the way that it was seen as a scientific or social priority by scientists, environmentalists and academics. Rather, it was treated as yet another lobby group wanting space in an already overcrowded curriculum (Gough 1997).

As a result of the Stockholm conference, both the United Nations Environment Programme (UNEP) and UNESCO's International Environmental Education Programme (IEEP) were established. The concerns about the natural environment as well as the human environment, expressed in Principle 1 of the 1972 United Nations Declaration on the Human Environment (United Nations 1973 – quoted earlier), are reflected in the Belgrade Charter (UNESCO 1975, 2) which stated that:

> the foundations must be laid for a world-wide environmental education programme that will make it possible to develop new knowledge and skills, values and attitudes, in a drive towards a better quality of environment and, indeed, towards a higher quality of life for present and future generations living within that environment.

Similarly, Recommendation No. 2 from the Report of the 1977 UNESCO-UNEP (Tbilisi) Intergovernmental Conference on Environmental Education stated: "Environmental education should consider the environment in its totality – natural and built, technological and social (economic, political, technological, cultural-historical, moral, aesthetic)" (UNESCO 1978, 27).

The Declaration and Recommendations from the 1977 Tbilisi Conference provided a framework for the development of environmental education internationally for more than a decade. Many national and local as well as UNESCO environmental education documents adopted the definitions and descriptions from Tbilisi. The goals from the Tbilisi conference on which these documents are usually based are as follows (UNESCO 1978, 26):

1. The goals of environmental education are:
   (a) to foster clear awareness of, and concern about, economic, social, political and ecological interdependence in urban and rural areas;
   (b) to provide every person with opportunities to acquire the knowledge, values, attitudes, commitment and skills needed to protect and improve the environment;
   (c) to create new patterns of behaviour of individuals, groups and society as a whole towards the environment.

The focus here is on the total environment and its improvement and protection as well as not having "harmful repercussions on people" (UNESCO 1975, 1).

Reorienting to education for sustainable development

Over the following decades there was a transition in terminology, with "environmental education" increasingly being replaced by "education for sustainable development" (United Nations 1993, 2002). In particular, the priority changed from a focus on "the role of education in pursuing the kind of development that would respect and nurture the natural environment [and] the process of orienting and re-orienting education in order to foster values and attitudes of respect for the environment and envisaged ways and means of doing so" (UNESCO 2004, 7) to a broadened vision which encompassed "social justice and the fight against poverty as key principles of development that is sustainable" (UNESCO 2004, 7). This change is significant in that the environment is now seen as a "natural resource base for economic and social development" in the World Summit on Sustainable Development report (United Nations 2002, 2), and notions of improving the quality of the environment, contained in earlier statements, have disappeared, replaced by a focus on the welfare of humanity – a major shift towards a humanist agenda.

Similarly, somewhere between the environmental education statements from the 1970s and those that have appeared in the last decades – generally labelled "education for sustainable development" (UNESCO 2004, 2005, 2014), a concern for the environment has been marginalised and the focus has become the human condition. This change is immediately obvious, for example, when comparing the *United Nations Decade of Education for Sustainable Development 2005–2014: Draft International Implementation Scheme* (UNESCO 2004) with the finalised *United Nations Decade of Education for Sustainable Development (2005–2014): International Implementation Scheme* (UNESCO 2005). Whereas the draft document included the sentences quoted about the changing educational priority and broadening vision, these are absent from the finalised scheme and instead "The basic vision of the DESD is a world where everyone has the opportunity to benefit from education and learn the values, behaviour and lifestyles required for a sustainable future and for positive societal transformation" (UNESCO 2005, 4) Indeed, the natural environment has become invisible – the word "natural" only appears four times in the final DESD scheme (UNESCO 2005) – as natural science (20), natural resources (21), natural resource conservation (28) and natural resource base (29), whereas "natural environment" appeared six times in the draft DESD scheme (UNESCO 2004).

Marginalising environmental education

In many ways, the draft scheme sowed the seeds for this marginalisation of environmental education when it described environmental education as being focused on the natural environment even though the Tbilisi recommendations saw environmental education as being concerned with the environment in its totality (UNESCO 1978, 27), as noted earlier. The draft scheme saw education for sustainable development (ESD) as encompassing environmental education and setting it in a broader context, which the Tbilisi recommendation had already encompassed:

> Education for sustainable development should not be equated with environmental education. The latter is a well-established discipline which focuses on humankind's relationship with the natural environment and on ways to conserve and preserve it and properly steward its resources. Sustainable development therefore encompasses environmental education, setting it in the broader context of socio-cultural factors and the socio-political issues of equity, poverty, democracy and quality of life. The development perspective – that of social change and evolving circumstances – is also a central to any treatment of sustainable development. The set of learning goals of sustainable development are thus wide-ranging. Sustainable development must be integrated into other disciplines and cannot, because of its scope, be taught as a discreet subject.
>
> *(UNESCO 2004, 16)*

The final DESD scheme only mentions environmental education once, as one of several partners "from a variety of fields that contribute to ESD" (UNESCO 2005, 19).

There was also a reduction in references to climate change as an environmental issue between the draft and final implementation schemes. "Climate change" is mentioned five times in the draft scheme, including "ESD must bring to the awareness of learners the crucial need for international agreements and enforceable quantified targets to limit damage to the atmosphere and check harmful climate change" (UNESCO 2004, 18), whereas "Climate change" is only mentioned once as one of several "major issues that have grabbed global attention" (UNESCO 2005, 7) in the final scheme.

Although the overall goal of the DESD was stated as being "to integrate the principles, values, and practices of sustainable development into all aspects of education and learning", UNESCO saw the major thrusts of education for sustainable development that they, and member states, were to pursue as:

- improving access to quality basic education;
- reorienting existing education programmes;
- developing public understanding and awareness;
- providing training.

(UNESCO 2005, 6,7)

The final implementation scheme for DESD became an omnibus document linking ESD with the Millennium Development Goal (MDG) process, the Education for All (EFA) movement and the United Nations Literacy Decade (UNLD). Thus, it is not surprising that there was a diminished environmental and climate change focus in this scheme.

That environmental education was almost invisible in the DESD created confusion and tensions in the education sector. While school and university curriculum statements embraced the terminology of ESD and education for sustainability (EfS) from the 1990s onwards, the content that was associated with sustainability was environmental. For example, in the Australian context, the symbol used in school curriculum statements to designate sustainability related content was (and still is) a leaf.

Some of the confusion came from the people's lack of understanding of the term "sustainable development", which was not helped by UNESCO providing a description in the draft implementation scheme (2004) but not in the final scheme (2005). In the draft scheme, the three interlinked key areas of sustainable development – society, environment and economy – give shape and content to sustainable learning:

> Society: an understanding of social institutions and their role in change and development, as well as the democratic and participatory systems which give opportunity for the expression of opinion, the selection of governments, the forging of consensus and the resolution of differences.
>
> Environment: an awareness of the resources and fragility of the physical environment and the effects on it of human activity and decisions, with a commitment to factoring environmental concerns into social and economic policy development.
>
> Economy: a sensitivity to the limits and potential of economic growth and their impact on society and on the environment, with a commitment to assess personal and societal levels of consumption out of concern for the environment and for social justice.
>
> *(UNESCO 2004, 12)*

That these descriptions were not in the finalised implementation scheme created ambiguity about the term.

Other confusion and misinterpretation came from environmental educators themselves. They continued to teach environmental education but called it education for sustainability. As well as the curriculum sustainability = leaf association, this was obvious in the naming of "sustainable schools" in Australia and England, which saw their action areas as being to reduce energy and water consumption, decrease waste production and improve biodiversity (Gough 2020).

While the DESD was meant to increase the profile of sustainability education, the reverse happened in many places. For example, according to the UK National Commission for UNESCO (2013, 17), the "reduced government focus on sustainable development has resulted in increased uncertainties amongst educational institutions and practitioners about how much emphasis to place on sustainability within teaching and learning". There was also an attempt to reduce the focus on sustainability in the Australian curriculum in Recommendation 17 of the Donnelly and Wiltshire review report (2014, 247): "ACARA reconceptualise the cross-curriculum priorities and instead embed teaching and learning about . . . sustainability explicitly, and only where educationally relevant, in the mandatory content of the curriculum". At a broader level, in their final report on the DESD for UNESCO, Carolee Buckler and Heather Creech (2014, 10) concluded,

> Despite the successes that have been achieved during the DESD, Member States and other stakeholders have indicated considerable challenges remain in realizing the full potential of ESD: the need for further alignment of education and sustainable development sectors; the need for more work towards institutionalizing ESD to ensure strong political support for implementing ESD on a systemic level; and finally, the need for more research, innovation, monitoring and evaluation to develop and prove the effectiveness of ESD good practices. While much has been done to advance the ethos and values of ESD, a full integration of ESD into education systems has yet to take place in most countries.

More recently, a UNESCO (2021a, 1) survey of 46 member states found that "45% of national education documents studied made little-to-no reference to environmental themes", so the invisibility of anything related to environmental education continues in many countries.

Education for environmental sustainability and climate change towards 2030

In 2015 the United Nations agreed on its agenda for achieving sustainable development by 2030, the Sustainable Development Goals (SDGs) (United Nations 2015a, 2015b). Education is one of the goals: "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all", which is consistent with one of the major focuses of the DESD. ESD is buried in Target 4.7 which states,

> By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development.
>
> *(United Nations 2015b, 21)*

Although sustainability education is marginalised within the SDGs, the visibility of the environment in UNESCO's ESD planning increased a little after the DESD. For example, the "definition" of ESD contained in the successor ESD plan, *Roadmap for Implementing the Global Action Programme on Education for Sustainable Development* (UNESCO 2014, 12), was: "ESD empowers learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society, for present and future generations, while respecting cultural diversity" (12).

This statement was consistent with the commitment to ensuring "the promotion of an economically, socially and environmentally sustainable future for our planet and for present and future generations" in *The Future We Want* (United Nations 2012, 1). It was also consistent with the post-millennium SDGs agenda (United Nations 2015a, 2), which saw environmental sustainability as "a core pillar of the post-2015 agenda and a prerequisite for lasting socioeconomic development and poverty eradication". Similarly, sustainable development was included as the second of five big transformational shifts that the UN Secretary-General's High Level Panel believed needed to be made in their universal agenda: "Our vision and our responsibility are to end extreme poverty in all its forms in the context of sustainable development and to have in place the building blocks of sustained prosperity for all" (United Nations 2013, iii). Sustained prosperity includes achieving universal primary education and an extension to universal secondary education, i.e. SDG 4.

While environmental sustainability is downplayed in this target, the more recent UNESCO *Education for Sustainable Development: A Roadmap* (#ESD for 2030) (2020, 6) ESD for 2030 is seen directly contributing "to SDG 4 on quality and inclusive education, in particular Target 4.7" (iii).

This roadmap recognises the need to address environmental sustainability crises in Section 1.1:

> The current climate emergency and other environmental sustainability crises are the product of human behaviour. . . . This means not only addressing environmental challenges but also revisiting the complex mix of social and economic issues such as inequality that are intertwined with the cause and impact of these problems. . . . We must urgently learn to live differently.
>
> *(UNESCO 2020, 6)*

> The roadmap sees ESD as empowering learners with knowledge, skills, values and attitudes to take informed decisions and make responsible actions for environmental integrity, economic viability and a just society empowering people of all genders, for present and future generations, while respecting cultural diversity.
>
> *(UNESCO 2020, 8)*

That the roadmap reinserts climate change into the ESD discourse is a notable shift given its mention being removed from the final DESD implementation scheme (UNESCO 2005). Of course, climate change had become much more prominent on the global agenda since 2005. "Take urgent action to combat climate change and its impacts" is Goal 13 of the SDGs (United Nations 2015a, 27), with the United Nations Framework Convention on Climate Change as the primary international, intergovernmental forum for negotiating the global response to climate change, such as at COP26 in Glasgow, Scotland, in November 2021.

The global challenge of the COVID-19 pandemic prompted the United Nations to reflect on each of the SDGs with a COVID-19 response and develop *A UN Framework for the Immediate Socio-Economic Response to COVID-19* (United Nations 2020). This document seems to be a pivot point, foregrounding the importance of the environment rather than just humans (as in the first SDG goal of overcoming poverty). However, the separation of animals from the environment is odd: "The current COVID-19 pandemic is a reminder of the intimate relationship among humans, animals and the environment" (United Nations 2020, 4).

In May 2021 UNESCO held a World Conference on Education for Sustainable Development in Berlin, Germany. The Declaration from this conference re-prioritised the environment on the education agenda, particularly in the mention of relationships with nature:

> We are convinced that urgent action is needed to address the dramatic interrelated challenges the world is facing, in particular, the climate crisis, mass loss of biodiversity, pollution, pandemic diseases, extreme poverty and inequalities, violent conflicts, and other environmental, social and economic crises that endanger life on our planet. We believe that the urgency of these challenges, exacerbated by the Covid-19 pandemic, requires a fundamental transformation that sets us on the path of sustainable development based on more just, inclusive, caring and peaceful relationships with each other and with nature.
>
> *(UNESCO 2021b, 1)*

This Declaration prompted UNESCO's Harare Office (2021) to proclaim, "UNESCO declares environmental education must be a core curriculum component by 2025". This is a very different positioning on the environment compared with the DESD implementation scheme (UNESCO 2005). The Declaration also included a commitment to "Recognize climate change as a priority area of ESD of particular importance to Small Island Developing States (SIDS), as they require special attention in terms of ESD implementation due to their increasing vulnerability to climate change and natural hazards" (UNESCO 2021b, 3). These statements firmly put climate change on the education agenda.

Discussions around the Anthropocene have also raised both the environment and climate change as priority issues, as well as nonhuman and material worlds (Gough 2021). However, as I have argued elsewhere (Gough 2021, 1),

> Education in an Anthropocene context necessitates a different pedagogy that provides opportunities for learning to live in and engage with the world and acknowledges that we live in a more-than-human world. It also requires learners to critique the Anthropocene as a concept and its associated themes to counter the humanist perspective, which fails to consider how the nonhuman and material worlds coshape our mutual worlds. In particular, education in the Anthropocene will need to be interdisciplinary, transdisciplinary, or cross-disciplinary; intersectional; ecofeminist or posthumanist; indigenous; and participatory.

The different pedagogy is not very different from the socially critical pedagogy that was seen as consistent with good environmental education in the 1990s (see, for example, Greenall Gough and Robottom 1993; Huckle 1991), but it is very different from the more traditional vocational neo-classical or liberal progressive approaches to curriculum and pedagogy (Kemmis et al. 1983) that are in general use in educational institutions. It is a socially transformative rather than socially reproductive approach to learning.

The acknowledgement of the more-than-human world expands notions of the total environment (natural and built, technological and social) that were in the Tbilisi Declaration (UNESCO 1978) to include consideration of the nonhuman and material worlds that co-shape our mutual worlds. Such considerations also mean a different approach to the content of environmental sustainability education, reinforcing that environmental issues are cross-disciplinary/interdisciplinary/multidisciplinary/transdisciplinary, not the provenance of a single discipline.

Conclusion

Sustainability education has had a rollercoaster ride over the past 50 years, as attention to environmental problems has seesawed in social prominence. When notions of environmental education were first formulated in the late 1960s, international concern was focused on pollution, depletion of resources and environmental quality. The focus changed over the intervening years with the advent of education for sustainable development marginalising environmental concerns in the 1990s and 2000s. The climate crisis, the COVID epidemic and discussions around the Anthropocene seem to have reoriented the focus back to needing to consider the environment in its totality, including nonhuman and material worlds. While the Berlin Declaration on Education for Sustainable Development (UNESCO 2021b) has much in common with the Tbilisi Declaration (UNESCO 1978), there are also important differences. In particular, the Berlin Declaration is assertive about the place of sustainability education in all education systems:

> Ensure that ESD is a foundational element of our education systems at all levels, with environmental and climate action as a core curriculum component, while maintaining a holistic perspective on ESD that recognizes the interrelatedness of all dimensions of sustainable development.
>
> *(UNESCO 2021b, 2)*

This sets a high priority for all educators at all education levels if we are to address the environmental problems, including climate change, that are currently facing humans everywhere:

> education is a powerful enabler of positive change of mindsets and worldviews and that it can support the integration of all dimensions of sustainable development, of economy, society and the environment, ensuring that development trajectories are not exclusively orientated towards economic growth to the detriment of the planet, but towards the well-being of all within planetary boundaries.
>
> *(UNESCO 2021b, 1)*

This is no time for complacency. A recent UNESCO survey (2021a) found that the 46 countries surveyed are not doing enough to ensure that what we learn helps us to address the environmental challenges that we face. As the report on that survey noted, "Climate change is affecting every country on every continent, but is mentioned in less than half of the policy and curricula" (2021a, ii). We need "to transform education through action to advance policy, adapt learning environments, build the capacities of educators, empower and mobilize youth and accelerate local level actions" (2021a, ii) as the central focus for sustainability education. Are you ready?

Notes

1 A persistent practical problem from this period is the frequent use of the term 'man' to refer to persons of both sexes in the literature of science, science education and environmental education. The frequent use of '[sic]' is tedious but I believe it is important that the use of the universal 'man' in these statements is acknowledged.
2 It was not until the 1992 United Nations Conference on Environment and Development (UNCED) that the relationship between women and the environment became institutionalised in international discourses on the environment. Principle 20 of the Rio Declaration on Environment and Development from that conference proclaimed: "Women have a vital role in environmental management and development. Their full participation is therefore essential to achieve sustainable development" (United Nations 1992, p. 1).
3 The language in this statement reflects its science groundings through the use of terms such as 'man' and 'man-made' in the supposed scientific sense of being inclusive of both genders and 'biophysical environment', a very scientific term. Similar phrasing was used in the 1970 IUCN definition of environmental education, also cited in this chapter, where reference was made to "man, his culture and his biophysical surroundings".

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7.3

SUSTAINABLE HUMAN DEVELOPMENT AND THE NEED FOR CLIMATE CHANGE GOVERNANCE

Olga Alcaraz Sendra and Bàrbara Sureda Carbonell

Key concepts for sustainability education

- Climate change is a global and systemic problem that requires governance systems at all levels, so it is a key issue in sustainability education.
- The 'Global Carbon Budget' is considered a useful tool for decision-making in order to reverse the climate emergency.
- It is essential to take into account the IPCC principles of equity to make an equitable distribution of the Global Carbon Budget.
- An important part of the Remaining Global Carbon Budget must ensure the development of the inhabitants of the least developed countries.

Introduction

Climate change is a global and systemic problem. We say that it is a global problem because despite the fact that each country has not contributed in the same way to the generation of the problem, the impacts of climate change can be observed throughout the world in every country. The effects of climate change are extremely varied: the increase in the frequency and intensity of extreme weather events, heat waves, rising sea levels, shorter winters, the retreat of glaciers, changes in the distribution of species, the disappearance of some coral reefs, etc. (IPCC 2021). As well as this, we also view climate change as a systemic problem because it has many causes and consequences, which are often interrelated. Furthermore, if the measures that are undertaken to reverse the climate crisis are only considered or implemented from a local perspective that forgets their impacts at a global level, there may be negative collateral effects. As a consequence, we argue that any governance system that wants to effectively address climate issues must do so by always incorporating both global and systemic perspectives.

Solving the climate problem is one of the greatest challenges that humanity must face in the 21st century. It is a challenge at the environmental level and also at a social and economic level, since it calls into question our current development model and proposes a model of sustainable human development as a possible alternative route. It is for this reason that sustainability should be at the heart of governance and of any climate action proposal.

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More specifically, in the context of education for sustainability, it is important to teach students how to establish connections between sustainability and climate change, since this skill will be a good basis for the systemic analysis of any proposals for action or climate emergency governance systems.

The Sustainable Development Goals (SDGs) of the United Nations Development Agenda 2030 allow us translate the theory into real sustainability goals in many different focus areas (United Nations 2015b). Figure 7.3.1 illustrates a possible exercise to complete. Firstly, it asks students to identify the SDGs that must be achieved if the climate emergency is not to worsen and then to discuss why they are vital. Secondly, they must identify which SDGs are threatened by the current climate emergency and discuss how to achieve them. This exercise allows us to develop a systemic vision of climate change and reflect on its multiple causes and consequences.

Here are some examples that illustrate how the failure to achieve some of the SDGs will worsen the climate emergency:

- SDG7: Affordable and clean energy. A failure to make the necessary energy transition towards clean energy sources and continuing to have an 80% dependency on fossil fuels worldwide would generate emissions and worsen global warming.
- SDG12: Responsible consumption and production. If we are not able to move towards more sustainable systems of production and consumption and evolve towards a circular economy, we will continue to increase the amount of energy and materials we use and the waste we generate, whilst also increasing greenhouse gas emissions.

We can carry out a similar exercise by identifying which SDGs are going to become more difficult to achieve as a consequence of the climate emergency. Two examples might be:

- An increase in temperatures can affect the production, processing, distribution and consumption of food, as well as the availability of food. It will also affect the quantity and quality of available water. As a consequence, achieving SDG 2 (zero hunger) and SDG 6 (clean water and sanitation) will be put at risk.
- Extreme weather events have a greater impact on the poorest segments of the population, thus affecting SDG 1 (no poverty) in terms of people's health, affecting SDG 6 (good health and well-being) and in general, affecting the most vulnerable populations of the planet, translating into an increase in inequality and therefore impacting on SDG 10 (reduced inequalities).

The governance of climate change

There are currently a multitude of levels of climate governance, ranging from the local level to the global multilateral scale. Decisions are made at these different levels, and these decisions affect both the many different variables that are the causes of climate change and also the decisions aimed at dealing with the consequences of the climate crisis. We can cite and give examples of governance at the local, regional, state, supra-state and global levels. For example, at the local level, municipal governments usually control the management of urban solid waste, the management of municipal public transport, the authorization of building permits for the construction of buildings, etc. Regional governments usually have the responsibility for, among other things, the preservation of forests and natural landscapes,

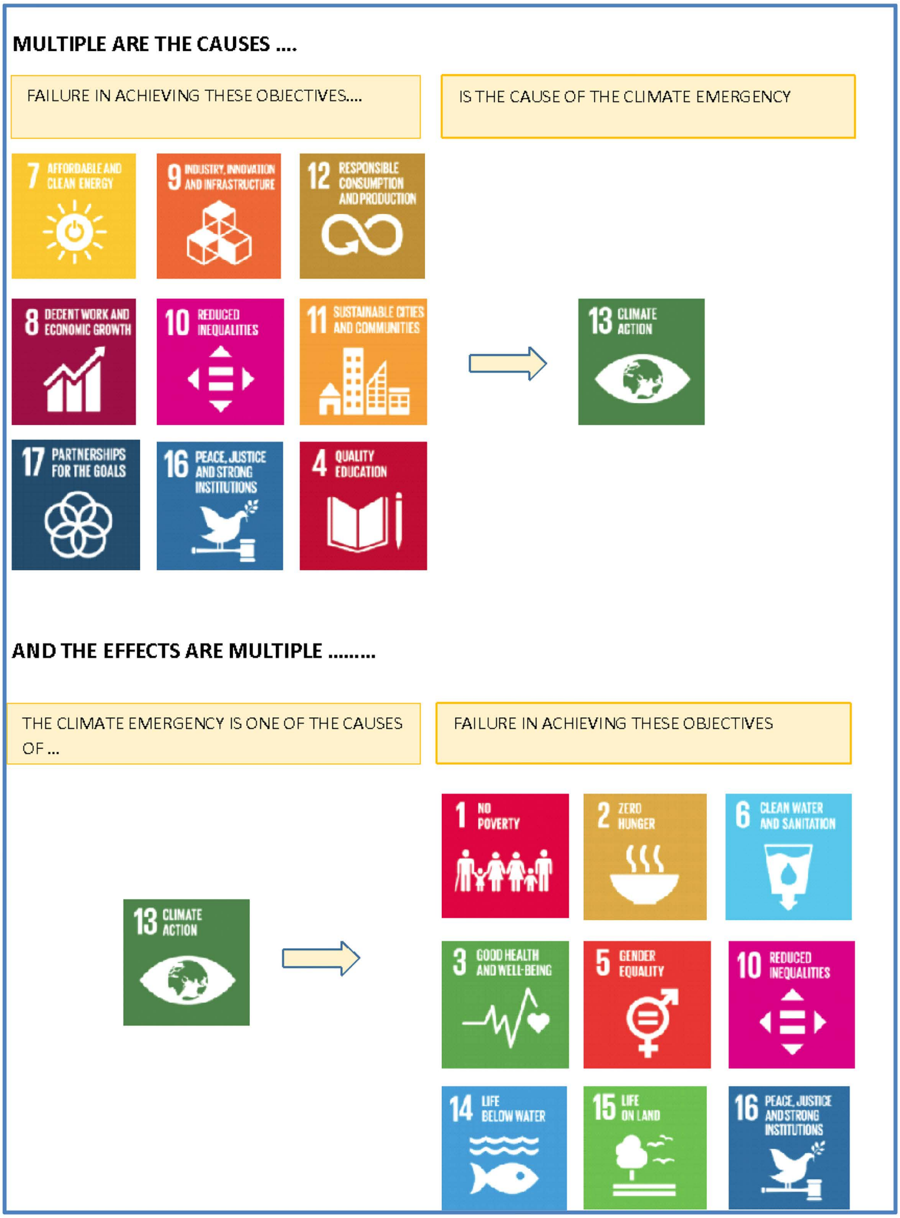

Figure 7.3.1 Relationship between SDG 13, Climate Action, and some other SDGs. Top image: The SDGs which, if not complied with, would negatively affect compliance with SDG 13. Bottom image: The SDGs whose fulfilment is being negatively affected by the current climate emergency.

Source: Authors' own elaboration

the management of railways, the promotion of certain industrial activities or the construction of adaptation infrastructures. At a higher level, state governments are responsible for energy policies (electricity production, energy pricing, the use of different fuels, etc.), agricultural and food policies, the promotion of certain sectors of the economy (tourism, industry, construction, etc.), the design and construction of large communication infrastructures (railways, motorways, ports and airports), policies for the mitigation of greenhouse gas emissions, etc. Governance at the supra-state level depends to a large extent on the structure to which we are referring. One example is the European Union of 27 states (EU-27). In the context of global climate governance, the EU-27 acts as a block. It is committed to emission reduction targets and since 2005 has hosted a CO_2 emissions market that over time has gradually achieved a progressive reduction in the total emissions that come from large, permanent installations (European Parliament and the Council of the European Union 2003). Finally, at the global level, climate governance has developed within the United Nations Framework Convention for Climate Change (UNFCCC) (United Nations 1992). The UNFCCC is the international treaty approved in 1992 by 196 countries plus the EU-27. Further treaties have emanated from this original agreement, such as the Kyoto Protocol (2008–2020) and the currently valid Paris Agreement (from 2020 onwards).

Facing a global and systemic problem such as climate change requires action at all levels of governance, and it is absolutely essential to include a global multilateral governance level. It is clear that if a country were able to reduce its greenhouse gas emissions to zero tomorrow, this would not mean the end of global warming, nor would it allow the country to avoid suffering the impacts of climate change. It is important to point out that the global action framework provided by the UNFCCC poses great challenges when attempting to reach urgently required and effective decisions, since at the heart of the UNFCCC is the principle that decisions must be made by consensus, that is, with the total agreement of the 196 countries that are currently party to the convention.

The international treaty that specifies the objectives of the UNFCCC, and under which global climate governance will be developed from now on, is the Paris Agreement (United Nations 2015a). The Paris Agreement was approved at the 21st Conference of the States that are members of the UNFCCC held in Paris in 2015.

Article 2 of the Paris Agreement contains three main objectives:

1. In relation to mitigation: Holding the increase in the global average temperature to well below 2 °C, and continue efforts to limit this increase in temperature to 1.5 °C with respect to pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change.
2. In relation to adaptation: Increasing the ability to adapt to the adverse effects of climate change and foster climate resilience and development with low greenhouse gas emissions, in a way that does not compromise food production
3. Regarding financing: Placing financial flows at a level compatible with a path that leads to climate-resilient development with low greenhouse gas emissions.

And furthermore, it emphasizes that the agreement should be applied in a way that reflects equity and the principle of common but differentiated responsibilities and respective capacities, in light of the different circumstances of each country. In other words, the Paris Agreement puts equity at the centre of the governance of climate change. In section 'Equity in the UNFCCC debates' we will speak more extensively about this issue.

The methodology that the agreement implements to achieve these objectives is a strictly bottom-up methodology; that is to say, it leaves it up to the states that are party to the agreement to develop their own policies to achieve the objectives. More specifically, in the area of mitigation (Article 4), states are required to prepare their nationally determined contributions (NDCs) every five years. These NDCs should contain greenhouse gas reduction targets, and successive NDCs should be increasingly ambitious.

In addition, the agreement sets up two systems for monitoring and evaluating compliance. The first says that each country must biennially report its emissions inventory and its progress in achieving the objectives defined in its NDC (Article 13: transparency). The second is a system to evaluate how we are progressing at the collective level with the objective of stabilizing the increase in global temperature. This is known as the global emissions balance (global stocktake) (Article 14: global balance). The global stocktake will provide information to the states/parties so that they can update and improve their mitigation measures as determined at the national level.

With regard to the three main objectives, it is clear that the Paris Agreement, as a governance system, has significant flaws:

- In the first place, the temperature stabilization objective does not directly translate into emission reduction targets either at the global level or for each country or state/party.
- Secondly, it leaves it entirely up to each state/party to decide what their emission reduction will be without providing them with any reference as to what reduction it would be desirable and expected for them to implement in order to globally achieve the aforementioned temperature stabilization objective.
- And finally, it does not include any mechanism that allows for redirection in the event of serious or unforeseen situations. A recent example is the information collected in the synthesis report prepared by the UNFCCC secretariat before COP26, held in Glasgow (UNFCCC 2021). Said report assesses the aggregate effect, in 2030, of the emission reduction targets of the NDCs presented so far. It shows that, in 2030, as a result of the implementation of these NDCs, emissions will have increased by 13.7% compared to 2010 levels. This is an extremely serious situation, since, to achieve the objective of stabilizing the temperature increase at 1.5 °C by 2030, CO_2 emissions must decrease by 45% compared to 2010 levels. However, when information such as this clearly shows that the commitments of the countries will move us away from the objectives, the agreement does not provide any effective mechanism to redress such a situation.

The Global Carbon Budget

Since the publication of the Intergovernmental Panel on Climate Change (IPCC) AR5 in 2014, the concept of a Global Carbon Budget (GCB) has gained importance when defining climate change mitigation goals and when helping countries to increase the level of transparency and ambition in defining their objectives in order to reduce greenhouse gases.

The Global Carbon Budget (GCB) can be defined as the total amount of accumulated CO_2 emissions that will lead to a specific increase in global mean temperature (Rogelj et al. 2016). The latest IPCC reports unequivocally establish that accumulated CO_2 emissions are the main agent responsible for global warming and show the proportional relationship between accumulated CO_2 emissions and long-term temperature increases (IPCC 2014c, 2018, 2021). This means that the rise in temperature does not depend on the level of emissions in any specific year, but on the cumulative emissions released over the years.

The AR6 shows the reduction of emissions that humanity as a whole should achieve in order to limit the increase in global average temperature to either 1.5 °C or 2 °C. It gives figures for the Remaining Global Carbon Budgets (RGCBs) that could still be emitted without exceeding the temperature stabilization targets. It specifically shows that in order to reach the goal of 1.5 °C with a probability of 67%, the RGCB from the beginning of 2020 onwards is 400 $GtCO_2$ and to reach the goal of 2 °C with the same probability, the RGCB is 1150 $GtCO_2$ (IPCC 2021).

It should be noted that these amounts are very small, since the current annual net CO_2 emissions are about 40 $GtCO_2$ per year (UNEP 2020). In other words, if we continue at the same rate of emissions as now, within a maximum of 10 years, i.e. in 2030, we will have reached 1.5 °C; and within 28 years, by the middle of this century, we will have reached 2 °C.

Taking all of this into account, the RGCB can be considered as an extremely useful tool for the decision-making that is needed at the different levels of governance in order to achieve reductions in emissions. By distributing the total RGCB using justice and equity criteria, it would establish the amount of emissions that could be emitted at a state, regional or local level or according to the activity sector during a determined period of time. Thus, the RGCB would establish a total amount of permissible emissions that could be distributed among the different levels of governance and that together would establish an emissions reduction itinerary. Some countries, such as Chile, Costa Rica or Australia, have already calculated the mitigation compromises of their NDCs by using the concept of cumulative emissions, i.e. carbon budgets (Australian Government 2021; Gobierno de Costa Rica 2020; Gobierno de Chile 2020). The problem is that this is not obligatory for all countries because the Paris Agreement does not even incorporate the concept of GCB.

One of the most important aspects to take into account is how to distribute the RGCB in a fair and equitable way. In AR5, the IPCC incorporates four basic principles of equity that serve as the basis for the majority of discussions about the equitable distribution of the GCB. They are responsibility, capacity, equality and the right to sustainable development (IPCC 2014b).

The concept of responsibility is based on the idea that, given the unequal contribution of different countries to the problem of climate change (due to the different amounts of greenhouse gas [GHG] emissions they have generated), it is necessary to compensate for the damage caused to other countries. The concept of capacity refers to mitigation capacity, meaning that those countries that have more economic resources, tools, technologies, etc., are the ones that should contribute the most to mitigating climate change. The concept of equality refers to the fact that all human beings are equal; therefore, they have the same right to emit GHG. Finally, the concept of the right to sustainable development defends the idea that all human beings have the right to self-development in order to satisfy their basic needs and recognizes the legitimacy of seeking economic growth in order to eradicate poverty (Mattoo and Subramanian 2012). Currently, various models exist for the distribution of the RGCB among countries based on these principles of equity (Raupach et al. 2014; Kanitkar et al. 2013; Giménez-Gómez et al. 2016; Gignac and Matthews 2015; Alcaraz et al. 2018). These models evaluate to what extent the carbon budget implied by the current NDCs is being used equitably (Robiou du Pont et al. 2016; Robiou du Pont and Meinshausen 2018; Winkler et al. 2018; Alcaraz et al. 2021).

At this point, some important questions need to be asked: What should this remaining carbon budget be spent on? And which countries would be entitled to use it? We will try to answer these questions by discussing equity in the next section.

Equity in the UNFCCC debates

The UNFCCC and the Paris Agreement place equity and the principle of common but differentiated responsibilities and respective capabilities at the heart of all actions. Based on these principles, developed countries (listed in Annex I of the UNFCCC) are challenged to lead emissions mitigation policies and provide developing countries (those not listed in the Annex I of the UNFCCC) with financial assistance for climate action. The problem is that, despite the fact that many speeches appeal to the aforementioned principles, there is no consensus as to how to go beyond the theory and convert principles into climate action.

From the viewpoint of observers of the climate negotiations, we see that there is a great gap between the discourse of the developed countries of the Global North and the developing countries of the Global South. The countries of the South of the world have put the great injustice that climate change represents at a global level on the negotiating table. Many of them are suffering from the most pressing effects of climate change whilst having hardly contributed to causing the climate crisis. Managing these effects represents a clear obstacle to their development, since they are forced to dedicate a part of their public budgets to reconstruction tasks and to mitigate the losses caused by the climate crisis.

On top of this, the countries of the Global North tend to ignore their responsibility for historical emissions and they flatly refuse to accept that perhaps they should recognize the immense ecological debt they have with the countries of the South. Instead, they point accusingly at some countries such as China and India because of their increasing levels of emissions.

Sustainability is a discipline that encourages the analysis of problems by including all dimensions and factors and that, in the event of any conflict between them, tries to use multidimensional analysis to approximate different viewpoints. Figure 7.3.2 is a simple exercise that analyses the same problem, GHG emissions, by looking at two different indicators: emissions in 2019 (left side of the figure) and cumulative emissions per capita in the period 1950–2019 (right side of the figure). It is important to remember what we mentioned in point 3: that it is the accumulated emissions over time that determine the increase in temperature. For this reason, accumulated emissions can, in a certain way, be used to quantify the historical responsibility of different countries, while accumulated emissions per capita can also be directly related to the level of development, lifestyle and models for well-being of a country over various decades.

This comparison gives us some keys to help understand the incompatible paradigms on which the arguments of the countries of the Global North (left) and the Global South (right) are based. The diagram on the left shows us the total emissions of six of the main emitters in the year 2019. Looking at this diagram, we can understand the arguments of states/parties such as the United States or the EU-27 that urge China and India to reduce their emissions and argue that if these countries do not undertake drastic emission reduction policies, the human race will not be able to limit global warming to levels that do not pose a risk to our species and the planet's ecosystems.

On the other hand, looking at the diagram on the right, which presents accumulated emissions taking into account the sizes of the country's population, gives us the key to

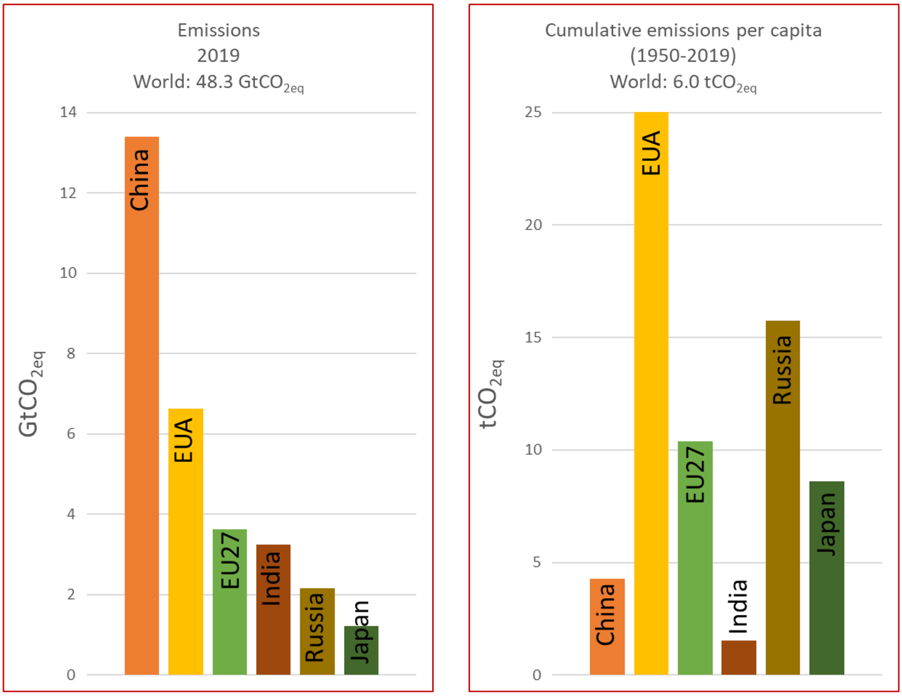

Figure 7.3.2 Left: Greenhouse gas emissions levels, in 2019, of the six countries that lead the global emissions ranking. Right: Cumulative emissions per capita, in the period 1950–2019, of the countries that are currently the main emitters. Emissions data from the Climate Analysis Indicators Tool (CAIT) database (World Resources Institute 2020) and population data from UNDESA 2019. Source: Authors' own elaboration.

understanding the enormous reluctance of countries like India to reduce their emissions. As mentioned earlier, many of the countries in the South of the world have accumulated historical emissions per capita that are well below the world average and that in some cases are a symptom of some still-pending developmental goals. For example, in 2019, India still had about 30 million inhabitants with no electricity supply and about 490 million without access to clean fuels and technologies for cooking ("Tracking SDG 7 | Progress Towards Sustainable Energy" n.d.). It is difficult to think that such a large amount of the population can be provided with these services without increasing the level of emissions in the country. Even if this objective was achieved through renewable technologies, it should not be forgotten that the construction, installation and maintenance of equipment all produce emissions (IPCC 2014a).

In fact, some authors argue that, historically, the development processes that were experienced by the countries of the Global North went through a first phase of per capita gross domestic product growth that carried with it a proportional growth in their per capita emissions (Al-Zahrani et al. 2019). These emissions are associated with the construction of basic transport infrastructures, the increase and expansion of the industrial sector, provision of essential public services, improvement of household installations and appliances, etc. Once this "take-off" in the development processes has been achieved, countries then can begin to worry about the environmental impacts of their societies and about their efficiency in the use of resources and energy. It is from this moment on that a decoupling between welfare growth and per capita emissions begins to be observed.

In the context of the multilateral governance of climate change, it would be fair that developing countries could use part of the RGCB to guarantee their development, since these countries have historically generated few emissions and their current emissions are very low when compared to those of developed countries. In addition, they have a lower economic and technological capacity. Therefore, it is a question of justice, and also of necessity, that they can use a good part of the RGCB, since, without this carbon budget allocation, the inhabitants of countries with low levels of development will not be able to deal with many of the development challenges that they still face: the end of poverty and hunger, the construction of basic infrastructures, access to electricity, education, health services, etc. (Rao and Baer 2012; Rao and Min 2018).

At this point, and being aware of the great gap that exists between the discourses of the Global North and the Global South, the following questions emerge: Where can we find a meeting point that will allow us to control the current climate emergency? What governance mechanism should be put in place to make such a meeting possible? Our answer is simple: it is necessary to agree on the emission reductions that countries should make by using reference points that are based on fairness. Providing these references means distributing the RGCB amongst all countries using the criteria of equality, historical responsibility, capacity and the right to sustainable development. As already mentioned, reversing the enormous injustices posed by climate change involves dedicating an important part of the RGCB to ensuring the development of the inhabitants of the least developed countries, because they are the ones who need it most. Our modest opinion is that until equity is operational within the Paris Agreement, we will not achieve the mitigation necessary to reverse the climate crisis.

Conclusion

In this chapter, climate change has been presented as a global and systemic problem that requires multilevel systems of governance that place a model of sustainable human development at the centre, and as the ultimate goal, of such governance. The importance of having a global multilateral level of governance has also been underlined. This level is currently represented and expressed through the UNFCCC and the Paris Agreement.

The main flaws of the Paris Agreement have been analysed, especially the problem of leaving it up to the states to decide what reduction in levels of emissions they will undertake and also of not giving them any reference points to indicate what levels would be expected or at the very least desirable.

Following on from this, it has been shown that the RGCB could be an extremely useful tool to assess progress towards the objective of stabilizing the temperature increase that was agreed in the Paris Agreement (Meinshausen et al. 2009; Alcaraz et al. 2019). Likewise, an agreement for the distribution of the RGCB among the countries that is based on equity criteria would serve to establish a reference framework for the emission reductions that each country must commit to. The fact that the Paris Agreement does not envision this reference framework greatly hinders the possibility of stabilizing global warming well below 2 °C. In order to reverse the current climate emergency, achieving agreement on this framework would make it possible to strengthen the current governance system and give it the effectiveness that the current Paris Agreement lacks.

We must be fully aware that it is essential to limit the rise in temperatures to levels that are compatible with human life and the viability of the planet's ecosystems. Achieving this requires deep structural changes that must be carried out with extreme urgency in order to avoid even more adverse effects of climate change (IPCC 2021). The governance of climate change must be able to take on the great challenge that lies ahead of humanity and recognize that there is still a long way to go.

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7.4

SEEING THE WOOD *AND* THE TREES

Sustainability education lessons from sustainable forest management

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Key concepts for sustainability education

- Forests play a critical sustainability role in global health, in CO_2 sequestration and climate change mitigation and in biodiversity conservation.
- Forests also play an intrinsic role in local and global ecosystems, and understanding natural resource management programs like forestry management can provide important framing and context in sustainability education.
- Sustainable forest management (SFM) principles are important in providing sustainable development norms for forestry management that can also be applied to other public and private resource sectors.
- SFM also highlights the latent and explicit tensions that exist between natural resource management and human consumption and production and the trade-offs that are involved in public and private resource decision making.
- SFM principles help demonstrate the importance of socio-ecological values and seeing the 'wood and the trees' in framing sustainability education.

Introduction

Sustainable forest management (SFM) offers a set of values, principles and practices that can be used to underwrite and enhance sustainability education. Sustainability education can foster both an understanding of and concern for the restoration of critical ecosystems such as forests in global health and carbon management. This chapter seeks to assist those who teach and develop sustainability education with an examination of the critical global role that forests play in climate change mitigation and biodiversity conservation.

Forest carbon dynamics must be considered over long timeframes (more than decades) to properly assess the contribution of forests and forest management to the global carbon cycle and sustainable management of forest carbon stocks. By way of example, Australian forests have a total stock of 19,417 million tonnes of carbon (Mt C) stored at the end of 2021. Of this, 85% was stored in non-production native forests, 14% in production native forests and 1.2% in plantations. (Montreal Process, ABARE SoF Report 2024).

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The examination of SFM highlights the important role of forests in carbon mitigation, global ecosystem health, natural resource management and the important use of policy, governance and accreditation structures to support sustainable resource management.

Six important concepts in SFM are presented in this chapter, and their value to sustainability education development discussed. In sustainability concept 1, the protection and conservation of our natural resources for future generations is discussed. Concept 2 discusses the importance of managing the global carbon balance from a climate change perspective. Concept 3 presents forest management as an important carbon sequestration strategy. Concept 4 discusses the role of natural resource management and governance in preventing common pool resource issues like those noted in Hardins's 'Tragedy of the Commons'. Concept 5 reviews the changing role of socio-ecological values in sustainable development thinking, and Concept 6 demonstrates the importance of sustainable resource management, governance and policy in both managing and protecting natural resources.

Sustainability concept 1: the protection and conservation of our natural resources for future generations

Forests are complex ecosystem webs of organisms that include plants, animals, fungi, viruses and bacteria. Forests take many forms, depending on their climate, terrain and soil. Humans began life as forest dwellers and depended on the forest for all their needs: food, clothing, shelter and biodiversity protection. Today globally around 1.6 billion people rely on forests for their livelihood. In raw material terms, modern lives depend on the forest for paper, timber, medicine, fuel, fodder, fencing, wind breaks and soil erosion mitigation and improvement, amongst many other benefits (Brook 2008). Several refined products are derived from forests such as honey, cane, fruit, fibre for cloth (bamboo) and essential oils and medicines, to name a few (Brook 2008). The important value of forests as a natural resource are demonstrated in Table 7.4.1.

It is estimated that 60–80% of the oxygen production on Earth comes from marine plants (phytoplankton) in the ocean and about 28% of global oxygen production comes from tropical rainforests.

In summary, forests are a critical part of our global water cycle, provide ecosystems services for considerable life on earth, regulate the climate and provide fuel and materials for human consumption and wellbeing. Therefore, the protection and conservation of key natural resources like our global forests for future generations are important concepts in sustainability education.

Sustainability concept 2: maintaining the carbon balance to ensure the health of global ecosystems

In 2023, the Intergovernmental Panel on Climate Change (IPCC) estimated that global "net anthropogenic GHG emissions to be 59 ± 6.6 GtCO2-eq in 2019". This is about 12% (6.5 GtCO2-eq) higher than in 2010 and 54% (21 GtCO2-eq) higher than in 1990, with the largest share and growth in gross greenhouse gas (GHG) emissions occurring in CO_2 from fossil fuel combustion and industrial processes (CO2-FFI) (IPCC 2023).

Forests are net sinks for CO_2 but indicators such as land use, land-use change and forestry (LULUCF) suggest that if there is a reduction in forest area, there is a corresponding

Table 7.4.1 Global benefits of forests

Forest services	*Use examples*
Provide ecosystems for all life forms.	Plants, reptiles birds, fungi, bacteria and mammals. Forests are home to 80% of the world's land-based animals and plants.
Prevent soil erosion, improve soil fertility and flood mitigation.	Maintain the environmental conditions needed for agricultural production and support soil biodiversity, which helps regulate pest and disease occurrence.
Regulate the climate.	Sequestration of carbon to mitigate climate change and regulate wind, temperature and global weather patterns.
Absorb CO_2, provide oxygen and purify air and water.	Remove CO_2, add oxygen, process minerals and metals through the soil and protect important water bodies from sedimentation and pollution, reduce air pollution.
Provide areas for recreation and tourism as well as provide aesthetic beauty, peace and tranquillity.	Human physical, recreational and mental health benefits, reduce noise pollution and the spiritual values many forest-dwelling people have for forest areas.
Provide wood and fibre products for everyday consumption.	Furniture, books, floors, doors, construction and housing, writing paper, newspaper, toilet and kitchen paper, and packaging.
Protection of the worlds water resources and global water cycle.	Forests absorb water from the atmosphere and soil and through evapotranspiration; they re-release water to the atmosphere. Without this process, a key part of the global water cycle would be interrupted, resulting in increased drought and desertification. Forested watersheds supply 75% of the world's accessible fresh water.
Provide fuel for cooking and heating.	Basic fuelwood and charcoal for indigenous and urban communities for daily cooking and heating.
Social benefits.	Indigenous livelihoods and cultural importance, rural development and local employment.

(*Source*: Adapted from PEFC.Org)

reduction in their ability to remove carbon from the atmosphere. At present the International Union for the Conservation of Nature (IUCN) estimates the world's forests are absorbing 2.4 $GtCO_2$ per year.

Protecting and restoring forest resources is therefore critically important in mitigating climate change. To this end the IUCN has been involved in a project called the 'Bonn Challenge' which seeks to restore globally 350 million hectares of deforested and degraded land by 2030. Reaching such a target could globally sequester an additional 1.7 Gt CO_2 equivalent annually (IUCN 2021).

One iconic example of a forest that is experiencing critical pressure is that of the Amazon rainforest. The World Wildlife Fund (WWF) notes that the Amazon rainforest contains:

- one in ten known species on Earth
- half of the planet's remaining tropical forests (1.4 billion acres)
- the world's second-longest river (the Amazon River)
- is 2.6 million square miles in size (about 40% of South America)

The WWF also notes the link between the Amazon rainforest and the health of the planet, which contains 90–140 billion tonnes of carbon and is essential in helping to stabilize local and global climate (WWF 2021). The ecological balance that has supported this forest ecosystem to create beneficial weather systems for the planet is being disrupted by ongoing deforestation, forest fires to clear land for agricultural production and global temperature rises, which have deleteriously affected the forest's health. Unhappily, decades of human activity and climate change have brought the Amazon rainforest towards a 'tipping point', and there are fears that the Amazon rainforest's water cycle may be irreversibly changed. Such a result would lock in a cycle of declining rainfall and longer dry seasons not just in Brazil but perhaps across the globe. As much as 17% of the Amazon rainforest has already been lost to deforestation, and a tipping point will be reached with 20–25% deforestation. Without systemic, restorative action, the Amazon and other world forests are in imminent danger (Time Magazine Report 2021).

Forests have been declining for the last 30 years across the world, including in Australia, and the impact on CO_2 emissions has been immense. Drawing on findings from the UN Food and Agriculture Organization (FAO), Table 7.4.2 shows the decline in worldwide forests and tree cover over the past 30 years.

Deforestation remains a huge issue around the world but is considerably more pronounced in a small set of countries including Australia. The 2021 New South Wales (NSW) Environment Protection Authority (EPA) State of the Environment (SOE) Report stated that "permanent clearing of native woody vegetation in NSW has increased about three-fold since 2015 and stands at an average of 35,000ha cleared each year. Permanent clearing of non-woody vegetation such as native shrubs and ground cover occurs at an even a higher rate". This vegetation clearing exacerbates and accelerates a loss of biodiversity, increases climate change impact and hinders the efforts of many carbon mitigation strategies.

Substantive CO_2 release and subsequent climate change have had and will continue to have major impacts on habitat, biodiversity loss, water availability, food production and security and weather pattern change (i.e. extremes of weather, coastal flooding, new diseases and species extinction (IPCC 2014b). Furthermore these problems will be exacerbated by climate change (IPCC 2021a). The IUCN (2021) maintains that forests are a stabilizing

Table 7.4.2 Annual rate of forest area change

Period	*Net change (million ha/year)*	*Net change rate (%/year)*
1990–2000	–7.84	–0.19
2000–2010	–5.17	–0.13
2010–2020	–4.75	–0.12

(*Source:* FAO 2020)

force for the climate. As a result, deforestation acts as a cause of further climate change pressure. Around 25% of global emissions come from the land sector, the second largest source of GHG emissions after the energy sector. About half of these (5–10 $GtCO_2e$ annually) come from deforestation and forest degradation (IUCN 2021).

In summary the carbon balance naturally provided by forest systems in absorbing CO_2 directly assists with climate change management, suggesting it is an integral part of modern sustainability education context.

Sustainability concept 3: forests as a carbon sink and important sequestration strategy for climate change

Natural (native) and man-made forests (plantations) are very important carbon sinks (IPCC 2021a). Forests are one of the most important solutions in addressing the effects of climate change and have a dual role in climate change management in carbon dioxide absorption through photosynthesis as well as in carbon sequestration in their storing of carbon in soils and in wood biomass. Increasing forest area and maintaining forests is an essential solution in climate change management (IUCN 2021) in sequestering carbon released to the atmosphere. Estimates show that nearly 2 billion hectares of degraded land across the world, an area the size of South America, offers opportunities for potential forest restoration and carbon sequestration (IUCN 2021). However, under future scenarios with increasing CO_2 emissions, land and ocean carbon sinks are projected to be less effective at slowing the accumulation of CO_2 in the atmosphere. Furthermore, there are increasing tensions between land availability for agriculture versus forest restoration and afforestation. For example, in Australia, current (2024) high prices for agricultural commodities make it very difficult to secure additional land for plantations, and the relatively long rotation times (one to five decades) often make forest enterprises financially unattractive.

If the world's forests remain net carbon absorbers, avoiding harvest could generate additional climate benefits in the short run. On the other hand, if mature forests become carbon sources through increased decomposition (and resulting CO_2 emission), increased harvesting may be the best mitigation option. Harvesting would reduce losses from decomposition while promoting wood as a fossil fuel substitute (Bellassen and Luyssaert 2014). Bellassen and Luyssaert (2014) also note that two-thirds of global forests are managed, and in the past few decades, the world's forests have absorbed as much as 30% (2 petagrams of carbon per year; Pg C year−1) of annual global anthropogenic CO_2 emissions, which is approximately the same amount as absorbed by the oceans.

In summary, forests are a crucial carbon sink and, whether the result of conservation or restoration and reforestation, play a vital role in global carbon sequestration. However, like many common pool resources, forests can also experience the challenges associated with the overuse of commons or public resources for private benefit, which is now discussed.

Sustainability concept 4: the important role of natural resource management governance in preventing 'Tragedy of the Commons'

Forests are vital to all living things on the planet and act as a 'commons' we all can rely on for both oxygen production, carbon sequestration, cooling of the Earth and biodiversity habitat. Forests are a valuable resource to humans and are an important means to offset some of the effects of global climate change. Why then do we have continued excess forest use and degradation, the ongoing mass clearing of forests and exploitation of programs that are meant to sustain natural forest area? These problems are a classic illustration of what ecologist Garrett Hardin (1998) called the 'Tragedy of the Commons'. A tragedy involving the overuse of commons or public resources for private benefit.

In 'Extension of "The Tragedy of the Commons" ' (Hardin 1998) highlighted the resource problems that can occur when individuals act selfishly and overutilize common pool resources – resources that belong to a much bigger group of people (e.g., 'the commons' or the 'public') – to the detriment of all. Depending on the resources being overused, the long-term effects can even be felt at a global scale. Whilst the use of natural resources is an important part of modern economic growth, the 'Tragedy of the Commons' focuses specifically on the inappropriate and potentially abusive use of such natural resources at the cost of, or to the detriment, of others.

Classic examples of the 'Tragedy of the Commons' include deforestation and the overharvesting of forest timber, degradation of water resources, air pollution, traffic congestion and overfishing. Hardin used the 'Tragedy of the Commons' as a metaphor for the problems of natural resource degradation and overuse. Climate change is certainly the most powerful example of the 'Tragedy of the Commons' the world currently faces. Hardin (1998) predicted the overall degradation of common pool resources, unless they were properly managed through private property right allocations or public ownership and management.

In relation to public resource management, Elinor Ostrom in her book *Governing the Commons* (1990), argued that the state is the most appropriate vehicle to solve complex common resource management problems. Ostrom's (1990) main concept was 'polycentrism', which refers to the idea that local decision-making groups should be "nested" structures at a high decision-making level to help provide the comprehensive and persuasive ability necessary to make local negotiation efficient and equitable. The theory of polycentrism rested on the concept that a variety of relationships between governmental units, public agencies and private businesses coexisting and functioning in a public economy "can be coordinated through patterns of inter-organisational arrangements" (Ostrom and Ostrom 1965). In a polycentric system, the state provides four crucial elements of commons governance to avoid the overuse or abuse of commons resources, including an arena for negotiation, a public-interest penalty default, relative neutrality and open information and monitoring and sanctioning. The UN IPCC is an important example of the use of a polycentric system to manage a global 'common' resource; namely, the biosphere. Turning now to natural resource management governance, specifically SFM, the United Nations has recognized forests as providers of multiple economic, social and environmental benefits and emphasized that SFM contributes significantly to sustainable development in such documents as the non-legally binding 'Authoritative Statement of Principles for a Global Consensus on Management, Conservation and Sustainable Development of All Types of Forests' (Forest Principles), among others.

In addition, the Montreal Process presents seven criteria for the sustainable management of temperate and boreal forests and provides a valuable natural resource management framework. These criteria include:

1. Conservation of biological diversity (9 indicators)
2. Maintenance of productive capacity of forest ecosystems (5 indicators)
3. Maintenance of forest ecosystem health and vitality (2 indicators)
4. Conservation and maintenance of soil and water resources (5 indicators)

5. Maintenance of forest contribution to global carbon cycles (3 indicators)
6. Maintenance and enhancement of long-term multiple socio-economic benefits to meet the needs of societies (20 indicators)
7. Legal, institutional and economic framework for forest conservation and sustainable management (10 indicators)

Signatories to the Montreal Process have committed to producing regular reporting of progress against these criteria and indicators like those used by the FAO, which are now discussed.

The FAO and member countries have used seven principles to identify themes that are desirable for appropriate SFM outcomes. These interlocking themes, as shown in Figure 7.4.1, are the extent of forest resources, biological diversity; forest health and vitality; productive functions of forest resources; protective functions of forest resources socio-economic functions; and legal, policy and institutional framework. Each of these themes is now considered.

Extent of forest resources. This theme concerns the need for adequate forest cover and stocks, including trees outside forests (e.g., 'urban forests'), to support the social, economic and environmental dimensions of forestry. For example, the existence and extent of specific

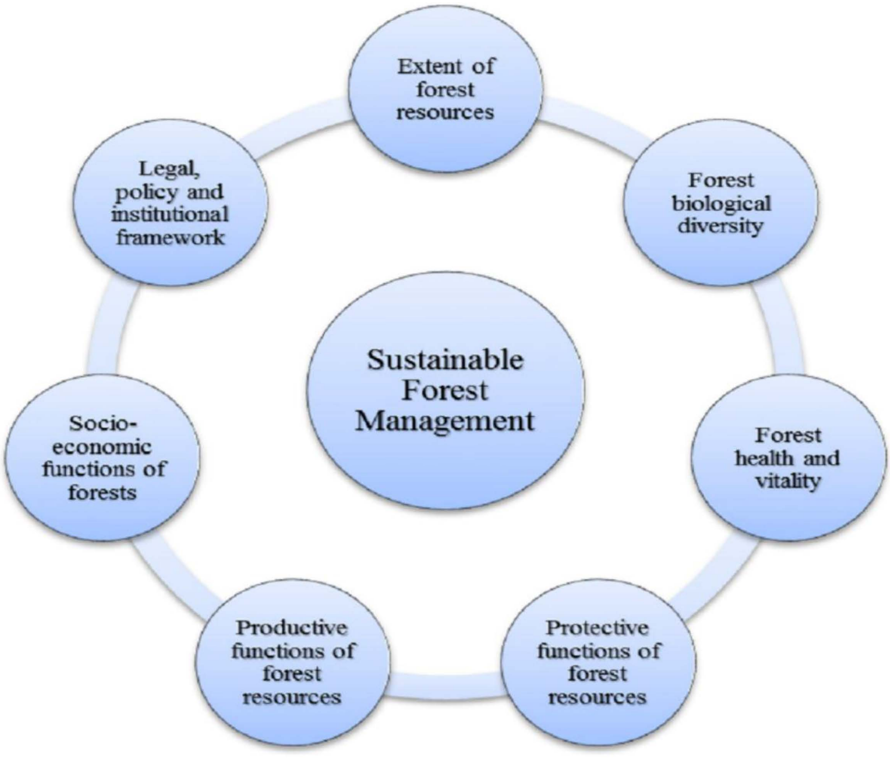

Figure 7.4.1 Sustainable forest management values. Adapted from FAO (2020).

forest types are important as a basis for conservation efforts. The theme encompasses ambitions to reduce deforestation and to restore and rehabilitate degraded forest landscapes.

Biological diversity. This theme concerns the conservation and management of biological diversity at genetic, species and ecosystem levels. Such conservation, including the protection of areas with fragile ecosystems, ensures that diversity of life is maintained and provides opportunities to develop new products in the future, including medicines. Genetic improvement is also a means of increasing forest productivity, for example, to ensure high wood production levels in intensively managed forests.

Forest health and vitality. This theme concerns the need for forests to be managed in such a way that the risks and impacts of unwanted disturbances are minimized. These disturbances include wildfires, airborne pollution, storm felling, invasive species, pests, diseases and insects. Such disturbances may impact social and economic as well as environmental dimensions of forestry.

Productive functions of forest resources. This theme refers to the fact that forests and trees outside forests provide a wide range of wood and non-wood forest products. It expresses the ambition to maintain an ample and valuable supply of primary forest products, while at the same time ensuring that production and harvesting are sustainable and do not compromise the management options of future generations.

Protective functions of forest resources. This theme addresses the role of forests and trees outside forests in moderating soil, hydrological and aquatic systems; maintaining clean water (including healthy fish populations); and reducing the risks and impacts of floods, avalanches, erosion and drought. Protective functions of forest resources also contribute to ecosystem conservation efforts.

Socio-economic functions. This theme relates to the contributions of forest resources to the overall economy through employment; the processing and marketing of forest products; and energy, trade and investment in the forest sector. It also addresses the important forest function of hosting and protecting sites and landscapes of high cultural, spiritual or recreational value, and thus includes aspects of land tenure, indigenous and community management systems and traditional knowledge.

Legal, policy and institutional framework. This theme includes the legal, policy and institutional arrangements necessary to support the aforementioned themes, including participatory decision-making, governance and law enforcement and monitoring and assessment of progress. It also involves broader societal aspects, including fair and equitable use of forest resources, scientific research and education, infrastructure arrangements to support the forest sector, transfer of technology, capacity-building and public information and communication.

From an SFM perspective, Kollmuss and Agyeman (2002) state there should be conscious, principled action to minimize the negative impacts on forests by creating desired behavioural outcomes through sustainability education. The seven FAO principles offer important insight for sustainability education in terms of the importance of natural resource management and governance, as well as an in providing and understanding of the latent and explicit tensions that inherently exist between natural resource management and human consumption and production.

Consider, for example, the tensions and potential trade-offs between valuing forests for the resources they provide for building and construction and the valuing of forests for their role in providing biodiversity habitat. Other tensions also exist between the benefits of job creation from forestry versus the benefit of forests associated with their role in CO_2

mitigation and climate change management. Managing these often conflicting values requires governmental policy support and sustainability-focused regulations and certification programs, which will be discussed in Sustainability Concept 6.

In summary, the lessons of the 'Tragedy of the Commons' and the corresponding insights into and principles of natural resource management and governance are highly relevant in a world facing constant tensions between public and private resource provision and should inform the development of sustainability education (see Chapter 8.3 in this volume).

Sustainability concept 5: the role of socio-ecological values in sustainable development thinking

Although the natural resource governance-related principles and themes noted earlier are necessary in the development of sustainability education, they are not sufficient. Social and socio-ecological values are also increasingly important. Over the last 200 years, the social demands on forests have been predominantly utilitarian, and their social value could be largely expressed in terms of market prices. However, as Western countries became progressively urbanized, the notion of romantic and symbolic forest values, which emphasized ecological and other environmental values rather than simply commodity production, have increased. Along with this view, the social values of forest recreation, landscape amenities, and non-game wildlife have been increasingly perceived as more important than wood production (Wiersum 1995). Thus, the meaning and valuing of 'forest' has evolved considerably from industrial to post-industrial times. Furthermore, globalization has also encouraged a trend for wealthier societies to reserve more of their forest land and to access their forest commodity needs from overseas, generally from less developed nations and economies. Australia is a large net importer of wood and timber products from nations in the Pacific, South America and until recently from the boreal forests of eastern Russia. Most consumers remain unaware of these supply chains or their implications for global forest growth and SFM.

This change has been a function of societal values moving from a single focus on economic concerns to a broader range of quality-of-life issues, in tandem with the growth of the environmental movement where forest management became associated with the evolving concepts of community participation and social inclusion (O'Brien 2003, 2005). Hamish Kimmins (1993) was among the first to write about evolving social values towards forests and their impact on forest management as an ongoing paradigm change for modern economic societies. This evolution in natural resource management is characterized by four phases: an exploitation phase, a regulation phase, an ecological phase and a socio-ecological phase.

The conceptual development from the ecological to the socio-ecological phase reflects changing social attitudes and the requirement for this change in sustainable development thinking. However, different countries and regions have progressed at different rates along this development pathway. Societal demands, however, have increasingly forced a more rapid requirement for change from one phase to another. As not all society values change at the same time, some form of conflict is to be expected. Kimmins (1993) noted that whilst a database of forestry information was increasingly needed to inform implementation of the regulation and/or ecological management phase in forest management, society was increasingly expecting forest management to reflect more focus on socio-ecological values. Consistent with this, Bengston (1993) maintained that forests should be managed to protect intrinsic social values held instead of a single-minded focus on their instrumental uses and benefits to society.

In summary, socio-ecological values are increasingly becoming an important part of resource allocation decision making. Sustainability education must reflect the evolving role and value of the environment in human lives and wellbeing, which will require increasing focus on stewardship for both humans and the biodiversity and ecosystems we share our lives with.

Sustainability concept 6: natural resource management governance and policy support to protect natural resources

Global policy coverage to improve the ability of forests to assist in climate change mitigation has been uneven across sectors (IPCC 2023). Policies implemented by the end of 2020 were projected to result in higher global GHG emissions in 2030 than currently expressed by individual nations under the UN Paris Agreement targets. This indicates a significant 'implementation gap' and, without a strengthening of policies, puts further pressures on 2100 global warming projections (2.2–3.5°C) (IPCC 2023).

This situation reflects the changing dynamic of both societal values and policy development conflicts because not all desired values can be achieved simultaneously by a government or policy directive (Stewart 2006). Governments are often confronted with the need to make trade-offs in resource management allocation to manage these value conflicts (Stewart 2006). Many of the public goods of sustainable forest management (e.g., carbon sequestration, oxygen production, biodiversity protection) can be undermined by allowing private interests to trump public interest. This, as noted earlier, is the challenge presented by the 'Tragedy of the Commons' when private benefits are taken at the cost of broader public benefits. An awareness of a broad range of stakeholder values should be presented in sustainability education with an understanding of the 'common' need to find trade-offs in negotiating natural resource allocation and decision making within the broader requirements of public good.

For example, in SFM, the IUCN's Red List of Ecosystem Health, a tool to assess the conservation status of ecosystems, are a number of international forest assessment programs to measure the significance of forests and their contribution to atmospheric carbon management. The REDD+ is a framework created by the United Nations Framework on Climate Change Convention (UNFCCC) Conference to guide activities in the forestry sector to ensure the sustainable management of forests and the conservation and enhancement of forest carbon stocks.

These measurement frameworks allow analysis of how deforestation contributes to the release of carbon or how afforestation or reforestation can increase the sequestration of carbon and assist in the mitigation of climate change. They assist in the sustainable allocation of natural resources at both an international level with frameworks such as REDD+ or at a global non-government level through standards such as the Programme for Endorsement of Forest Certification (PEFC) and those from the Forest Stewardship Council (FSC). The PEFC is an international SFM standard developed in 1999 that accounts for around 75% of global forest certification. Like the FSC, the PEFC is a non-profit, non-governmental organization focussed on promoting sustainable forest management through independent third-party certification. The PEFC requires all national certification systems to have a standard set of sustainable forest management features, which include:

- Maintenance, conservation and enhancement of ecosystem biodiversity.
- Protection of ecologically important forest areas.

- Prohibition of forest conversions.
- Recognition of free, prior and informed consent of indigenous peoples.
- Promotion of gender equality and commitment to equal treatment of workers.
- Promotion of the health and well-being of forest communities.
- Respect for human rights in forest operations.
- Respect for the multiple functions of forests to society.
- Provisions for consultation with local people, communities and other stakeholders.
- Respect for property and land tenure rights as well as customary and traditional rights.
- Compliance with all fundamental International Labour Organization (ILO) conventions for worker rights.
- Working from minimum wage towards living wage levels.
- Prohibition of genetically modified trees and most hazardous chemicals.
- Exclusion of certification of plantations established by conversions, including conversions of ecologically important non-forest lands (e.g. peatlands).
- Climate positive practices such as reduction of GHG emissions in forest operations.

Similarly, the Global Reporting Initiative (GRI) is an international independent standards organization that provides best practice standards and certification programs for sustainability reporting across a wide variety of industries and businesses. Transparent reporting provides an opportunity for industries and businesses to take responsibility for any negative environmental or social impacts as well as their overall sustainability performance (see Chapters 2.7 and 8.4 in this volume).

The utilization of frameworks and standards either through governmental regulations or those developed by industry and organizations like the PEFC, SFC or GRI promotes both accountability in sustainability management and transparency in reports of sustainability performance. Such certification programs provide credible sustainability standards and measures and ensures sustainability performance can be assessed across valuable independently determined sustainability metrics.

In summary, natural resource management governance, assessment frameworks and standards provide an opportunity for transparent management of natural resources and can help demonstrate good sustainability management through transparency, accountability, inclusiveness and equity in sustainability education.

Conclusion

The sustainability concepts practised in SFM and presented in this chapter have the potential to make important contributions to sustainability education and to inculcate the values, principles and governance required to sustainably manage our land resources.

Our education systems and community and social values must recognize the role and value of our natural systems in supporting human lives. A full appreciation of the role of forests and the meaning and practice of wise stewardship is necessary to elevate our thinking and knowledge so that we can see both the ‘wood through the trees’ and the wood and trees as separate valuable entities. The intrinsic role of the forest in sustaining many lives on the planet, not just human, is crucial and demonstrates the importance of local and global ecosystem understanding and protection in framing sustainability education.

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7.5
CLIMATE CHANGE POLICY
Mitigation, adaptation, and resilience

Hiroshi Ohta

Key concepts for sustainability education

- Climate change is a complex set of global issues involving public good.
- The main objective of the United Nations Framework Convention on Climate Change (UNFCCC) was to reduce concentrations of greenhouse gases (GHG) in the atmosphere to "a level that would prevent dangerous anthropogenic interference with the climate system" (UNFCCC Article 2).
- The third Conference of Parties to UNFCCC (COP 3) was held in Kyoto, Japan, in December 1997 and formally committed many nations' signatories (excluding the United States, China, and Australia) to reduce GHG emissions in accordance with the agreed and binding individual targets.
- The Paris Agreement (COP 21) was the first universal climate agreement adopted by 195 parties (excluding Iran, Eritrea, Libya, and Yemen) in December 2015 to limit temperature rise to 2 degrees Celsius, aspiring to 1.5 degrees Celsius, compared to pre-industrial levels by aiming at net carbon neutrality by 2050.
- Climate change education should include reference to how we will cope with, mitigate, and adapt to climate crisis on our path to a sustainable future.

Introduction: climate change as a complex set of global commons

A stable global climate system is beneficial to all living things, whereas conversely its instability negatively affects all. This feature of the global commons resembles the characteristic of public goods that requires cooperation among the beneficiaries. Many states, through international negotiations, have agreed to reduce emissions of carbon dioxide (CO_2), a greenhouse gas (GHG). Nevertheless, some states do not fully comply with international agreements to reduce CO_2 emissions by burning fossil fuels pursuing economic growth. The latter behavior is a free-rider problem associated with public goods (Olson 1971). If we conceive the climate change problem from the issue of how much CO_2 can be emitted to maintain climate stability, the concentration of CO_2 in the atmosphere would conform to that of the cattle grazed by villagers in Garrett Hardin's "tragedy of the commons" (Hardin

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1968; Soroos 1997). Sizeable CO_2 emitters, such as affluent individuals, large companies, and industrialized countries, derive more benefits from using more fossil fuels than small emitters, while the negative consequences of climate change are shared worldwide. Individuals' short-term benefit-seeking behavior leads to the long-term disruption of the global climate system. Thus, dealing with climate change, or not doing so, involves global commons issues of overriding importance.

According to the National Aeronautics and Space Administration of the United States, the global temperature in 2020 was 1.02 degrees Celsius (°C) warmer than it was in 1880.[1] On August 9, 2021, the Working Group I (WGI) of the Intergovernmental Panel on Climate Change (IPCC) issued its most recent physical science assessment of climate change. This is a part of the IPCC's Sixth Assessment Report (AR6), which is followed by two other WG assessments. The report affirmatively stated for the first time that "It is unequivocal that human influence has warmed the atmosphere, ocean, and land" (IPCC 2021, 5). It also indicated that in all the five illustrative emissions scenarios, including the most stringent GHG emissions reduction scenario, the global surface temperature will reach 1.5°C above pre-industrial levels for the 20-year term (2021–2040) (IPCC 2021, 17–18). On February 28, 2022, IPCC's WGII on "Impacts, adaptation, and vulnerability" observed that "human-induced climate change, including more frequent and intense extreme events, has caused widespread adverse impacts and related losses and damages to nature and people, beyond natural climate variability" (IPCC 2022, 8). It also maintains that approximately 3.3–3.6 billion people are highly vulnerable to climate change (IPCC 2022, 12). The Paris Agreement of 2015, signed by 195 parties (including the European Union), called on the signatory states to limit the increase in global temperature to "well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels." The Paris Agreement also stipulated net carbon neutrality, specifically by achieving a balance between CO_2 emissions and absorption by 2050. To attain this goal, IPCC's Special Report on Global Warming of 1.5°C has suggested that the world reduce GHG emissions by 45% below the 2010 levels by 2030 (IPCC 2018).

How can these goals be achieved? What kinds of risks should we anticipate if the global mean temperature rises to or above 2°C? Can we avoid such risks, and what can we do to cope with them? Can a stable global climate be maintained for sustainable development? How comfortable can we be with the knowledge that what we do is in the interests of the world? To answer these questions, this section describes the genesis of climate change as a global issue. The relevant history, understanding and agreement on related matters, broad responses (whether advocated or made), and the complex structure of the challenges faced compose the context of climate change policy. Then, it introduces broad policies to cope with climate change, such as adaptation and mitigation. The remainder of this subsection discusses the contents of climate change policies in detail. Looking forward to a decarbonized world, it concludes by pointing to the significance of climate change policies for sustainability education while mentioning the outcomes of the most recent United Nations (UN) climate conference.

The critical contexts of climate change policy

Since the mid-1980s, global environmental problems have gained prominence and increasing attention on the international diplomatic stage. International cooperation was demonstrated by the attention given to the depletion of the stratospheric ozone layer when nations concluded the 1985 Vienna Convention for the Protection of the Ozone Layer and the 1987 Montreal Protocol on Substances That Deplete the Ozone Layer. In 1987, the World Commission on Sustainable Development (WCSD) issued a final report disseminating the concept of sustainable development worldwide. During the summer of 1988, a series of extreme weathers (severe droughts and floods) occurred in several countries. In the same year, the UN Environment Programme (UNEP) and the World Meteorological Organization (WMO) jointly established the IPCC. In March 1989, British Prime Minister Margaret Thatcher hosted an international conference on the depletion of the ozone layer, while France, the Netherlands, and Norway jointly sponsored a meeting on the protection of the global atmosphere. In July, diplomatic campaigns culminated at the annual meeting of G7 in Paris, when global environmental problems, including climate change, became one of the most important international political agenda items.

UN Conference on the Environment and Development and UN Framework Convention on Climate Change

The UN Conference on the Environment and Development (the Earth Summit) held in Rio de Janeiro in June 1992, adopted the UN Convention on Biological Diversity and the UN Framework Convention on Climate Change (UNFCCC). The Intergovernmental Negotiating Committee for a Framework Convention on Climate Change, under the UN General Assembly's auspices, drafted the convention through intense negotiations that lasted from February 1991 to June 1992. The Scandinavian countries and the European Commission were willing to reduce their CO_2 emissions to 1990 levels by 2000, while Australia, Germany, Japan, and New Zealand committed to reducing their emissions by 2000 or 2005. However, large energy consumers, such as those in the United States, and large energy suppliers, such as Brazil, Canada, China, India, and the Arab states, opposed such regulations (Chasek and Downie 2021). Ultimately, they agreed not to mention a specific numerical CO_2 emissions reduction target. Instead, the states would adopt measures to return the amount of CO_2 emissions to earlier levels by the end of the 1990s without accepting a legally binding obligation (Ohta 1995, 264–265). The UNFCCC includes several crucial principles for guiding climate policymaking. One of the most important principles is that of "common but differentiated responsibility and respective capability (CBDR-RC)." This principle means that all states are responsible for mitigating climate change, but not in the same way as the industrialized and developed parties listed in Annex 1 of the UNFCCC (Dessler and Parson 2020, 29–30). The UNFCCC entered into force in 1994, and its parties began another round of negotiations to conclude a legally binding regulatory treaty.

Kyoto Protocol

The first Conference of the Parties to the UNFCCC (COP1), held in Berlin in 1995, began negotiating a legally binding agreement to regulate CO_2 emissions and set the timing for adopting such an agreement at COP3. Japan hosted COP3 in Kyoto in 1997, but the negotiations were complicated and troubled by divisions and differences. One of the outstanding discords lay in the North-South divide, or the contention between Annex 1 countries and non–Annex 1 (developing) countries. Developing countries, referring to the CBDR-RC principle, refused to take any responsibility, demanding that developed countries first bear the burdens of reducing CO_2 emissions because they themselves caused the current problems. Annex 1 countries, especially the United States, called for developing countries' participation in CO_2 emissions reduction partly because prior to COP3, the US Senate unanimously passed the Byrd-Hegel Resolution, refusing to sign any agreement unless developing countries agreed to bear responsibility.

Concerning the agreed numerical targets and substances to be controlled, the Kyoto Protocol (KP) allowed different CO_2 reduction targets among the signatory parties and included five more GHGs in addition to CO_2: methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Developed countries were obliged to reduce GHG emissions by an average of 5.2% below 1990 levels during 2008–2012. However, the reduction target differed among Annex 1 (listed in Annex B of the KP) states. While the EU, the United States, and Japan had to reduce emissions by 8%, 7%, and 6%, respectively, Russia, Ukraine, and New Zealand could only hold emissions at 1990 levels, and Australia could increase emissions by 8% (Chasek and Downie 2021, 170; Dessler and Parson 2020, 29). Moreover, different reduction targets were allowed within the EU; some countries, such as Germany and Denmark, agreed to bear substantial reductions of over 20% relative to 1990 levels, whereas Portugal and Spain could increase their emissions by 27% and 15%, respectively (Grubb et al. 1999).

The KP also allowed parties to utilize market mechanisms called "flexible mechanisms" or "Kyoto mechanisms" to reduce GHG emissions. These mechanisms included emission trading (ET), joint implementation (JI), and clean development mechanism (CDM). They represented a quest for cost-effective ways of reducing GHG emissions. These mechanisms were overseas emission reduction schemes for implementation in other countries. However, only developed countries could utilize ET and JI between themselves, while CDMs were joint emission-reduction schemes between developed and developing countries. When the United States proposed ET, the EU and developing countries were concerned about Russia's tradable allowance, or "hot air." Russia could freeze its CO_2 emissions to 1990 levels, but its emission levels were more than 30% below the 1990 levels because of the severe economic recession after the USSR collapsed. This meant that Russia could sell 30% or more of its allowance at the emission trade market and not have to make any effort at home. Ultimately, the parties agreed to restrict overseas credits, which could be counted as a reduction in domestic emissions. International negotiations further meandered in the face of the crisis of the United States' rejection of ratifying the KP by the George W. Bush administration. It took seven years to agree on the KP's various operational rules while ironing out multiple discrepancies and settling divisive problems. It eventually came into force in 2005.

Paris Agreement

Although the KP, a legally binding international agreement, went into effect, it was far from sufficient to mitigate climate change. The 2007 IPCC's Fourth Assessment Report and a host of climate scientists called for much more substantial emission reductions than 5.2% below the 1990 levels as being necessary to avoid grave consequences. The delegates of the parties attending COP13 in Bali in 2007 concluded an international agreement in Copenhagen in 2009 for ambitious emissions reduction for the period beyond 2012. The Bali negotiations at COP13 had two tracks: one for dealing with a second commitment period under the KP and the other for "long-term cooperation action" under the UNFCCC (Dessler and Parson 2020, 29). However, the Bali talks were also hindered by the North-South discord revolving around the CBDR-RC principle. Developing countries were unwilling to agree to universal participation in mitigating global warming, insisting that, first, developed nations substantially reduce GHG emissions.

The North-South disagreements remained unsettled going into COP15 in Copenhagen in 2009. This UN climate conference could not agree to adopt any legal instrument to shape international cooperation for a long-term commitment by all the nations, but only agreed to "take note of" the Copenhagen Accord prepared by a relatively small number of the parties. However, it explicitly stated a long-term goal of limiting temperature rise to below 2°C, and a procedure for facilitating voluntary emissions reduction targeting and actions of both developed and developing countries (Chasek and Downie 2021, 175–176). Nevertheless, several Latin American states blocked the adoption of the Copenhagen Accord, criticizing it as a small-group decision that was "untransparent and undemocratic." Even though EU leadership and UN-centered diplomacy suffered from credibility deficiency at the Copenhagen climate conference, the next climate conference, COP16 in Cancun, in 2010, regained trust in international multilateral negotiations and eventually adopted the Cancun Agreement. It contained the key elements of the Copenhagen Accord, which paved the way for the Paris Agreement.

International negotiations took place on a single track in the Ad Hoc Working Group on Durban Platform for Enhanced Action at COP17 in Durban in 2011, which launched a new round of negotiations for a protocol or another agreement and included both developed and developing countries' actions after 2020. A watershed in international climate change approaches was the Doha Climate Gateway, which departed from the KP's top-down commitments in favor of bottom-up voluntary contributions that included top-down monitoring and implementation schemes. COP18 in Doha in 2012 called for a new global agreement by COP21 in 2015 to deal with the post-2020 period (Chasek and Downie 2021, 180–183). The following two years of intense negotiations addressed a wide range of issues and policies, such as mitigation, adaptation, technological and financial transfers, damages and compensation, capacity building, and transparency. Under the Paris Agreement, all the nations pledged nationally determined contributions (NDCs), or voluntary emissions reduction targets, which were to be strengthened every five years, to limit the increase in global temperature "well below 2°C above pre-industrial levels" and aspiring to limit it to a 1.5°C increase. The Paris Agreement came into effect in 2016, and the international community started on an arduous journey to achieve net carbon neutrality by 2050. Moreover, according to the IPCC's Special Report of 2018 that assessed the impacts of a 1.5°C temperature increase for the first time, it is necessary to reduce GHG emissions by 45% from 2010 levels by 2030 (IPCC 2018). This report also showed that even the consequences of a 1.5°C increase are unbearable for the regions whose ecosystems have already suffered significant damage by a 1°C temperature rise.

How can we cope with climate change?

We face tremendous challenges in stabilizing the global climate, and the time left to accomplish this is short. We must strive to steer society toward a sustainable path by transforming the economy and society by 2030. This section addresses general climate change policies and discusses more detailed policy measures.

We face many challenges in both the adaptation to and mitigation of climate change. The world population is expected to reach 9.9 billion by 2050 (Population Reference Bureau 2020), and most people will live in urban areas. Economic growth through industrialization is necessary to feed the people and develop land for crop farmers, cattle ranchers, houses, and community structures. However, we must reduce GHG emissions and maintain ecological integrity to mitigate climate change. At the same time, we must also address difficult issues, such as those of factory farms, substituting plant-based protein for meat, methane production by farm animals, and clearing of forest land. For this, we require the help of technological innovation and massive investments in an environmentally sound infrastructure. Good governance is also required to correct inequality, as access to natural resources and social services in many poor communities in developed and developing countries worsens with climate change.

The IPCC is one of the most reliable sources to obtain scientific knowledge, assessments of climate change effects, and policies to mitigate it. The IPCC comprises three WGs.[2] WGI (science) assesses the physical science climate change and provides scientific information relevant to the global community to meet the challenges of climate change. WGII (impacts and adaptation) assesses socio-economic and natural systems' vulnerability to climate change, negative and positive consequences of climate change, and options for adapting to it. WGIII (mitigation policy) focuses on climate change mitigation, assessing methods for reducing GHG emissions and removing GHGs from the atmosphere. WGII and WGIII specialize in two broad worldwide policies to cope with climate change: adaptation and mitigation. Another measure (not discussed in this chapter) is large-scale but controversial: modifying the climate system by geoengineering or climate engineering (Dessler and Parson 2020, 113). Throughout the international negotiations on the climate change regime (as addressed by the UNFCCC and the KP), mitigation policies were central concerns. However, as climate change impact has become discernible and progress in mitigation policy development has been slowed, climate change adaptation has been given high priority. Therefore, the Paris Agreement addressed both mitigation and adaptation issues for the first time.

Adapting to climate change

Responding to the projected impact of climate change is an essential element of adaptation. According to the UNFCCC, adaptation refers to adjustments in ecological, social, and economic systems in response to actual or expected climatic changes and their impacts. It also refers to "changes in processes, practices, and structures to moderate potential damages or benefit from climate change opportunities."[3] In common parlance, adaptation means how people, local communities, and countries respond to the changing climate and its impacts and prepare for future changes.

However, as the Fifth Assessment Report's risk assessment indicates, the distribution of climate risks is uneven (IPCC 2014a). The most vulnerable populations, which are often the least responsible for climate change, are those least able to cope with climate risks. Thus, adaptation to climate change is an issue of global concern and equity. The international community needs to help vulnerable communities become resilient to disruptions, shocks, and stress from climate change to receive environmental and social benefits and acquire a foundation for economic and human development. Climate resilience is vital for a sustainable society, particularly in the vulnerable communities of developed and developing countries.

There are various approaches to adaptation. Effective adaptation strategies and actions have synergistic effects on the broader strategic goals of sustainable development. Although there are many ways to sort adaptation approaches, the IPCC encapsulates them into several categories: human development, poverty alleviation, livelihood security, disaster risk management, ecosystem management, spatial or land-use planning, structural and physical, institutional matters, social matters, and spheres of change (IPCC 2014b, 27). Some adaptation approaches in the categories overlap, forming a loose cluster of vulnerability and exposure reduction, structural and physical adaptation, incrementally transformative adjustments, or transformative approaches.

Vulnerability and exposure reduction through development, planning, and practices include human development, poverty alleviation, livelihood security, disaster risk management, ecosystem management, spatial or land-use planning, and structural and physical approaches.

- Human development should provide access to education, public health, energy, safe housing, and equality for all genders, marginalized people, and communities.
- Poverty alleviation requires improved access to and control of local resources, land tenure, and social safety.
- Livelihood security involves income, asset, and livelihood diversification; improved infrastructure; access to technology and decision-making; changed cropping; livestock and aquaculture practices; and reliance on social networks.
- Disaster risk management MUST address early warning systems, hazard and vulnerability mapping, improved drainage, flood and cyclone shelters, building codes and practices, storm and wastewater management, and transport and road infrastructure improvements.
- Ecosystem management REQUIRES the maintenance of wetlands and urban green spaces, coastal afforestation, watershed and reservoir management, maintenance of biodiversity, and community-based natural resource management.
- Spatial or land-use planning should provide adequate housing, infrastructure, and services; manage development in flood-prone and other high-risk areas; and implement urban planning and upgrading programs, land zoning laws, and protected areas.

The structural and physical category of adaptation consists of four sub-categories: engineered and built environment, technological, ecosystem-based options; and services.

- The main features of engineered and built environment options are hardware such as sea and coastal protection structures, flood levees, water storage, improved drainage, transport and road infrastructure improvement, floating houses, and power plants, and electricity grid adjustment.
- Technological options regarding food production and relatively small-scale hardware include new crops and animal varieties; indigenous, traditional, and local knowledge; technologies and methods; water-saving technologies; desalinization; and mechanical and passive cooling.
- Ecosystem-based options encompass ecological restoration, soil conservation, afforestation and reforestation, green infrastructure (e.g., shade trees and green roofs), controlling overfishing, and community-based natural resource management.
- The service category consists of social safety nets, food banks, water and sanitation, and vaccination programs.

The transformative approach category consists of institutional, social, and spheres of change. Institutional transformation encompasses economic options such as financial incentives, insurance, catastrophe bonds, payments for ecosystem services, and public-private partnerships. Another institutional approach category deals with laws and regulations, including land zoning laws; and laws encouraging insurance purchases, protected areas, and fishing quotas. National and government policies and programs also need to be transformed as national and subnational adaptation plans are essential administrative guidelines. In addition, disaster planning and preparedness; and integrated water resource, integrated coastal zone, ecosystem-based, and community-based management can help prepare for climate change.

Educational options are foundational to social approaches. They raise awareness and integrate it into education, gender equity; extension services; sharing indigenous, traditional, and local knowledge; participatory action research and social learning; and knowledge-sharing and learning platforms. Transformative social methods subordinate to informational options include hazard and vulnerability mapping, early warning and response systems, systematic monitoring and remote sensing, and participatory scenario development (through multistakeholder decision-making).

The last category, spheres of change, consists of practical, political, and personal spheres. The practical sphere involves social and technical innovations and behavioral shifts. Political sphere refers to political, social, cultural, and ecological decisions and actions that support adaptation, mitigation, and sustainable development. The personal sphere of change pertains to individual and collective assumptions, beliefs, values, and worldviews that influence climate-change responses.[4]

However, these adaptation measures are not easy to implement because they call for public spending, necessitate fair redistribution of such expenditures, and restrict private property (Dessler and Parson 2020, 119–120). For instance, when a government decides to build flood levees, where and how robustly they are made them becomes contestable, including differences in views on the technical feasibility and environmental impacts. Furthermore, if the government chooses to relocate the community in the vicinity of the flood-prone river as the best choice, this decision can conflict with private property rights. Nevertheless, the current state of climate change has prompted us to take immediate and precautionary measures to alleviate harm to humans and the natural environment.

Overall, adapting to climate change in less costly and more manageable ways requires mitigating climate change as quickly and deeply as possible.

Mitigating climate change

a.) Technological approaches to reduce GHG emissions

According to the UNEP Emission Gap Report 2022 (EGR 22), GHG emissions reached a record high of 52.8 billion metric tons of CO_2 equivalent (52.8 Gt CO2e) in 2021 without land-use change (LUC) emissions[5] (UNEP 2022, 5–6). The International Energy Agency (IEA) estimated a 4.8% increase in emissions in 2021, after a 5.8% decline in 2020 (IEA 2021) during the COVID-19 pandemic. By 2030, annual emissions need to decrease by 13 Gt CO_2e (range: 10–16 Gt CO_2e) lower than current unconditional NDCs for a 2°C goal, and 28 Gt CO_2e (range: 25–30 Gt CO2e) further down for the 1.5°C goal (UNEP 2021, 32–35).[6] The ERG 22 warns us that the current NDCs would result in warming of about 2.4–2.6°C by 2050 (UNEP 2022, 35). China, the EU, India, Indonesia, Brazil, the Russian Federation, the United States, and international transport accounted for 55%, while the

G20 members were responsible for 75% of global GHG emissions in 2020 (UNEP 2022, xvii). Global collective efforts are imperative to meet the goal of the Paris Accord.

Energy-related industries account for approximately 70% of the world's GHG emissions (IEA 2022). Thus, transforming energy from fossil fuels into renewable energy is crucial for mitigating climate change by achieving net-zero GHG emissions by 2050. Major technological transformations require across-sector efforts, which include:

- Full decarbonization of the energy sector based on renewable energy and electrification across sectors, including phasing out coal-fired power plants.
- Decarbonization of the transportation sector in parallel with modal shifts to public transportation, cycling, and walking.
- Shifts in industrial processes toward electricity, zero carbon, and the substitution of carbon-intensive products.
- Decarbonization of the building sector, including electrification and greater efficiency.
- Enhanced agricultural management and demand-side measures, including dietary shifts to more sustainable, plant-based diets and measures to reduce food loss and waste.
- Zero net deforestation, adoption of policies to conserve and restore land carbon stocks, and protecting natural ecosystems, aiming for significant net CO_2 uptake in this sector (UNEP 2019, 29).

These transformations across the energy, manufacturing, transport, commercial, and residential sectors, and individuals can lead to decarbonization by galvanizing technological innovations, institutional reforms (such as carbon pricing [e.g., carbon tax and emission-trading schemes]), and individual efforts. Similarly, Project "Drawdown" (the future point in time when levels of GHGs in the atmosphere stop increasing and start to decline steadily; Hawken 2017, x) presents comprehensive and substantive approaches to reverse global warming. This project constantly reviews the most effective solutions available by showing what individuals, communities, cities, companies, and governments can do to arrest global warming.[7]

The world is equipped with technologies to meet this global challenge and establish a sustainable society. Technological options for reducing GHG emissions include increasing energy use efficiency, reducing carbon intensity (CO_2 emissions per unit of energy), and switching to non-fossil fuels. Existing technologies can improve energy efficiency at a low cost in various sectors and activities, such as energy, motors, industrial machines, vehicles, buildings and housings, electric equipment, lighting, cooling, and heating (Dessler and Parson 2020; Hawken 2017; Henson 2019; Jacobson 2023; Lovins and Rocky Mountain Institute 2011; UNEP 2020). One of the transitional options is to shift from burning coal to using natural gas to reduce carbon intensity. The "shale gas revolution" in the United States has substantially contributed to the recent emissions reduction (Yergin 2020). As an incremental approach, technologies for capturing CO_2 from thermal power plants have been developed to promote the continued use of fossil fuels. This is called CO_2 capture and storage (CCS), and more recently, CO_2 capture, utilization, and storage. The basic idea of CCS is to capture CO_2 before it is emitted into the air and stored in depleted oil and gas wells or seabeds. However, doing so is costly and not sufficiently widespread enough to contribute to the 2030 CO_2 emissions reduction target (Henson 2019, 424–429). More importantly, this is not the ultimate option toward decarbonization.

Switching from fossil fuels to renewable energy sources (hereafter renewables) is the most viable and sustainable option for mitigating climate change (see Chapter 2.6 in this volume). Renewables include wind, solar, hydropower, tidal, geothermal, and biomass. However, there are some problems associated with renewables. For instance, the utilization of solar power is limited to sunny days, the wind does not blow all the time (intermittency problem), and the storage of electricity is difficult and costly. Despite these concerns, renewables have rapidly increased in popularity worldwide owing to technological advances, financial incentives, subsidies, and, in many cases, increasing returns to scale that reduce costs. However, the global energy demand for fossil fuels remains significant, particularly by emerging economies. Thus, the global consumption of renewables in 2019 remained low at 10.5% of the total final energy consumption (International Renewable Energy Agency (IRENA) 2020, 18–19). According to the IRENA, to achieve the Paris Agreement's goal, the international community must achieve 28% renewables in the total final energy consumption in 2030 and 66% in 2050 to keep the rise in global temperatures to well below 2°C and towards 1.5°C in this century (IRENA 2020, 19).

The aforementioned technological mitigation measures are not exhaustive. However, they show us that there are sufficient technological approaches and paths to mitigate climate change. Nevertheless, without climate policies to promote them, the technological progress remains useless. Thus, the next question is how to galvanize people to help mitigate climate change.

b.) Policies to promote mitigating climate change

Unlike the air pollution problems in the past in which polluters were limited or relatively easily identifiable for regulation, the causes for climate change are too diverse to justify regulatory approaches alone. Conventional regulatory measures addressed air pollution caused by sulfur dioxides emitted from factories or nitrous oxide emitted mostly from automotive exhaust gas. In the past, the regulatory approach to air pollution was an end-of-the-pipe approach to prescribing acceptable emission standards for polluters. In contrast, for climate change, industrial and non-industrial producers, intermediaries, retailers, and consumers all emit GHG to contribute to climate change. It is inefficient and impractical, if not impossible, to regulate GHG emissions by establishing acceptable emission standards. Thus, a wide range of policies must be implemented to address climate change, including market-based approaches, prescriptive regulatory approaches, a combination of these two, and public initiatives and voluntary measures.

Following the success of the ozone regime consisting of the Vienna Convention and the Montreal Protocol, the climate regime adopted the KP to materialize the UNFCCC's ultimate objective of stabilizing the global climate system (Hale et al. 2013). The KP adopted a prescriptive regulatory approach and introduced market-based measures. It is preferable to establish a universal GHG emissions reduction target through the participation of all the states. However, due to the principle of "common but differentiated responsibilities," only industrialized countries (belonging to the Organisation for Economic Co-operation and Development) and former socialist states (in transition to market economies) accepted the responsibility of reducing GHG emissions. Simultaneously, the KP adopted ET, JI, and CDM, as previously mentioned. The underlying rationale for all three measures was the cost-effectiveness of reducing GHG emissions. As GHG emissions anywhere contribute to global warming, it is cost-effective to reduce a large amount of GHG emissions, where the marginal cost of reducing it is cheaper.

The main feature of market-based climate change regulations is carbon pricing, of which tradable emissions-permit (or cap-and-trade) systems and carbon taxes are the most common. They pursue environmentally friendly behavior by providing incentives to reduce carbon emissions, allowing individuals and companies to respond flexibly to taxes or ET. Under the cap-and-trade system, each emitter holds a permit. It either remains within its emission limits or purchases permit units from other emitters with surplus permits for sale (Newell and Paterson 2010, 25). Usually, the government distributes a fixed number of permits used by emitters to authorize emissions or trade them with other emitters. Both carbon taxes and ET offer the theoretical advantages of flexibility and cost aversion.

However, there are numerous and diverse sources of carbon emissions. Some are large and concentrated, such as refineries, power plants, and steel mills, whereas others are small and diffused, such as automobiles and individuals. The most effective with the least administrative cost is taxing the "upstream" of fossil products and services; that is, the well, mine, or point of import. A price hike in the "upstream" raises the prices of all the rest of the goods and services that depend on fossil fuels (Dessler and Parson 2020, 139). However, no government has taxed upstream prices, mainly because of the organized political efforts to oppose this policy. Similarly, applying stringent emission caps to energy-intensive industries in a cap-and-trade system has been met with strong resistance in many countries, including the EU.

National and sub-national governmental initiatives play a significant role in stimulating the decarbonization efforts of producers and consumers. A government can allocate a considerable amount of taxpayers' money to research, development, and demonstration for technological innovation that promises to mitigate climate change (Sivaram 2018). The impact of technological breakthroughs can be disruptive by making the current technology obsolete in a short period (Seba 2014). Governmental policy innovations are crucial to decarbonization. The feed-in-tariff system is a popular policy for promoting renewable energy worldwide. Power companies or transmission entities are obliged to purchase electricity generated by renewables such as solar and wind at a fixed rate for a certain period (e.g., 10 or 20 years). Another governmental policy is to provide people with subsidies for purchasing eco-cars (e.g., electric vehicles [EVs]) or installing roof-top solar power systems. Finally, governmental infrastructure provisions for decarbonization are an indispensable part of the endeavor; for example, electricity charging stations for EVs and hydrogen stations for fuel-cell cars are a case in point.

Voluntary measures, private initiatives, and individual actions are also essential policies to mitigate climate change. The voluntary action plans of business associations and individual firms are among the main items for climate policy options. The UN Task Force on Climate-related Financial Disclosure recommends that companies disclose climate change-related risks and opportunities. RE100, a voluntary business forum, pledges to 100% renewables for business operations. Furthermore, for example, Apple, one of RE100 members, declared that it will become carbon neutral across its entire business, manufacturing supply chain, and product life cycle by 2030 (Apple 2021). The divestment movement initiated by 350.org (a global social movement advocating divesting from fossil industries) now influences institutional investors to withdraw money from fossil fuel businesses and invest in renewables. Anyone can mitigate climate change by riding bicycles, using more public transportation, carpooling, reducing air travel, changing to light-emitting diode (LED) lighting, reducing beef consumption, using reusable shopping bags, and more.

Conclusion

Path to a sustainable future

During the UN COP26 climate conference in Glasgow in November 2021, governmental and non-governmental leaders urged accelerating action to mitigate and adapt to climate change. One hundred and nine countries signed the Global Methane Pledge to cut emissions by 30% by 2030, whereas 141 countries pledged to halt and reverse forest loss and land degradation by 2030.[8] Over 2,000 companies are now committed to developing science-based targets to reduce their emissions, while over 400 financial firms that control over $130 trillion in assets are committed to aligning their portfolios to net-zero by 2030.[9] COP26 adopted the Glasgow Climate Pact that upheld the target of limiting to 1.5°C, and 151 countries ratcheted up their NDCs to reduce their emissions by 2030. Furthermore, COP27, held in Sharm El-Sheikh, Egypt, in November 2022, maintained the 1.5°C goal and agreed on a fund to address the issue of "loss and damage" after long years of dragged negotiations since COP19 in 2013 (UNFCCC 2022). Loss and damage are concerns in many climate-vulnerable countries already suffering from climate change.

Governments, international organizations, private companies, non-governmental organizations (NGOs), and citizens have participated in the recent official and non-official global climate conferences to support accelerating decarbonization and building resilient communities. Climate mitigation and adaptation policies are the core elements for achieving sustainable development, and understanding and promoting these policies are indispensable in sustainability education. By 2030, we will be at a crossroads between a sustainable future and falling into the abyss of climate disasters. We must galvanize all individuals, communities, cities, companies, and governments to mitigate climate change, for which we have the required tools. Therefore, we must use them and choose the right path for our future.

Notes

1 "Global Temperature." NASA. Accessed March 28, 2021. https://climate.nasa.gov/vital-signs/global-temperature/.
2 "The Intergovernmental Panel on Climate Change." IPCC. Accessed April 14, 2021. https://www.ipcc.ch/.
3 "Adaptation and Resilience." UNFCCC. Accessed April 27, 2021. https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/what-do-adaptation-to-climate-change-and-climate-resilience-mean.
4 These adaptation policy measures summarize the Fifth Assessment Report's *Synthesis Report* (IPCC 2014b).
5 Carbon dioxide equivalent (CO_2e) is a way to place emissions from various radiative forcing agents on a common footing by accounting for their effect on climate. It describes the amount of CO_2 that would have the same global warming ability when measured over a specified time for a given mixture and amount of GHGs (UNEP 2020, ix).
6 Conditional NDC means that some countries propose an NDC contingent on a range of possible conditions, such as the ability of national legislatures to enact the necessary laws, ambitious action from other countries, the realization of finance and technical support, or other factors (UNEP 2021, xii). Unconditional NDC is the absence of such conditions.
7 "The Drawdown Review 2020: Climate Solutions for a New Decade." Project Drawdown. Accessed November 26, 2021. https://drawdown.org/drawdown-review.
8 "Fast Action on Methane to Keep a 1.5°C Future within Reach." Global Methane Pledge. Accessed November 22, 2021. https://www.globalmethanepledge.org/; Taylor, Rod, et al. "What COP26

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7.6
REGENERATIVE VALUES IN SUSTAINABILITY EDUCATION
Learning with ecological family

Sandra Wooltorton, Mindy Blaise, Anne Poelina and Laurie Guimond

Key concepts for sustainability education

- Regenerative sustainability is a paradigm of transformative action for healing people, places, and planet through co-creating regenerating communities based on cultures of reciprocal flourishing. The focus is on wellbeing, restoration, and revitalisation.
- Regenerative sustainability education is about recognising and participating with local ecosystems, enabling active, engaged, practical, and relational learning. The point is to relearn how to see, hear, and feel our ecosystem homes. The primary value is Land as the living, storied foundation for ecological family, inclusive of spiritual, legal, and socio-economic systems.
- Indigenous and local place-based knowledge systems facilitate sustainable ways to live by regenerating ancient wisdom, regenerating health, regenerating climates, and regenerating species alongside knowledge-holders to guide, show, and explain. Ancient wisdom is also within the history of the West.
- Learning with local ecological communities enables an enhanced sense of local community oriented towards integrity, justice, and non-violence.
- The importance of Indigenous thinking and guidance in regenerative sustainability education is to include the wisdom and knowledge of Indigenous people and cultures in promoting sustainable practices. It is also to guide a deep connection to the natural world – of which all humans are a part.

Introduction: regenerative sustainability

We acknowledge the lands, elders, traditional owners, and cultural custodians of the Lands we live and walk with and where you live and work. We see this as the first protocol in regenerative sustainability, and in Australia, the acknowledgement is common practice.

Regenerative sustainability is a holistic worldview supportive of continual proliferation of whole-system health and wellbeing (Gibbons, 2020). Similarly, regenerative sustainability education is underpinned by a holistic worldview of continual proliferation of whole-system health and wellbeing. Within this paradigm, teachers, young people, and

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community members together collaboratively learn new ways of being, knowing, doing, and thriving within an ecosystem of interrelatedness. Regenerative sustainability learning takes place not in ways that dominate, but in ways that enable deep cooperation and place enmeshment. Guided by Indigenous wisdom, insights are generated for living together within the laws of natural systems (Poelina et al., 2022). At the core of the paradigm is a personal-collective search for belonging, meaning in life, and authentic self. These qualities of transformational change apply to local, regional, national, and global scales in education, governance, infrastructure, transport, housing, and water management and, at the systems level, food systems, health systems, social systems, energy systems, and economic systems.

Fundamental questions within regenerative sustainability, are: why are we doing this, followed by what should we be doing'? (Wahl, 2016). Five personal-collective aspirational qualities of regenerative sustainability are: every action helps personal, cultural, and planetary wellbeing; maintains daily participative practices for the wellbeing of natural systems (such as a river); understands oneself as an integral ecological community member; lives with integrity and commitment to wellbeing of self and ecosystem revitalisation; and thinks in ways that recognise relationality, complexity, and holism.

To illustrate a regenerative sustainability learning practice, we four writers each walk as relations or kin with our local rivers: one in Québec and three in Western Australia. We use this learning practice because we love our rivers and our river-lands. In his book on designing regenerative cultures, Daniel Wahl asks, "Why change the narrative now?" (2016, p. 24). His answers include love of wisdom, finding deep joy in cultivating relationships with all of life, recovering deep meaning in belonging to our world, and cherishing wisdom to turn the healing crises all around us into drivers of deeper cultural transformation. Questions, rather than answers, he says, can lead to collective wisdom. These conversations are the core of regenerative sustainability education, which emphasises learning to recognise and nurture relationships everywhere. It is to learn to respond to place, or as Bruno Latour (2018) says, to learn to belong to a territory, to "come down to earth" (p. 2). It is also to learn to cooperate in deeply democratic ways with each other as members of more-than-human families.[1]

Practical regenerative work comes from deep engagement with local places. As we see it, to regenerate living systems means to live lives that matter to and with more-than-human beings with whom we are interdependent, that matter to our ancestors and our great-grandchildren's futures, and that improve our shared wellbeing (Poelina et al., 2022). What might it be like, we wonder, to cherish places as if the ground we walk on and with is precious? Or to live as if these places are sentient and responsive, as Reason and Gillespie ask (2021)? They are, of course.

There are many knowledge systems in the world that can teach us more about our places. For example, see *Pluriverse: A Post-Development Dictionary*, by Kothari et al. (2019), which offers 100 narratives of different cultural ways of respecting and nurturing life on Earth.[2] There are local common worlds we share, with whom we can walk, watch, and communicate. Taylor et al. (2021) write that our common worlds are "the interdependent, life-sustaining ecological communities that we share with all manner of other beings, entities, and forces on earth" (p. 74). However, for many adults in the Global North these common worlds are hard to notice, because a modernist worldview has given us a mistaken impression that human existence is separate. Rather, we suggest that we do have the ability to respond to places and more-than-human-beings with whom we share lives, and there are concepts, values, and skills to learn how. Indigenous people have been describing and publishing these ways of doing, being, and learning relationship for decades (for example Bawaka Country et al., 2019; Bunbury et al., 1991; Christie, 1990).

In this chapter, we address the personal-collective dimension of regenerative sustainability, a starting point for stepping out. We share narratives using techniques from the environmental humanities. This research field offers transdisciplinary and interdisciplinary ways of understanding landscapes that include socio-ecological systems whereby social and ecological systems connect. We draw from the literature that opens doors to worlds of beauty, commonality, communication, and love of place. We show connections to planetary issues that affect everyone and everything, everywhere. We narrate our walks before illustrating how walking with places can be decolonising, thereby reducing impact on cultures everywhere. Next, we bring concepts and values together into the notion of ecological family to begin regenerative sustainability education. Our intention is to inspire the cultivation of relationships with life in local places, to enable learners to feel a sense of belonging and recognise themselves within ecosystems rather than separate. We offer this as an entry into deeper transformation at personal and community levels. As pedagogy, it adapts to schools, out-of-school programs, colleges, and universities, as well as everyday life teachings and learnings. We see it as being fundamental to sustainability education because it blends theory and practice and enables transformative engaged practice locally as a key source of learning.

Some background

The sciences increasingly show a nuanced, complex, living, relational world. For instance, Jenkins et al. (2018) show the integral connection between health, wellbeing, culture, and environments in Oceania. As another example, in their article *Sustainability Crises Are Crises of Relationship,* Milgin et al. (2020) describe the kinship ecology of Nyikina culture, whereby people live a reciprocal relationship with the Western Australian Kimberley Region's Martuwarra Fitzroy River. Similarly Redvers et al. (2020) show that Indigenous first laws are laws of the natural world, and these laws organise Indigenous tradition, values, and relationships.

One reason for the slow response to climate change in the Global North is that these relationships are unrecognised and overlooked in the 'everyday' of business-as-usual, whereas relational practices and protocols of respect need to be part of everything we do (Theriault et al., 2020). Indigenous researchers and research teams show the depth and meaning of these integral connections and active relationships. It seems that some people think 'knowing about' relationships is sufficient, but knowledge needs to be active, engaged, and practical for transformation to happen.

From this place-based perspective, regeneration is also to recover people and places from colonial forms of power that forces compliance (Poelina et al., 2020). It is to acknowledge stolen lands and to re-enliven traditional and local language and knowledge systems. It is to rekindle intergenerational resilience and to liberate all peoples towards re-Indigenisation with the Earth. In this way, regeneration is to recognise that everyone is Indigenous to the Earth, even if centuries or perhaps millennia ago, therefore everyone has the capacity to experience place-relationship on that basis. It is to understand and apply a participatory way of engaging together, with deep respect and care (Williams, 2018, 2021). Regenerative education is to learn anew, in response to developing regenerative relationships as the basis of ways of living. It is relational, cooperative, innovative, place-based, learning process-oriented, and multisensory (Poelina, Wooltorton, et al., 2020).

Regenerative sustainability is just one of the sustainability paradigms[3] to have emerged in recent years – each of which has value and validity in particular contexts. Regenerative sustainability is necessary to revitalise and rejuvenate systems, processes, and cultures. A business-as-usual framework which harmonises with modern economics, underpins the Sustainable Development Goals (SDGs). Elsewhere, concern has been expressed about SDG 8, Decent work and economic growth, as critics say economic growth is unsustainable (Sachs, 2017).[4] Business-as-usual economics is just one way of understanding ourselves in relation to places. Sadly, it has brought multiple extinctions (Díaz et al., 2019), pandemics (Tollefson, 2020), poverty of spirit (Pope Francis, 2015), continuing colonisation (Poelina, Brueckner, et al., 2020), and a devastating rich-poor divide (Sachs, 2017).

The world is changing rapidly. As we now know very well, climate change is no longer a threat: it is a reality (Norman et al., 2021). Our daily news programs broadcast stories of floods, mudslides, droughts, and fires (Hasham, 2018); shocking wars with global impact confront nations; and fierce storms drop volumes of rain never seen in living memory. In response, we need to learn to live anew. We need to learn how to behave as if we love places as our families, our communities, and each other. This uses a local knowledges perspective to refine regenerative sustainability (Poelina, Wooltorton, et al., 2020).

A regenerative sustainability paradigm influences the concepts, skills, and values we recognise in sustainability education. A global and local movement towards regeneration is already in place. For example, Mueller (2017) documents removals of dams in the United States and Norway, and festivals of renewal celebrate the homecoming of the salmon. Commenting on the release of a Biden administration report supporting dam removal on the lower Snake River, the chair of the White House Council on Environmental Quality said: "Business as usual will not restore salmon" (Geranios, 2022, p. 1). In other examples, the rewilding movement has been growing over the last three decades (Jepson, 2018; Rewilding Charter Working Group, 2020), and the Transitions Movement continues to grow in thousands of towns and cities around the world (Hopkins, 2016; Transition Network, n.d.) and young people everywhere are striking for climate action (Verlie, 2021; White et al., 2022). Coalitions, alliances, and collaborations everywhere – locally and globally – are working towards societal transformation, and connections between programs and movements are rapidly establishing.

Ancient and traditional knowledge systems

Indigenous peoples are showing ways forward, inviting the formation of coalitions of hope for regeneration (Poelina, 2019). For this to come into being, there is a necessary condition. This is the necessity for 'decolonising' society, which means reorganising modern socio-economic systems to remove power over decision-making structures because they (on everyone's behalf, with collective consent) often destroy beloved places and life-sustaining cultures (Williams, 2021). It means responding to histories and acting against continuing and extractive colonisation. Extractive colonisation is to perpetrate further colonisation against Indigenous peoples by taking control of Indigenous Lands without free, prior, and informed consent and mining, extracting from it or otherwise destroying it and/or its values (Poelina, Brueckner, et al., 2020).

Ancient knowledge systems, in which Land is a core value according to First Law (the law of the land), were once common all around the world, including Europe (Ghosh, 2021). These knowledge systems precede colonisation. The perspective that features vital, living landscapes is increasingly coming to be known as holistic science (Harding, 2006) and holistic health (Horwitz & Parkes, 2019). It is emerging in all disciplines including philosophy (Mathews, 2021) and is everyone's business. Ghosh (2021) asserts these vital, ancient knowledge systems form the North's 'repressed other'. This forms part of a regenerating story – all around the world – about deep reconnection, relatedness, and cherished, living places (Abram, 1996; Harding, 2006).

This is a boldly different story to the one that began with Newton and Descartes, which claims that only our thinking minds are important and our experiences, feelings, and imagination need relegating to the backroom (Mueller, 2017). Of course, that story is misleading, as it causes the separation of people from each other and our environments and the destruction of places and beings we love. It led to modernity and prioritising the interests of the economy – as if economy can feel, hear, and see. It cannot.

We suggest our task as learners, teachers, and leaders – wherever we are across the planet, whether we teach in a preschool or a university, or in any other context – is to heal broken place-connections everywhere and practise ways of hearing, seeing, and feeling to add richness, arts, and qualities to our lives. When done well, this is a powerful way of decolonising – or undoing colonial ways of thinking, working, and living (Williams, 2021) in that deepening place-relationship leads to care, engagement, gatherings, ceremonies, and protection of places. Healing relationships help us to restore and re-activate values that produce sustainability outcomes like resource conservation and biodiversity protection through learning to love and engage with places. Implicit in regenerative values is care and engaged practice. We return to the idea of decolonising later in the chapter.

Ecological family

A key concept in regenerative sustainability education is to recognise our home places as family (McMillen et al., 2020). We say ecological family to indicate the concept is greater than our human extended family, in the sense that we recognise local species such as birds who live alongside us as family members with whom we come to know, love, and relate, and they come to know, love, and relate with us. This needs a fuller description of Land than is usual in English and in the Western world where people see Land primarily as a resource for use. It is one in which the concept is inclusive of all relationships and interconnections within the Land. Some Australians refer to this fuller description of Land as 'Country'. Both terms are capitalised to denote inclusion of social, spiritual, and family-oriented values such as love, and these values come from and are nourished through the relations Land has with us and those that we have with Land.

The term more-than-human is another key concept because it is significant in recognising ecological family. Widely used since Abram (1996), it includes humans and relationships with and among species, rivers, mountain ranges, and beyond. The intention is to convey deep relationality, the way everything exists, because nothing can be alone. We use the term more-than-human because it is inclusive without 'othering'. Abram (1996) explained that modern technologies merely reflect humanity back to ourselves, causing us to forget our senses, sensualities, and abilities to perceive and respond to the textures, shapes, and sounds within more-than-human worlds of being. Yet our bodies respond to phenomena when we pay attention, when we intentionally notice.

Now we can say more about Land or Country. Bird Rose (1996) used the term 'nourishing terrain' to describe the notion of a living, active, caring place, as her Indigenous friends taught her. Each Indigenous nation has its own language, which describes nourishing terrain in its own words. For example, in Noongar language, the word is *Boodjar*, and in Nyikina language, the word is *Booroo*. These terms do not fully translate into English because they are inclusive of socio-ecological systems, relationships, and ideas about spirituality.

The idea of ecological family is a way of learning the value of Land and more-than-human worlds (McMillen et al., 2020). It derives from kincentric ecology whereby ecological systems are framed around kin relationships (Salmón, 2000) in which humans care for living systems as a way of life (McMillen et al., 2020). Put simply, ecological family comprises all our place relations. Ecological family is waiting for us to participate, to acknowledge kin relations, and to learn to respond. We are response-able, that is, we can respond in communicative ways too.

Learning pathways

We invite you to join our story making while we walk on a learning pathway and then walk to create your own story of learning with Country. Sandra and Mindy are walking with Noongar *Boodjar*, the Noongar nation in southwest Western Australia. Mindy is walking in Perth, Wadjuk *Boodjar*, while Sandra is in Bunbury, Wardandi *Boodjar*. Anne introduces a Nyikina ceremony in the Kimberley region of northwest Australia. Laurie is in the *Unamen Shipu* Romaine River in the Nitassinan region of Québec, Canada. In the vignette that follows, italicised words are Nyikina language. In her vignette, Anne shows how she welcomes two children to her ecological family of Martuwarra River Country.

Introduction to river

Jayida Boorroo Nyikina. Welcome to Nyikina Country. *Ngajanoo nilawal* Anne Poelina, *ngayoo Yimarmardoowarra marnin*.

My name is Anne Poelina. I am a woman who belongs to Mardoowarra Fitzroy River.

Jeanne and Flavie, young French-speaking girls, arrive. For them, I had come into their lives by inviting them all to come to Country. Soon we are talking and sharing, getting ready for cooking. We sit around the campfire and make plans for what the following day could bring. There is an important protocol. The family needs to be properly 'welcomed to Country'.

No sooner do we arrive then Jeanne and Flavie are out of the car and full of excitement to be in the space, constantly asking questions. I explain what we must do in order to be safe, as *Yoongoorookoo*, the Rainbow Serpent, is keen to get to know them too.

We begin to gather the bushes and we bring the special branch, *koongarra*. We walk along the bank of the billabong and see small freshwater crocodiles pretending not to see us. We gather the scented leaves to make the smoke. Once the fire is alight, we add the *koongarra* bush, and before long, the sacred fire is burning. I share with them it will not burn their eyes, and they move into the smoke. They open their eyes and walk through, excitedly commenting, "the smoke is magic"!

Down on the bank, I explain the order of activities to complete the ceremony. Jeanne and Flavie are looking for the right type of mud, dry pieces of clay, which they and their parents place under their armpits, so *Yoongoorookoo* can smell their scent and keep them safe. Calling out to *Yoongoorookoo*, each of them call their names, and all with deep respect throw their clay, a scented piece of themselves, into the water. They have shown respect, and the sacred serpent must reciprocate.

We drive to the picnic spot, passing Jarlmadangah, our sacred site, named by settlers as Mount Anderson. On the way, we pass families of different animals and finally arrive at our destination. We have a lovely day all swimming in the Martuwarra, sharing stories before returning to our community. That night we sit around the fire sharing stories of the day and learning more about family and their home country.

The finale is when Jeanne and Flavie recount their beautiful day swimming and picnicking in the river. Importantly they inform us, "because of the smoking ceremony the serpent keeps us safe". I share, one day they may come back to the Kimberley, as they are now 'Martuwarra Fairies'. I keep them in my heart and mind.

A film accompanies this story: please view https://vimeo.com/452252670/ea98c2f1d7

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Epilogue by Laurie Guimond, mother of Jeanne and Flavie.

After their special encounter with Martuwarra River and Country, Jeanne and Flavie returned to Turtle Island, Québec, Canada. They then spent time with *Unamen Shipu*, Romaine River, which flows through Nitassinan. Holding lands and waters in their hearts and minds, they introduced *Unamen Shipu* Romaine to her sister River Martuwarra and shared *liyan*[5] (wellbeing), shared lives, shared stories, shared hope, one water but many Rivers. Martuwarra Fairies, everyday teachers, singers, dancers, philosophers, and learners, call out for care, love, and justice to Home.

Please view the River's official presentations, introduced by Jeanne and Flavie here: https://vimeo.com/709831829?from=outro-local[6]

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In the vignette that follows, italicised words are Noongar language. Sandra shows how ecological families exist within everyday colonial worlds.

Walking to learn with ecological family

The roar of the recently redeveloped port proclaims itself as I arrive to the east of *Derbal Elaap*. The *derbal* (estuary) was renamed Leschenault Inlet around 150 years ago. Keen to revisit the waterway after an absence of several years, I walk 30 metres along a path. I feel overwhelmed by the shimmer emanating from the glassy water. It discloses a luminosity, a mirror surface reflecting the sky, while the slightly rippled water towards the west hosts a huge red sun setting over the regional city of Bunbury.

I sing out to *Ngangungudditj walgu,* hairy-faced snake, announcing my return and happiness to be here. I notice fish jumping. I feel welcomed, as if Derbal recognises me and celebrates my homecoming. *Wardang* the crow (bird), one of the two traditional Noongar moiety leaders of this Wardandi *Boodjar*, vociferously broadcasts his overseer role. I see two dolphins towards the west, silhouetted by the sunset. A white egret flies low and lands near a school of fish.

As I prepare to walk on the concrete paths around the inlet, I notice beside the road five beautiful tall, white-trunked, profusely flowering trees. I assume this was recently a replanting of saplings from elsewhere that people carefully and maybe lovingly selected.

This is *Derbal Elaap*, estuary of the *Wardandi* Noongar people. There are forever stories for this *Boodjar*, dreamings evolved over aeons. Noongar Elder Joe Northover tells how the *Ngangungudditj walgu* formed this estuary. After slithering down the Collie Hills forming what is now the Collie River, Bilya, he turned his big body around in the *Derbal*, before travelling back up river and dropping his people off at Minninup Pool, near Collie. (Northover, 2008)

I walk along the path, over a road bridge across the inlet where I notice *stilts* (birds) fishing in the rocks beside the bridge, directly under the noisy trucks and cars. I continue alongside riparian sedges, wild grasses, and casuarina trees onto a little jetty and into the luxuriant mangrove. I feel enclosed within the mangrove, surrounded by lushness, where plants of varying sizes encircle me – and watch what I do. I hear hoots, whistles, fish jumping, and a very slight zephyr touches my face. Noongar *Boodjar* is my home, my heartlands, my ecological family. Mangrove, dolphin, egret, and fish are my kin.

***

In Mindy's vignette, italicised words are Noongar language.

Walking to learn with children

I've been walking with *Derbarl Yerrigan* with a group of preschool-aged children and teachers for approximately a year. *Derbarl Yerrigan* is an important *bilya* (river) in Western Australia, running from the Darling Range down through metropolitan Perth towards its mouth at Fremantle, where it meets the Indian Ocean. In Noongar language *derbarl* means mixing (Nannup, 2008), and this naming is relevant because *Derbarl Yerrigan* is a permanently open estuary that changes from fresh water conditions in *Makuru* (winter), *Djilba* (first spring), and *Kamabarang* (second spring) to salty conditions in *Birak* (first summer), *Bunuru* (second summer), and *Djeran* (autumn). Similar to the rhythms of this *bilya* (river) system, as fresh and salt waters are always coming together and mixing, walking with *Derbarl Yerrigan* involves *bilya* (river) mixing with animals, plants, and children. These moments are important because connections are being made.

Today, *Derbarl Yerrigan* is a place where *Mali* (black swan) feed, *Djenark* (silver gull) nests, moonjellies (jellyfish) drift, dolphins play, and people boat, exercise, fish, and gather on the foreshore. *Derbarl Yerrigan* is a lively and significant part of the land where children are walking and learning with *bilya*. These water, plant, animal, and human mixings are one way for understanding the deep connections and relations of place.

Making connections

If you had been walking with us on that warmish *Djilba* morning you might have felt the cool wind blowing across your face, while noticing three preschool-aged girls on the foreshore, facing and waving out towards *Derbarl Yerrigan*.

"Hi *Djenark*. Good morning!"

"Hello *Derbarl Yerrigan* . . . hey, look . . . there . . . in *Derbarl Yerrigan*. I see something moving. I think it's moon jellies."

"Windy"

Mary squats down low to get a better look. Beside her, Susan is bending and reaching out towards *bilya* and places her hand gently on top of the surface. Quickly she pulls it back. Again, she reaches out towards the water, but this time submerging her entire hand down, under, in, and with *bilya*. She splashes . . . and pauses. Carefully and using both hands, she scoops *bilya*, bringing her cupped hands closer for a longer look. Slowly and with intention, she shows Mary.

"Is it alive?"

"Yes, it's moving."

"Be gentle"

"Oh, I think it might be a baby moonjelly".

"Do you think it has a mum?"

If you had kept walking with us, on that warmish *Djilba* morning, hearing and seeing how *Derbarl Yerrigan* and moonjellies make connections with the girls, you might have been distracted by the loud squawking of three *Djenark* (silver gulls) leaning forward, heads down, and heaving upwards towards the sky before turning towards *bilya*. Their screeching stops as they chase *bilya*, quick, quick, quick out and away they run; followed by quick, quick, quick in and back towards the foreshore. The girls watch and then begin following the movements of *Derbarl Yerrigan* and *Djenark*. If you had stayed with us, you would have seen connections being made between *bilya*, the girls, moonjellies, and *Djenark*.

Walking to learn: process

As we reflect on our stories, we notice that for each of us, water is relational, living, animate, active, and sentient. It is the source of life – even as we live in a modern world with cars, busy ports, noise, and distraction. Each of us acknowledges 'presence' in water and places; we interact and engage in subtle communication with our ecological families. We also notice children's responsivity and relationality to the more-than-human world, especially River.

Members of our author group are part of learning networks where participants use forms of cooperative learning to engage with, enhance, and teach familiarity with places. Cooperative methods can be collaborative with people and/or more-than-human worlds. For example, Kurio and Reason (2022) and Wooltorton et al. (2021) utilise and explain a formal process of cooperative inquiry to engage with rivers. Woodlands or parks are also good places to begin. Walking with place, it is important to remember the goal of being there to re-familiarise oneself with ecological family. It is about understanding their role in our lives and the values they bring, such as reciprocity and mutual care.

Bringing the learning together: integrating concepts, more-than-concepts, and skills

Cooperative ways of learning with responsive places and/or people can lead us towards post-conceptual or participative forms of knowing (Heron, 1996). That is, when considered together, experiential, creative, and conceptual knowledge includes and extends concepts, in that participative knowing embeds each through practice. Integrating and applying these place-based ways of knowing can help to recognise and respond to ecological family. Learning methods that build in more-than-human worlds through nurturing relationships are important because many people have forgotten them since childhood.

Relational learning practices such as walking-with place, offer skills – first steps – towards regenerative sustainability. For teachers, parents, and educators, this is Land-led and developed by students through their own response-abilities, relationships, and orientations to relationality and skills in watching, looking, seeing, feeling, and empathising in paying attention.

Decolonising practices

We mentioned earlier that healing place-relations is a way of decolonising, and walking is a de-colonial practice we advocate for this purpose. Structures of power in society that privilege human interests over more-than-human beings in this era of habitat and species loss is a colonising practice. It is a continuity of the colonial practices perpetrated against Australian landscapes since colonisation of the alliance of nations renamed Australia over 200 years ago. By noticing, coming to know, and communicating with more-than-human place-relations, we begin the journey of stepping out of patterns that reinforce a colonial (power-over) mind-set.

Almost every day in some nations such as Australia, there are stories of environmental or green crimes resulting in environmental destruction or agri-business developments such as water harvesting from the Murray Darling Basin which deprives ecosystems of survivability at multiple scales (Grafton et al., 2020; Poelina, Brueckner, et al., 2020). This societal violence is structural, that is, it happens in modern societies with our (possibly unwitting) participation. It can be painful to recognise our collusion in structural forms of colonial violence. On the other hand, we can reclaim, re-wild, and relearn to be in this world anew through responsive actions, in full knowledge of how collective power works. As schools, universities, communities, and organisations, and as humans, we can step out together to make change and link with alliances and coalitions forming to regenerate our world. The transformative learning ideas and practices we speak of are for personal-professional development with general applicability.

Discussion: regenerative values

A set of values that connect with active, engaged, practical, and relational learning sits behind this chapter. There are many ways of thinking about values, each of which connects to beliefs about what makes a good life, a good community, a good nation, and a good citizen. There are personal values and virtues, school values, organisational values, and national values. Sustainability and regenerative values are overarching values that hold national, community, and personal values together. In the introduction to their edited book on cultural sustainability, Meireis and Rippl (2018) alert readers to the profound implications for day-to-day societal routines of the concept of sustainability. They comment that the ways we understand prosperity, wellbeing, the good life, and the values we hold relate to our notions of sustainability. As we alluded to earlier in this chapter, there are business-as-usual sustainability paradigms, regenerative sustainability paradigms, and a range of sustainability paradigms between these two.

We learn new cultural lifeways and reprioritise values by regular practice. In our reflection on practice, we notice we are (already) part of living, feeling, storied places that hold memory: these are *already* relations, which are responsive. Indigenous knowledge systems embed and describe these wisdoms, which illustrates the high value we place on Indigenous and traditional knowledge keepers forming part of local curricula and decision-making at all schools, universities, communities, organisations, and corporations. These decolonising practices include truth-telling about local and regional places. Indigenous knowledge keepers tell us that Country is our heartlands; we need to love and care for ecological families, stories and full shared histories. To become *famil*iar with ecological *famil*y by relearning relationships, stories, and histories is of vital importance to sustainability education. This is within a regenerative sustainability paradigm. The context for learning is every day: in our classrooms; in our gardens; in our homes; by our waterways or wetlands; at our local sports grounds and parks; and in our communities, towns, and cities. We do not mean only in the future; we mean where we live today.

Conclusion

Regenerative sustainability education

Considering our vignettes and thinking together with new directions in sustainability literature, we define regenerative sustainability education as learning to recognise and practice relationships everywhere. We *already* live in layered worlds of relationships, and now it is time to participate in reciprocity and mutual care more deeply. We *already* live in a relational, participative world in our everyday, which we might be ignoring or overlooking. When we rush to the bus, do we regularly ignore a bird calling us with an important message? Pay attention – the messages we need to heed might be in our landscapes, in the wind touching our faces, in the excitement in our heart when seeing a whale, or in the whispering grasses near our feet. Regenerative sustainability education is re-learning how to live lives that matter to more-than-human beings with whom we are interdependent, that matter to our ancestors and our great grandchildren's futures, and that improve our shared wellbeing to enable a future worth aspiring to.

Regenerative sustainability is a holistic paradigm of life that is substantively different from the paradigm of modernity, which prioritises the interests of economy and sees Land as a resource for development rather an as a place for relationship, love, and life. Regenerative sustainability is underpinned by transformative action for healing people, places, and planet through co-creating regenerating communities based on cultures of reciprocal flourishing. The focus is on wellbeing, restoration, and revitalisation. In connection with this, regenerative sustainability education is regenerating our learning; recognising, retelling, and renewing local place-embedded stories and sets of knowledge that are ancient – everywhere in the world. It is to re-kindle the fire of life in innovative, creative, justice-oriented, active, and reflective ways. It functions to develop a new narrative, this time featuring commitment to love, care for, and heal relationships with each other and more-than-human beings in our common worlds. It is to understand, identify, call out, and stand against structural and colonial violence. It is to learn to see and value the wealth of life in our faces, communities, and landscapes and to support our places, stories, histories, and more-than-human families to return to life.

Notes

1 More-than-human is a term used by Abram (1996) to include humans, places, and all species within ecosystems.
2 This Handbook is available as a free download from ResearchGate.

3 A paradigm is a pattern of meanings or a worldview supportive of a methodology of science.
4 The point of this chapter is not to critique, but to illustrate and showcase regenerative sustainability.
5 *Liyan* is a Nyikina (Kimberley) word meaning wellbeing through connectedness, which Jeanne, Flavie, and Laurie learned on their Kimberley visit.
6 There are two films at this site with a pause between. They flow together.

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7.7
RISK AND RESILIENCE
Learnings from the blue economy

Sebastian Thomas

Key concepts for sustainability education

- Understanding risk means recognising the potential for unknown harms that arise from our actions and taking early, proactive decisions that limit or avoid these.
- The precautionary principle – meaning 'look before you leap' – is the appropriate and agreed approach to global environmental governance that should always be applied to minimise and manage risk in development.
- Resilience is neither positive nor negative, but a feature of many complex systems. For sustainability practitioners, resilience refers to the ability of a social-ecological system to anticipate, prepare for, resist, absorb and adapt to, and recover from both chronic stressors and occasional extreme events.
- A regenerative approach to the blue economy is needed to balance risk and opportunity and to support repair of planetary climate systems, ecological processes, and biodiversity.

Introduction

The Old Man and the Sea is a short novel written in 1951 by the great American writer Ernest Hemingway. It tells the story of Santiago, an old fisherman living in Cuba who has gone for 84 days without catching a fish. On the 85th day he decides to test his luck farther out to sea, and by midday has hooked something big, a fish he believes to be a marlin. Unwilling to risk the fish breaking the line should he tie it to the boat, Santiago holds it for two days and nights, giving slack as needed, reeling it in when he can. The fish tires slowly and on the third day begins to circle the boat. Santiago has slept very little but is finally able to kill the marlin with a harpoon. It is a huge animal and too large to lift into the skiff. Instead, Santiago ties it to the side of the boat and sails for home, taking another day to reach port. On the way he must defend the marlin from marauding sharks, killing several but eventually losing his harpoon and knife. At last the school of sharks closes in and consumes most of the flesh of the giant fish tied to the boat (Hemingway 1951).

The Old Man and the Sea is a simple but remarkable tale of risk, resilience, and human connection with the ocean. Santiago sails alone in a small skiff perhaps 4 or 5 metres long.

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He is experienced and skilful and knows the sea well, but also understands the dangers of the open ocean. The marlin he catches – and which he speaks to, often calling the fish 'brother' – is measured on his return to port at 18 feet (almost 6 metres) from head to tail. In the story Santiago hardly sleeps for three days, returns with nothing he can sell, yet succeeds in an extraordinary contest of strength and will.

This chapter explores the concepts of risk and resilience through the lens of the blue economy – the ocean frontier of social-ecological sustainability. These two principal ideas are discussed and defined, using Hemingway's text to illustrate key concepts; unless otherwise attributed, all quotes are from Hemingway (1951). The chapter then explores the blue economy, first considering the four great challenges to ocean health and thereafter examining the development trends and trajectories now facing marine environments. The chapter concludes by summarising the risks for and from future ocean development and considers how a resilience approach might contribute to a sustainable and just future blue economy. Understanding this topic will be vital for sustainability practitioners through the next decades of this pivotal century.

Understanding risk

In 1992 the United Nations Conference on Environment and Development was held in Rio de Janeiro, Brazil. The Declaration that resulted from the conference enshrined the 'precautionary principle' as an approach to environmental governance that should be applied by states according to their capabilities.

> Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.
>
> *(United Nations Conference on Environment and Development 1992)*

The precautionary principle is an old precept represented in traditional adages such as 'look before you leap,' 'better safe than sorry,' and 'prevention is better than cure.' Similar expressions appear in many languages and cultures, balanced by contrary concepts: 'he who hesitates is lost,' 'fortune favours the bold,' and 'live on the edge.' These contrasting ideas represent alternative approaches to decision-making, but since 1992 the precautionary principle has been agreed upon by the global community as the appropriate and preferred approach to environmental governance. Despite this, there is extensive evidence to suggest that as a global civilisation we have failed to act with precaution in response to the great challenges of climate change mitigation and adaptation, potentially undermining our own best interests in the long term (Huggel et al. 2022).

> 'I may not be as strong as I think,' the old man said. 'But I know many tricks and I have resolution.'

In 2019, for example, a global analysis of 226 coastal adaptation policies affecting 136 of the largest coastal port cities in 68 countries found that there was no evidence of policy implementation in half the cases, that planned adaptation actions were not driven by present or future climate impacts or risks in almost 85% of cases, and formal adaptation planning had mostly occurred recently and in developed countries (Olazabal et al. 2019).

This study relates to adaptation policies, governance approaches that are implemented to address the results of a problem – cure rather than prevention. It is then perhaps unsurprising that despite the extraordinary array of deeply concerning scientific evidence (Masson-Delmotte et al. 2021), we have failed to take a precautionary approach to climate change by implementing a transition away from fossil fuel energy and other unsustainable industrial and agricultural practices (United Nations Environment Program 2022). As a result, multiple climate hazards occur simultaneously and interact with non-climatic risks to create compounding overall impacts that cascade across sectors, demographics, and regions (United Nations Environment Program 2022; The Lancet 2022).

Risk means choosing a course of action when its outcomes are uncertain or unknown. Where risks are understood with increasingly high confidence, humanity must act with ever greater purpose and effect to reduce those risks. We must also build capacity to adapt to changes and keep social and ecological systems as strong as possible in the face of changing conditions and challenging impacts. This brings us to the concept of resilience.

Defining resilience

The concept of resilience comprises a range of meanings that can be understood differently in separate disciplines. In engineering, for example, resilience is often interpreted as the ability of systems to maintain their processes and functions despite novel stressors and changes in the system's variables and parameters. How effectively can infrastructure endure the effects of extreme events, of shocks – a bridge in a flood, an airport runway in a heatwave? In this sense, resilience means the ability to *resist*.

He rested sitting on the unstopped mast and sail and tried not to think but only to endure.

In ecology, resilience is often understood as the capacity of systems to maintain their functions in the context of environmental change. How well does a near-shore coral reef cope with increased amounts of chemical pollution in run-off water from local rivers? In this case, resilience is the ability to *adapt*.

The thousand times he had proved it meant nothing. Now he was proving it again. Each time was a new time and he never thought about the past when he was doing it.

In the field of disaster response, resilience can mean the ability of a system (a community or area) to return to its pre-disturbance state. How quickly can a community return to homes and jobs after a bushfire event? In other words, the ability to *recover*.

'They beat me, Manolin,' he said. 'They truly beat me.'
'He *didn't beat you. Not the fish.'*
'No. Truly. It was afterwards.'

Social-ecological resilience is a concept that integrates these different concepts of resistance, adaptation, and recovery. Social-ecological resilience is the ability of linked human and natural systems (see Chapter 3.6, Thomas, this volume) to absorb shocks and maintain functions, adapting to new conditions through processes of learning and self-organisation. Social and economic governance processes should operate in the same way that natural ecosystems do.

In the 2012 *Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*, an important new idea was introduced to resilience thinking. This shift in thinking was demonstrated in the Intergovernmental Panel on Climate Change's (IPCC's) definition of resilience as the 'ability of a system and its component parts to *anticipate*, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration, or improvement of its essential basic structures and functions' (Field et al. 2012). For the first time, resilience was explicitly understood as including an *anticipatory* capability.

For sustainability practitioners, **resilience can therefore be understood as the ability of a complex system to anticipate, prepare for, resist, absorb and adapt to, and recover from both chronic (long-term, ongoing) stressors and occasional, or episodic, extreme events.**

Resilience is not inherently positive or negative. Many undesirable phenomena are highly resilient, including domestic violence, institutional child abuse, drug addiction, racism, and gender inequality (Cadet 2016). For sustainability practitioners, understanding resilience in the context of complex systems allows us to identify interventions that might strengthen or weaken the system characteristics we want to address. For example, a coastal community might be vulnerable to storm surges and flooding in extreme events and be experiencing declining yields from near-shore fisheries. A resilience-focused solution might be to restore coastal mangrove forests as a buffer against storms and an improved spawning habitat for marine species.

Resilience thinking is relevant to economics and socio-technical transformation as much as climate adaptation (Geels 2002; Fulton 2021; Judson et al. 2020). In short, understanding resilience concepts facilitates effective change management.

The past 10,000 years and the next 100

During the last 10,000 years humans have established agriculture, built towns and cities, made technological and scientific innovations, explored new territories, engaged in sports and tourism, harnessed powerful energies, manipulated biological and genetic resources, and developed and exploited natural environmental assets of their terrestrial domains. All these activities that have occurred on land over the last 10 millennia will happen in the ocean within this century. Competition for ocean resources is intensifying as governments and the private sector look to the ocean as the next great economic frontier (M. Voyer et al. 2012).

Ocean industries have already had widespread, large-scale, cumulative impacts on ocean health, marine biodiversity, and livelihoods (Plagányi and Fulton 2017; Halpern et al. 2012; Doney et al. 2020). The expansion of economic activities in established fisheries, shipping, oil and gas, and military industries as well as emerging sectors of aquaculture, marine tourism, offshore renewable energy, deep sea mining, and bioprospecting for genetic resources is bringing new and complex threats to natural ecosystems and coastal communities (Arbo and Thủy 2016; Gentry et al. 2017). These threats will need to be addressed through expanded conservation areas, good governance, and perhaps even geoengineering (Talberg et al. 2018). As island nations succumb to sea level rise, it is entirely possible that new, large-scale living habitats will be established. The blue economy may quickly grow to include marine cities, whether floating and anchored, drifting or steered, or in the blue depths (Trebilco et al. 2022; Pungetti 2022).

In macroeconomic terms, **the blue economy therefore involves all aspects of national, regional, and global governance, economic development, security, environmental protection**

and sustainability, trade and transport, and international communication. The blue economy concept must integrate the objectives and targets of the Sustainable Development Goals with the concept of green growth – and must endure beyond the 2030 Agenda. This requires large-scale marine spatial planning and coordinated development between ecological, social, and economic systems across marine and coastal zones (Lu et al. 2019).

Ocean change: hot, sour, breathless, and clogged

The ocean is faced with four great environmental threats: warming, acidification, deoxygenation, and pollution. These are separate and linked in complex feedback patterns. These fundamental challenges to ocean health undermine the planet's capacity to sustain life and societies as we know them today.

As increased atmospheric greenhouse gas concentrations trap more and more solar radiation the Earth's energy imbalance grows, and more than 90% of this excess heat is absorbed by the ocean (Marti et al. 2022). ***Ocean heating*** is driving longer and more frequent marine heatwaves – from 1925 to 2016, global average marine heatwave frequency and duration increased by 34% and 17%, respectively, with a 54% increase in annual marine heatwave days overall (Oliver et al. 2018). The impacts of these marine heatwaves include coral bleaching and stress or collapse of other ecosystems.

For example, over a few months in late 2015 and early 2016, large areas of coastal mangrove wetland vegetation died along 1000 kilometres of the Gulf of Carpentaria in northern Australia (Duke et al. 2017). The dieback coincided with an extreme weather event of high temperatures and low rainfall and affected 7400 hectares, or 6%, of mangrove vegetation in the area. This occurred after an extensive period of severe drought conditions, unprecedented high temperatures, and a temporary drop in sea level (Duke et al. 2017). Similarly, Australia's Great Barrier Reef was affected by major marine heat events in 1998, 2002, 2006, 2016, 2017, 2020, and 2022 (Spady et al. 2022) with both direct and indirect negative effects on reef fish communities. Heatwaves can cause total reef fish biomass and abundance to decline by more than 50%, probably because fish move to cooler waters, but severely bleached reefs are found to lose 70–100% of coral larval supply and demonstrate impaired recovery following heat stress (Cheung et al. 2021; Magel et al. 2020). These impacts of ocean heating are cumulative and are changing the nature of marine ecosystems and reducing overall resilience over time. Coral reefs and other ocean habitats are becoming less diverse in terms of the species that are part of those ecosystems, and their ability to resist or recover from extreme events is in decline (Cheung et al. 2021; Hughes et al. 2018) (see Section 2 – Stevenson *et al.*; in this volume).

Ocean acidification is the second key challenge to ocean health and closely tied to ocean heating. The ocean absorbs heat from the atmosphere and is also a sink for atmospheric carbon dioxide. The more carbon dioxide that is dissolved in the ocean, the more difficult it becomes for marine animals like corals and shellfish to build their shells and skeletons (Fasham 2003). Since the beginning of the first industrial revolution, the pH of surface ocean waters has fallen by 0.1 pH units. This logarithmic change represents an increase in acidity of approximately 30%. Ocean acidification is proportional to the atmospheric concentration of carbon dioxide, and carbon dioxide absorbed at the surface diffuses down into the deep ocean. While this process takes decades and centuries, anthropogenic carbon dioxide absorbed by the ocean has already been detected at depths of nearly 1000 metres and is affecting deep sea ecosystems globally (Gruber 2011).

Ocean deoxygenation, or hypoxia, refers to water conditions where the concentration of oxygen is so low that very few organisms can survive. Some organisms can swim away from those conditions, and do, but sometimes they are trapped, so hypoxia events are associated with large-scale fish die-offs. Hypoxia can affect habitat through loss of benthic (seabed) fauna, which are important food sources for more mobile species. Organisms that are not as mobile such as shellfish and worms often suffocate and die in hypoxic conditions. Many crustaceans and fish species cannot tolerate low oxygen concentrations for extended periods, and very low concentrations are lethal for almost all complex organisms. Average ocean oxygen concentrations will remain viable, but in many regions they will decline enough to create 'dead zones' where life cannot survive (Gruber 2011).

These three stressors – ocean heating, acidification, and deoxygenation – operate at global scales with regional differences (Gruber 2011). Some regions will be affected by all three stressors, and thus likely to be hotspots for substantial biochemical change and ecological shifts. We can only speculate about the combined effects of these stressors, such as acidification-caused changes in the type and magnitude of organic matter export to the ocean's interior, which could then cause changes in the oxygen concentrations. However, this is also reason to look for synergies between responses to these threats and other planetary repair priorities, such as protecting marine areas and conserving or restoring biodiversity. Integrating policy responses to acidification and deoxygenation in particular can have particular impacts on biodiversity and local ocean health (Harrould-Kolieb 2021). Ocean heating, acidification, and deoxygenation operate over centuries, and once they have occurred the ocean will take centuries to recover, assuming the drivers of these impacts have been mitigated or removed (Gruber 2011).

There is, however, an additional threat to ocean health that must be considered when thinking about the blue economy. This is ***ocean pollution***, and as much as 90% of marine pollution is made up of different types of plastic (see Section 2 – Rumsa et al.; in this volume). More than 220 million tonnes of plastic are produced globally each year, and it is estimated that the volume of discarded plastics will outweigh the fish in our oceans by 2050. As far back as 2006, the United Nations Environment Programme estimated that every square mile of ocean contained 46,000 pieces of floating plastic. A single plastic bottle can last up to 450 years in the marine environment (Lebreton et al. 2018). Ocean plastic pollution is yet another threat to the health of marine biodiversity, and in turn, to humans. Microplastics have been found in the stomachs of countless marine species, in the deepest depths of the ocean, and even in human breast milk. Species that exist on Earth in millennia to come will have evolved to metabolise the plastics we create today.

The extent to which marine biodiversity and significant natural assets such as Australia's Great Barrier Reef will be able to resist, adapt to, and recover from ongoing stressors and episodic extreme events is uncertain. What is most likely is that ocean ecosystems will continue to degrade through the next decades and beyond until climate change impacts stabilise and allow remnant habitats and populations to re-establish as new ecological assemblages able to tolerate the changed conditions. This transition is already underway, and the large-scale loss of biologically diverse ecosystems is indicative of the further radical shifts still to come if global heating progresses beyond the 1.5° centigrade pre-industrial level (Hughes et al. 2018, 2019; Hoegh-Guldberg et al. 2007).

The impacts of ocean change on human communities are very real. Sea level rise, for instance, has been a threat to Pacific Island communities for many decades. In combination with higher sea levels, the increased frequency and severity of extreme storms, clearing of coastal mangrove forests, degradation of protective reefs, the building of poorly designed artificial structures in coastal areas, and complex systems of land tenure all increase the vulnerability of coastal communities. Attempts to protect villages through engineered solutions such as the construction of sea walls have been made since the 1970s and in most cases fail within decades or years. Salination of soils prevent food crops from growing and island communities are heavily dependent on these subsistence resources. Tides that encroach further inland every year take trees, areas of land and property, and the traditional burial grounds of local communities (Long 2018). Ironically, those Pacific communities who will be among the first to suffer the loss of their homes to sea level rise are migrating to places where they find work in the low-skilled, carbon-intensive, unsustainable industries that are driving the environmental changes that are, among other impacts, stealing the graves of their ancestors (Constable 2017; Yamada et al. 2017).

The ocean is becoming hot, sour, breathless, and clogged – these threats to ocean health present very real risks to the continuity of human social and economic activities that depend on the marine realm. Let us now consider the characteristics of the emerging blue economy and how it might evolve in coming decades.

The blue economy

The ocean covers around 70% of the Earth's surface but represents more than 98% of all living space on the planet. Four-fifths of all life exists in the ocean – a teaspoon of sea water can contain more than a million living organisms. Marine phylogenetic diversity is much higher than on land: 30% of all phyla are exclusively marine, whereas only one phylum is exclusively terrestrial. The ocean contains 97% of all water and produces more than half of the oxygen we breathe.

The ocean is similarly significant in social and economic terms. The global marine economy is valued at around US$1.5 trillion per year, 90% of global trade by volume is transported by sea, and 350 million jobs worldwide are linked to fisheries. The ocean provides the primary source of protein for 3.5 billion people, with aquaculture the fastest-growing food sector, currently providing about half of fish for human consumption. By 2025 it is estimated that 34% of crude oil production will come from offshore deep sea fields (Brears 2021; Spalding 2016).

The importance of the ocean as well as the threats it faces are reflected in Sustainable Development Goal 14 – 'Life below water.' SDG 14 includes seven targets that support conservation and sustainable use of marine resources for sustainable development. Yet the idea of the blue economy remains poorly defined, and very different priorities are revealed in the language used by diverse stakeholders – the ocean as an economic realm, business opportunity, natural capital, provider of livelihoods, climate engine, or innovation frontier (Michelle Voyer et al. 2018).

What should be fundamental to and shared by all definitions of the blue economy is that marine economic development should lead to improved human well-being, social justice, and equity and mitigate environmental risks while improving ecological conditions (Steven et al. 2019; Bennett et al. 2019). The World Bank and UNDESA (2017) define the blue economy as comprising the range of economic sectors and related policies that together determine whether the use of oceanic resources is sustainable. An important challenge of the blue economy is thus to understand and better manage the many aspects of oceanic sustainability, ranging from sustainable fisheries to ecosystem health to pollution.

The blue economy therefore involves exploration, development, and use of ocean resources in ways that protect and regenerate marine ecosystems and support sustainable livelihoods for ocean-dependent communities. The blue economy includes traditional marine industries (fisheries, tourism, fossil energy and mineral production, shipping, naval construction, and ports) as well as new and emerging industries including marine renewable energy, marine aquaculture, biological resources including pharmaceuticals and chemicals, nature-based climate solutions such as blue carbon, deep sea mining, and more. These emerging sectors are discussed briefly next.

As well as existing ***marine renewable energy*** applications such as offshore wind turbines, research frontiers in this field are in tidal and tidal current energy, wave energy, temperature- and salt-difference energies, design and improvement of triboelectric nanogenerators, and artificial reefs or islands. Countries such as the United Kingdom, the United States, Sweden, and Argentina are estimated to have some of the highest potential, with monthly wind power exceeding 800 terrawatt hours (TWh). Brazil and New Zealand are estimated to have extractable wave power output potential above 250 TWh per month (Weiss et al. 2018). Many other countries with ocean resources could generate above 300 TWh per month through wind and wave technologies, or a combination of these. For context, total electricity consumption in Australia from July 2021 to June 2022 was less than 200 TWh (Australian Energy Regulator 2022). While the extreme conditions of marine settings pose challenges for the durability of energy generation facilities, the development of energy conversion technologies bodes well for the future economic viability of ocean power (Hu et al. 2022; Weiss et al. 2018) (see Section 2 – Say; in this volume).

Global ***fisheries*** are currently being exploited well beyond sustainable levels, and many marine species are in crisis or facing extinction (Dulvy et al. 2021; Spijkers et al. 2018). There are, however, opportunities to improve fisheries management and productivity through ecosystem-based approaches, quotas, gear controls, spatial management, and better governance (Fulton 2021; Aburto-Oropeza et al. 2008; Fulton et al. 2014). ***Marine aquaculture*** represents an opportunity to build on the successes of coastal aquaculture in cultivating species like salmon, barramundi, tilapia, and perch through artificial breeding techniques and innovations in technology (Choudhary et al. 2021). Ocean farming of marine flora and fauna species (aquaculture and mariculture) is likely to provide more food resources than wild-capture fisheries within the next decade (Msangi and Batka 2015). The current total landings of all oceanic fisheries could be produced through marine aquaculture using less than 0.015% of the global ocean area (Gentry et al. 2017).

The economic potential of marine ***biological resources*** cannot be overstated, and opportunities exist in the areas of food and feed, biofuels, pharmaceuticals, bioplastics, and potentially carbon sequestration. Microalgal biomass is in high demand for food and feed ingredients, nutraceuticals, cosmetics, high-value chemicals, biofuels, and biomaterials, with global market revenue worth estimated at over US$850 billion by 2026 (Choudhary et al. 2021). The global market for carbon-neutral biofuels including biodiesel, biogas, bioethanol, and bio-hydrogen was valued at approximately US$4.7 billion in 2017 and is expected to generate revenue of almost 10 billion by the end of 2024, a compound annual growth rate of 8.6% from 2017 to 2024. Microalgae also produce biopolymers or bioplastics, which have useful applications in the medical, pharmaceutical, and food sectors as novel materials.

Macroalgae – or seaweeds – present multiple opportunities including as food additives (in yoghurts, jellies, ice creams, beers, and meat products), animal feed, soap and other hygiene products, and more (Choudhary et al. 2021). ***Seaweed farming*** has the advantages of fast growth cycles, low-level requirements in terms of capital and technology, and growth without fertilisers. Seaweed farming is thus an important environmentally friendly livelihood strategy with positive social and economic benefits for coastal communities in developing countries (Garcia-Vaquero et al. 2017). Ocean-based seaweed farming – mariculture – offers economies of scale and can reduce chemical pollution in coastal waters. There is also interest in large-scale oceanic macroalgae farming for carbon sequestration (Hill et al. 2015). This contributes positively to biodiversity and fast removal of atmospheric carbon dioxide, although carbon sequestration outcomes remain uncertain given the potential displacement of phytoplankton communities and impacts on benthic ecosystems. The legality of such activities is also unclear within the scope of international ocean treaties (Ross et al. 2022).

Mangrove forests, tidal saltmarshes, and seagrass meadows are coastal habitats with exceptional capacity to sequester and store carbon – often up to four times higher than mature tropical forests (Lovelock et al. 2014; Atwood et al. 2017). These ***blue carbon*** ecosystems are being rapidly degraded yet are considered an important and attractive opportunity for conservation and restoration initiatives that can be funded through international voluntary carbon markets (Friess et al. 2019; Thomas 2014). Blue carbon can be considered as a proxy for many other social and environmental benefits including reducing impacts of storm events and sea level rise, mitigating local acidification, and providing spawning habitat and refugia for many different species. Healthy blue carbon ecosystems can provide food, fuel, building materials, and livelihoods for communities – and the economic and climate change adaptation benefits provided by these ecosystems are important given that tens of millions of people in low-income coastal communities are highly vulnerable, particularly in Southeast Asia, Africa, and the Caribbean (Nunn and Mimura 1997; Harborne et al. 2006; Aburto-Oropeza et al. 2008; Nordlund et al. 2016).

The deep seabed (the ocean floor at depths greater than 200 metres) is the only area of our planet where there is yet no commercial extraction of mineral resources. The growing demand for the minerals and metals needed in renewable energy systems has led to keen government and private sector interest in ***mining the deep seabed***, where resources including copper, cobalt, nickel, zinc, silver, gold, lithium, vanadium, indium, and other rare earth elements are found together in commercially viable concentrations (L. A. Levin et al. 2020). These resources are found as nodules on abyssal plains at depths of 3,000–6,500 metres; ferromanganese crusts on seamounts between 800 and 2,500 metres and at hydrothermal vents near mid-ocean ridges (Miller et al. 2021; Levin et al. 2020). In areas such as the Clarion-Clipperton Fracture Zone in the north Pacific Ocean (covering approximately 4.5 million square kilometres), a commercial analysis found that extracting half of the available nodules would provide the manganese, nickel, cobalt, and copper to electrify a billion cars, while producing less than a third of the greenhouse gases that would result from terrestrial mining (Levin et al. 2020). There are, however, substantial risks and potential impacts on pelagic and bottom-dwelling biodiversity and marine ecosystem services. There are also concerns that commercial exploitation of deep sea resources would not result in equitable benefit sharing for present or future generations (Christiansen et al. 2020; Miller et al. 2021).

The sustainability of ***marine trade***, shipping, and tourism can be improved. Already 80% of global trade by volume and over 70% by value is carried by sea and moved through ports (Choudhary et al. 2021). Decarbonising shipping and expanding sustainable marine tourism could provide important sources of income. Marine tourism and even ocean urbanisation – floating or submerged cities – are increasingly discussed as infrastructure challenges and opportunities rather than science fiction (Dafforn et al. 2015). There are also immense opportunities for sustainable development that integrates diverse cultural traditions and perspectives, so that culture and sustainability become intertwined and distinctions between economic, social, and environmental dimensions of sustainability begin to disappear (Dessein et al. 2015).

Opportunity versus risk: the devil is in the deep blue sea

The ocean frontier is exciting in many ways, especially when the focus is on opportunity rather than risk. Considering the last 10,000 years of development and progress on land, however, a precautionary approach to blue growth and consideration of potential injustices and environmental harms that may occur without careful stewardship of development is needed.

Social injustices that could result from unconstrained growth in the blue economy include dispossession and displacement of communities through 'ocean grabbing' to secure resources; environmental justice issues related to pollution and waste; environmental degradation and damage to ecosystem services; negative livelihood impacts for artisanal fishers; loss of access to marine resources required for food security and well-being; the inequitable distribution of economic benefits; unintended social and cultural impacts; the marginalisation of women and other minority or disempowered groups; abuses of human and Indigenous rights; and exclusion from governance processes (Nathan James Bennett et al. 2021). Gender equity and agency for women are particularly critical to ensuring community welfare and genuine sustainable development; blue economy initiatives should address the needs and aspirations of local communities and involve women in their design, implementation, and governance (Nathan James Bennett et al. 2021; Arora-Jonsson et al. 2016; Mcleod et al. 2018; Thomas 2016; Thomas et al. 2018; Wabnitz et al. 2021; Rousseau et al. 2019).

Much existing blue economy rhetoric is relentlessly positive, arguing that market approaches to natural capital will ensure sustainable outcomes. There is, however, little evidence to date that financing of ocean health priorities has succeeded. It seems more likely that control of and access to marine resources is being driven toward large-scale, capital-intensive uses, with negative impacts on local communities and small-scale stakeholders (Barbesgaard 2018; Benjaminsen and Bryceson 2012). It is not evident that the necessary financial capital is being directed toward transformational solutions in the blue economy (Tirumala and Tiwari 2020; Shiiba et al. 2022), so that small-scale fishers and their allies are increasingly framing their objectives around food sovereignty or self-determination (Barbesgaard 2018). Blue carbon is an example of a nature-based solution that after more than a decade of extensive work by conservation organisations, governments, and the private sector shows few, if any, examples of commercially successful projects (Friess et al. 2022; Vanderklift et al. 2019).

The ocean is the newest frontier not only in energy and resources but in politics. The most powerful nation-states recognise the economic opportunity of marine resources but – perhaps even more so – the strategic military and political advantages of ocean power. Consider former US President Barack Obama's 'Pacific Pivot,' the Pacific Island Countries' 'Blue Pacific Strategy,' and China's 'Maritime Belt and Road' initiative. The global ocean 'seascape' is very active, increasingly contested, highly dynamic, and a context in which environmental degradation, social marginalisation and injustice, and political and commercial conflicts are occurring from local to global scales (Bennett 2019).

Territorial conflicts that reflect competition for different resources already occur in many parts of the global ocean – the South China Sea, the Arctic, the Indian Ocean, the Southern Ocean (Spijkers et al. 2018; Abhinandan 2019). These conflicts are likely to change and grow as climate change and the threats to ocean health discussed earlier drive geographic shifts in the distribution of marine animals (Spijkers et al. 2018; Pinsky et al. 2018). The ocean does not recognise national borders or other political boundaries (Poloczanska et al. 2013).

In response to these different challenges the United Nations Environment Programme's Finance Initiative (UNEP FI) has developed a set of principles for a sustainable blue economy. These are that the blue economy should be:

1. Protective – supporting activities that restore and protect the diversity, productivity, resilience, core functions, value, and health of marine ecosystems and the communities dependent on them.
2. Compliant – supporting activities compliant with international, regional, and national frameworks which underpin sustainable development and ocean health.
3. Risk-aware – investment, decision-making processes, and activities to address potential risks, cumulative impacts, and opportunities.
4. Systemic – identifying systemic and cumulative impacts of investments, activities, and projects across value chains.
5. Inclusive – including, supporting, and enhancing local livelihoods and effective engagement with relevant stakeholders.
6. Cooperative – working with financial institutions and relevant stakeholders to promote and implement these principles.
7. Transparent – making information available on investments, banking, and insurance activities and projects and their social, environmental, and economic impacts, both positive and negative.
8. Purposeful – directing finance to projects and activities that contribute directly to the achievement of SDG 14 and good ocean governance.
9. Impactful – investments, projects, and activities that go beyond the avoidance of harm to provide social, environmental, and economic benefits.
10. Precautionary – activities that have assessed environmental and social risks and impacts using sound scientific evidence.
11. Diversified – investment, banking, and insurance instruments to reach a wider range of sustainable development projects in traditional and non-traditional maritime sectors, and in small and large-scale projects.
12. Solution-driven – driving innovative commercial solutions to maritime issues (both land- and ocean-based), that have a positive impact on marine ecosystems and ocean-dependent livelihoods.
13. Partnering – engaging public, private, and nongovernment sector entities to accelerate progress towards a sustainable blue economy, including through coastal and marine spatial planning approaches.
14. Science-led – applying knowledge and data on the potential risks and impacts associated with financial activities and opportunities in the blue economy.

The full principles are available at https://www.unepfi.org/blue-finance/the-principles/.

A resilient and regenerative blue future

The ocean is the most significant component of the Earth's system. The ecosystem goods and services provided by the ocean – its contributions to human economic prosperity, cultural identities, and fundamental well-being – are critically important. Yet marine environments are in crisis, facing systemic threats that are growing and compounding. A *regenerative* blue economy – not just a new economic frontier – is necessary to support climate change mitigation, adaptation, and repair of planetary climate systems, ecological processes, and biodiversity (Cisneros-Montemayor et al. 2021; Fath et al. 2019) (see Prologue; Section 2 – Stevenson *et al.*; Section 3 – Thomas; in this volume). We must implement development processes that rebuild and enhance ecological health and diversity as well as social well-being.

As the blue economy expands in coming decades and the marine industrial revolution proceeds, genuine sustainable development and human well-being will only be achieved if the negative social and environmental impacts of earlier development pathways are avoided – and this is entirely possible (Fulton 2021; Golden et al. 2017). It is vital that justice and equity, power and politics, knowledge and narratives, culture, scale, and history are all central to thinking about blue growth and blue futures (Bennett 2019; Contreras and Thomas 2019; Vierros 2017).

A resilience approach to the blue economy will include anticipatory thinking – how we prepare for the expected effects of a changing climate, the impacts of pollution and resource depletion, and the economic and political contests that will continue to develop (see Section 3 – Thomas; in this volume). Understanding the risks of inaction and continuing unsustainable resource extraction, instead choosing restorative and regenerative approaches to ecosystem-based adaptation and economic development, will support habitat restoration and improved biodiversity, better public health outcomes, recreation and tourism opportunities, and greater carbon sequestration and air quality (Wamsler et al. 2016).

> *But who knows? Maybe today. Every day is a new day. It is better to be lucky. But I would rather be exact. Then when luck comes you are ready.*

This is how we must define and pursue the blue economy of the future. The alternative is to pursue unconstrained extractive development that will inevitably lead to political conflicts, social injustice, environmental degradation, and ecological collapse. It is vital that sustainability students and practitioners understand the importance of the ocean and blue economy for future sustainable development and the necessary understandings of risk and resilience in securing that sustainable future.

Conclusion

Recognising the risks, we must proactively choose restorative policies and governance approaches as fundamental to a transformational rather than simply expansive blue economy (Cisneros-Montemayor et al. 2019, 2021). Despite all the challenges we face in the ocean frontier, and despite what has been lost and what will continue to change, we must take bold steps to ensure the blue economy of the future is just, equitable, and environmentally regenerative. The risk of allowing ocean health to continue to decline is too great.

> *What I will do if he decides to go down, I don't know. What I'll do if he sounds and dies I don't know. But I'll do something. There are plenty of things I can do.*

Our relationship with the ocean is fundamental and critical, so we must choose to do what must be done to ensure long-term ocean health and the resilience of communities. This means applying the precautionary principle in decision-making, thereby seeking to minimise and manage risk in development. The risks are well understood, and there are clear pathways to create resilient environmental, social, and economic ocean systems. A regenerative blue economy requires that we establish resilience as a key principle of social-ecological governance ambitions and processes. We must heed the advice of *The Old Man and the Sea*:

> *Aloud he said, 'I wish I had the boy.'*
>
> *But you haven't got the boy, he thought. You have only yourself and you had better work back to the last line now, and cut it away and hook up the two reserve coils.*
>
> *So he did it.*

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SECTION 8

Ethics, values and governance

"Scientists may depict the problems that will affect the environment based on available evidence, but their solution is not the responsibility of scientists but of society as a whole".
(Mario Molina. Cited in Physics Today, 74 (2), 60, 2021)

Section 8 explores the essential role of ethics, values, and governance education in establishing a clear understanding of our sustainability responsibilities in the Anthropocene. This section reviews the changing nature of sustainability ethics, values, and governance across the globe and their important role in modern education in helping to develop an understanding of the overarching structures of responsibility and accountability that will be essential in delivering the Sustainable Development Goals. This section also investigates ethics and values in sustainability education and discusses their important role as fundamental tenets of sustainability education.

Ethics and values are critical elements in sustainability education. Ethics are typically thought of as sets of rules or moral principles that are established by a group or culture that govern the behaviour of an individual, whereas values are the beliefs held by an individual that influence their behaviour. Ethics and values are important in decision making, where ethics help determine what is morally right, and values help determine what is important.

They are therefore important constructs in guiding sustainability thinking and decision making. Ethical thinking gives students of sustainability a sense of right or wrong, just or unjust, fair or unfair practices, and helps them to understand what an ethical person should do, their obligations, and what should be considered fair, not just for individuals but for all of society or for the planet. On the other hand, values tend to influence the emotional state of mind of an individual, which then influences an individual to behave in a particular manner. Core values set the priorities for our lives and influence the choices we make.

> Ultimately the behaviour of entire societies towards the biosphere must be transformed if the achievement of conservation objectives is to be assured. A new ethic, embracing plants and animals as well as people, is required for human societies to live in harmony with the natural world on which they depend for survival and wellbeing.

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> The long-term task of environmental education is to foster or reinforce attitudes and behaviour compatible with this new ethic.
>
> *(IUCN-UNEP-WWF 1980)*

Lundqvist and de Fine Licht (see Chapter 8.1 in this volume) note that education for sustainable development (ESD) should promote thinking and action that reflect sustainability values and can assist the changing of prevailing norms towards sustainability-focused outcomes. Education in ethical decision making is an important agent in assisting the development of sustainability management thinking and outcomes. Students need to be aware of values, norms, and normative theories and how to apply them, particularly in relation to sustainable development. Students should also receive insights into their own sustainability norms and values and understand them relative to the sustainability norms and values of society.

Tormey (see Chapter 8.2 in this volume) suggests that ethics education should educate students (and professionals) in responsible decision making, which also reflects the needs of wider society and the environment. Whilst ethical codes, norms, and standards do help guide ethical decision making, students need to be instructed in moral reasoning, moral sensitivity, and empathy in order to assist ethical decision making. Tormey notes that students need to be taught to recognize ethical issues when they arise (ethical sensitivity), to make good decisions (ethical judgement), to care enough to follow through (ethical motivation), and to be able to work within their environment to achieve their goals (ethical agency).

Wilson and John (see Chapter 8.3 in this volume) recommend that leadership and governance for the public good are critical framing concepts in sustainability education. Leadership and governance for public good examines the role of leadership and governance in protecting public goods (often referred to as social goods or collective goods) in society, including the rights to a clean environment, protection of local ecology and biodiversity, and even the right to ensure management of CO_2 to ensure global warming limits can be managed. Sustainability leadership and governance are needed to ensure that public goods are provided and managed in a sustainable way and private, institutional, and political management work together to support public-good provision and protection.

Governance is an increasingly important part of sustainable development in terms of governments, companies, and individuals being held to account for their sustainability management responsibilities. It is the accountability and transparency of our current and future actions in terms of sustainable development that result in good governance practice becoming an important part of sustainability management education.

Sustainability governance is about how organisations direct and steer their management and performance towards sustainability outcomes and improved sustainability performance. It is increasingly embedded in corporate social responsibility (CSR) management where 'governance' structures that direct management efforts towards sustainability outcomes that can also be held to account are seen as important.

Tanimoto (see Chapter 8.4 in this volume) suggests that CSR involves businesses conducting their activities such that there is a focus on all stakeholders through due care of both environmental and social impacts. There are many new models of CSR, including standards and norms focusing on social responsibility guidelines, sustainability reporting, and stakeholder engagement. The focus of CSR is to integrate sustainability into management processes and strategy and contribute to the community through core business and philanthropic activities. Modern sustainability (business) education should include the norms and values being developed around CSR and be able to articulate their value in helping to achieve the SDGs and sustainability outcomes more generally.

Transnational decision making poses challenges in the achievement of the SDGs and, in particular, has tested global governance models in climate change and international trade. Brohmer (see Chapter 8.5 in this volume) suggests that sustainability education should provide an understanding of the role of transnational decision-making frameworks in sustainable development education, given the critical role of international governance in solving resource issues (like water access and fishing boundaries) together with climate change.

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8.1
EDUCATION FOR SUSTAINABLE DEVELOPMENT AND THE NEED FOR EDUCATION IN ETHICS

Ulrika Lundqvist and Karl de Fine Licht

Key concepts for sustainability education

- Education for sustainable development should result in professionals and citizens who are motivated to act according to the values of sustainable development and who can contribute to the change of prevailing norms to assist development towards sustainability.
- Ethics in education can to some extent support the social dimensions of sustainable development.
- Students should *know* about values, norms, normative theories, and tools and be able to see when these are applicable in their daily life and then be able to *apply* them correctly.
- An important part of the learning in ethics education is that students should get insights in their *own* norms and values, while in education for sustainable development, it is important that students get insights into the norms and values of *society*.

Introduction

The aim for education for sustainable development is to educate students to become professionals and citizens who have insights and are motivated to act according to these values and who can contribute to the change of prevailing norms for a development towards sustainability. Thus, education for sustainable development requires competencies in ethics, both for students and teachers. Sustainable development is a societal goal based on certain values such as the "Brundtland definition", which says that "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987). Insights and competencies in ethics are necessary not just for the long-term goals for sustainable development but for all kinds of interactions with people and society also in the short-term. For example, a code of conducts for engineers includes norms on how to behave in their interaction with colleagues, customers, public, etc. Therefore, it can be argued that ethics is a subject that should be included in all education.

At Chalmers University of Technology in Sweden, a policy to integrate environmental aspects in all engineering and architecture educations goes back to the 1980s. This

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policy was later broadened to sustainable development and changed to a requirement for content corresponding to a full-time five-week-long course (Holmberg et al. 2012). More recently, there was a requirement to also include ethics across all disciplinary education, which can support the development of social goals in sustainable development. The strategy at Chalmers was from the start to not have a separate education focusing of environment and sustainable development, but to integrate it within all education (Lundqvist 2016). Architects and engineers in all domains should have competencies in sustainable development since all domains can have an impact on and contribute to sustainable development.

The integration of sustainable development and later also ethics across all educations at Chalmers University of Technology has resulted in extensive experience and insights and has provided many good examples of how this can be done (Holmberg et al. 2012; Lundqvist 2016). The purpose of this chapter is to share these experience and insights and to describe and reflect upon how ethics and sustainable development can be integrated in education programs in an effective way.

In educations that will result in a professional degree, such as engineering, architecture, economics, medicine, etc., it is preferable that ethics and sustainable development are integrated as discipline specific ethics education (Harris et al. 1997; Herkert 2002). Ethics and sustainable development should be taught in context and should include content that is relevant for the profession and can enhance motivation and support deep learning (Hanning et al. 2012).

Even though domain-specific integration of ethics and sustainable development is preferable, its development can be challenging. Teachers who have their main competence in the discipline of the program should preferably do the teaching in ethics and sustainable development, in which, however, they may not have a solid background. This could then jeopardize the quality of the ethics and sustainable development education provided. The alternative is to bring in a professional educator in ethics and sustainable development, but his might defeat the purpose since the students might come to think that ethics and sustainable development are irrelevant or additional non-core subjects, since their usual teachers do not provide this themselves. Therefore, this chapter suggests that there is an important need for teachers in general to learn about ethics and sustainable development and how to integrate them in a relevant and effective way in their courses.

The aim of this chapter is to give support and inspiration to teachers on the integration of ethics and sustainable development in education programs and teaching courses. The structure for *constructive alignment* (Biggs and Tang 2007) is used to describe and reflect upon how ethics and sustainable development can be integrated into education development in an effective way, with the aim to support students to gain relevant and deep learning. The first step in constructive alignment is to formulate *intended learning outcomes*, followed by the design of *teaching and learning situations* that should support this learning, and finally the design of the *assessment* that should evaluate how well the students fulfil the learning outcomes.

Intended learning outcomes

Examples of learning outcomes for ethics and sustainable development can be found in the Swedish national degree ordinance for a five-year-long master of science in engineering degree (Swedish Ministry of Education 2006). It can be noted that both ethics and sustainable development should be strongly connected to the specific domain of the program. According to the learning outcomes, the students who graduate should demonstrate:

- the ability to develop and design products, processes, and systems while taking into account the circumstances and needs of individuals and the targets for economically, socially and ecologically sustainable development set by the community;
- the ability to make judgements informed by relevant disciplinary, social, and ethical aspects as well as awareness of ethical aspects of research and development work;
- insight into the possibilities and limitations of technology, its role in society, and the responsibility of the individual for how it is used, including both social and economic aspects and also environmental and occupational health and safety considerations.

The intended learning outcomes for an education describe the competencies that the students must have to get their degree (Biggs and Tang 2007). The courses in their education should then contribute to this intended learning by supporting a progression in learning through the education. This could, for instance, be that the students must have knowledge about certain norms, values, ethical theories, and general approaches when it comes to dealing with issues of ethics and sustainable development (Segalàs et al. 2009).

The learning outcomes should (at least) include the competencies that are required for the degree, according to some certificate or some national requirements, such as the Swedish national degree ordinance in the example earlier. Ethics or sustainable development may not be included in such requirements but can be added at the initiative of a university, education manager, or teacher with the aim to contribute to a general, as well as specific learning, among citizens and professionals in society. Certificates and requirements for specific degrees evolve over time, and one possible driving force for change can be universities that choose to be proactive and include local requirements that go beyond the existing ones that they must follow. It can even be considered a responsibility of a university to act as a change agent towards such a development to contribute to a transformation towards sustainable development. Chalmers University of Technology chose to introduce a requirement for the integration of sustainable development before there was a requirement in the Swedish national degree ordinance (Holmberg et al. 2012).

One way to divide different types of competencies that should be aimed for includes knowledge, skills, and attitudes (Baartman and de Bruijn 2011). We might think that students at least need to *know* about values, norms, normative theories, and tools, but that they preferably also need to be able to see when these are applicable in their working life, be able to *apply* them in these cases correctly, and they also need to think that getting these things right is *important*. In the example from the Swedish national degree ordinance, the students should be able to "*develop* and *design* products, processes and systems" and "*make judgements*". Of course, sustainable development and ethics cannot be the only things which are important, for example, for an engineer, but they should think that these things are important, nevertheless. For example, it is important that the new algorithm I produce for the justice system does not impact the court proceedings unfairly. However, this does not mean that I should not also think about how to make it work as a tool and as a product on which I can make a profit.

Another dimension for competencies is the depth of learning, which can be described by a taxonomy such as Bloom's (Bloom et al. 1956) or the Structure of Observed Learning Outcomes (SOLO) (Biggs and Tang 2007), which both are taxonomies for the cognitive domain. In line with constructive alignment, the intended learning outcomes should include active verbs for what the students should be able to do after the completion of a course. The motives for using active verbs are that such verbs better describe: the intended depth of learning, the expectations for what the students should be able to do in the assessment, and thus also what needs to be practiced in the teaching and learning situations. Some examples of active verbs in this context are that the students should be able to *describe* some normative theories (knowledge) and *apply* normative theories to *analyse* a case from different moral perspectives (skill) and *explain* why some acts are right and others are wrong. In the example from the Swedish national degree ordinance, it can be noticed that these learning outcomes are quite demanding, not at least "the ability to *make judgements* informed by relevant disciplinary, social and ethical aspects".

A question that is much discussed is to what extent the learning outcomes should require a change of the students' norms and values, i.e., their attitudes. A strong but common opinion is that education should be value neutral or value free and not force any opinions upon the students, and instead focusing on making them conscious decisions through knowledge and skilled through methods and tools. However, the 'attitude competency' is connected to norms and values and can be described as "a capacity that exists in a person that leads to behavior that meets the job demands which brings in desired results beyond knowledge and skill". Sustainable development is furthermore a value-laden and deeply normative concept (for example, UN 2015), where there can be an expected ambition to foster good for citizens.

For example, in many business schools today, future economists are educated in ethics because it has been found that economists only thinking about maximizing profits (i.e., Friedman thinking) which can lead to suboptimal results at a societal level. This because such moods of thinking and acting more easily produce social and ethical dilemmas like the 'tragedy of the commons'. Here, when everyone acts in their own self-interest, they produce worse results than if they would have acted on more altruistic motives that would have provided more value for more people instead. In the example from the Swedish national degree ordinance, it can be also noted that it is explicit that the normative societal goals for sustainable development should be aimed towards learning outcomes that are *not* value neutral. The third learning outcome, which is a learning outcome for attitudes, require that the students should "demonstrate insight into . . . the responsibility of the individual for how it [technology] is used, including both social and economic aspects and also environmental and occupational health and safety considerations".

In addition, it should be noted that no (or almost no) educational effort is, strictly speaking, 'value free'. When we educate students in science or the humanities, we often try to imbue them with certain values or norms, for example, based on good research practice, or what a good theory is, etc. For example, a goal (a value) when it comes to physics is not only to produce theories which can withstand rigorous testing. We also want theories that are simple, graceful, and have a high degree of explanatory power. There is also a wide variety of norms we try to teach students such as how to behave in a lab, how to write a paper, and what it is to cheat and instil in them the values that they should not cheat. However, there are many norms and values we regularly try to teach students, but sustainable development and ethics are relatively new topics to education.

There are also notable differences between education for sustainable development and education in ethics when it comes to norms and values. This difference can be noticed in their formulation: the aim of education *for* sustainable development is not just to support the development of competences *in* a subject but also to contribute to a change in society *towards* sustainable development. Therefore, one part of education for sustainable development is focused on a normative goal even though there can be variations in how sustainable development is defined. However, the UN Sustainable Development Goals are currently the most prevailing definition (UN 2015). Education *in* ethics lacks this normative focus and is therefore more like other subjects in education in the way that the aim is to support the development of certain learning competencies. An important part of learning in ethics education can be that students should get insight into their *own* norms and values, and in education for sustainable development that the students get insight into the norms and values of *society*.

Teaching and learning situations

Teaching and learning situations in a course should support the fulfilment of the intended learning outcomes, and students should get opportunities to practise these competencies (Biggs and Tang 2007). Practice together with feedback is a good combination to support students' learning and to make sure that they are on the right track. Additionally, motivation is maybe an even more important factor to enhance learning (Deci et al. 1991).

One way to motivate students in this domain is to demonstrate the relevance of ethics and sustainable development to their profession and future career. An effective way to do this can be to integrate ethics and sustainable development formally into course programs. For example, design for recycling and responsible design can be included in product development courses (Enelund et al. 2013) and gender equality in courses in ergonomics in mechanical engineering education. Other examples are personal integrity, i.e., privacy, that can be included in courses on security and big data in information technology, and environmental risk assessment for emissions of substances in chemistry education. Additionally, the teaching can include cases from the profession that can be used, for example, to show how it can go wrong or how a judgement was made. Sometimes in ethics education one can see extreme examples of cases including those involving whistle blowers and attracted large media attention. One such famous example is the scandal in 2015 when Volkswagen had intentionally programmed some of their diesel engines to produce up to 40 times less nitrogen oxide emissions during laboratory tests compared to real-world driving testing with the purpose to be able to sell these cars in the United States (Hotten 2015). It is valuable to include such examples in teaching, but it is perhaps favourable to focus on cases that are less extraordinary and more like situations that students will more likely encounter in their professional lives (Harris et al. 1997; Lynch and Kline 2000), which is in line with the insights given by Tormey see Chapter 8.2 in this volume).

In the example from Sweden on the MSc in engineering degree, one of the requirements is to have "the ability to make *judgements* informed by relevant disciplinary, social and *ethical aspects*". One part of this requirement is to have knowledge on any ethical considerations. There are many examples of professional codes of conduct that often includes a variety of ethical considerations, such as loyalty towards different actors, safety aspects, and environmental issues, which should be considered in connection to different actors that one can encounter in a profession, such as employers, colleagues, customers, and the public (Doig and Wilson 1998). Such codes of conduct can then be used in practice exercises in the teaching of ethical considerations. However, it can be challenging to use codes of conduct for guiding judgements on decision making in real-life scenarios. There is a wide range of norms and values which might differ from context to context. In addition, we also have a wide range of normative theories which are not always that straightforward to apply. As a result, there is no single algorithm to give us the right answer when it comes to what we should do to produce an ethically viable result or to achieve sustainable development goals. There are, however, decision-making tools that can be used when trying to come to make ethical decisions. These are not algorithms for producing perfectly ethical decisions either, but they can often be of much help if the student and teacher are knowledgeable on the expected norms, values, and normative theories that are relevant to the decision at hand. To make judgements to decide on actions, especially in more complex situations, it can be useful to use a well-structured framework such as the ethical cycle (Poel and Royakkers 2007). Such a framework gives the student an opportunity to apply knowledge, practise skills, and get critical insights into their own attitudes (i.e., norms and values), which is also an important component in ethical competencies.

The ethical cycle (Poel and Royakkers 2007) is an example of a systematic tool for decision support. It has been developed by philosophers at Delft University of Technology with the purpose to be used in education to support engineering students to approach moral problems in a structured way. However, the tool can fulfil a broader purpose than just in education and can be a valuable asset for professional application also. The ethical cycle is mainly useful when the moral problem in a specific situation involves many stakeholders and is complex to solve given that there is no obvious answer for how one should act. An advantage is that the tool includes a broad analysis to cover many important aspects or perspectives that help result in a well-founded decision for the decision maker that should be able to stand up to and present transparent moral arguments and reasoning. The five phases in the ethical cycle are:

1. *Moral problem statement*: in which the problem is clearly stated and the actors who have to act are identified.
2. *Problem analysis*: in which stakeholders and their interests and conflicting values are identified, as well as facts that are relevant and important but may be uncertain and missing.
3. *Options for action*: in which not just black-and-white strategies are identified but also more creative middle-way strategies.
4. *Ethical evaluation*: in which the options for action are assessed from different moral perspectives (i.e., norms and values) with the support of normative theories.
5. *Reflection*: which should result in a final decision for how one should act in the specific situation and in which the relevance of different moral perspectives for the specific situation is critically reflected upon.

The value of the ethical cycle framework in comparison with other decision support tools in ethical decision making is that the ethical cycle involves more fundamental normative theories and a broader array of relevant norms and values. Therefore, when using the ethical cycle, we might examine what the different norms are according to the company we work for as well as the more refined normative theories such as utilitarianism and Kantianism. This results in potentially a more legitimate and reliable review of ethical responsibilities since we have examined a broader array of contextual norms and values.

As mentioned before, it can be quite demanding to gain the required competencies in ethics and sustainable development in just one course or part of a course. To support a progression in learning, ethics and sustainable development are preferably integrated in several courses in a program (Hanning et al. 2012). Experience has shown that a three-step approach can be beneficial: 1) introduction, 2) teaching, and 3) application (Lundqvist and Svanström 2016). In the first step, ethics and sustainable development are introduced early in a program together with an introduction to the profession, with the aim to enhance motivation by showing the relevance of ethics and sustainable development in the future career of the students. In the second step, the students gain knowledge about ethics and sustainable development in general as well as more domain-specific knowledge and tools and methods that can be used in this context. In the last step, this knowledge is applied in preferably several courses within the domain for the program as well as in BSc and MSc theses when relevant.

Assessment

A summative assessment has the purpose to assess how well the students fulfil the intended learning outcomes of a course and should be designed so that the students can demonstrate the abilities gained (Biggs and Tang 2007). In ethics education, a reflective essay can be used to fulfil this purpose or an argumentative text where students must take a stand on an issue. A challenge here may be to convince the students that the assessment does not assess *their norms and values*, but their knowledge, skills, and their insights about their own attitudes (i.e., norms and values) and other norms, values, and normative theories relevant to the case they are set to analyse. This can be done by clearly communicating how well the *argument* is formed that is then assessed and not the *results* of the argument itself. Examples of assessment criteria can be that the students should show that they have knowledge about ethical considerations and how these can be valued differently, depending on perspective, and that an opinion is based on facts as well as values and a distinction is made between these. An example can be an argumentative text about nuclear power. An argument for nuclear power is that it can be used instead of fossil fuels and in this way reduce climate change pressures, but an argument against nuclear power is the production of associated radioactive waste. A student can get a pass result independent of whether he or she is arguing for or against nuclear power, but the text must include arguments based on the values associated with the potential negative consequences of climate change compared to nuclear waste, as in utilitarianism, and based on norms on how one should act such as the precautionary principle, as in deontological ethics.

As we have reflected upon earlier, there is a notable difference between education for sustainable development and ethics education that also has a large impact on the assessments chosen. For both there is a value-neutral assessment of the students' competencies, for example, concerning how well they can explain moral theories or sustainability principles and how well they can apply these in a decision support tool such as the ethical cycle or in life cycle assessment. In ethics education, a teacher can encourage and expect that students take a stand for their own opinions, and if the students use the tools in an appropriate way and have well-founded arguments, they can get an approved mark from the teacher independent of the opinions that they have expressed. However, in education for sustainable development, students are usually not expected to argue against the norms and values in society for sustainable development, but here the assessment is instead focused on the knowledge of the societal norms and values and the ability to apply this knowledge, for example, in decision support tools.

Conclusion

Education for sustainable development should result in professionals and citizens who are motivated to act according to the values of sustainable development and who can contribute to the change of prevailing norms to assist development towards sustainability. Thus, education for sustainable development requires competencies in ethics. Ethics and sustainable development should be taught in context and should include content that is relevant for the profession, which can enhance motivation and support deep learning for the students. This chapter therefore suggests that there is an important need for teachers in general to learn about ethics and sustainable development and how to integrate them in a relevant and effective way in their courses.

The structure for constructive alignment can be a useful and effective support for teachers in their planning and development of education in ethics and for sustainable development to reach good quality. The formulation of intended learning outcomes for courses and programs is the necessary and important first step since learning situations and assessments should be aligned with these. Teachers and universities can be proactive to make sure that competencies in ethics and for sustainable development that are relevant for the students in their daily lives as citizens and in their professions are included and explicit in learning outcomes. The learning outcomes should include competencies for *knowledge,* such as about values and norms, and for *skills* such as to apply normative theories and tools. The learning outcomes should also include competencies for *attitudes*, but here there is a notable difference between education for sustainable development and education in ethics. An important part of the learning in ethics education is that the students should get insight into their own norms and values, whereas in education for sustainable development the students should get insights into the norms and values of society.

Teaching and learning situations should support students' deep and long-lasting learning of the intended learning outcomes. Examples and cases similar to situations that the students will likely encounter in their lives and careers can show the relevance and enhance motivation. To make judgements to decide on actions, especially in more complex situations, it can be useful to use a well-structured framework such as the ethical cycle that can give the students an opportunity to apply knowledge, practice skills, and get critical insights into their own attitudes (i.e., norms and values), which is also an important component in ethical competencies. To support a progression in learning, ethics and sustainable development are preferably integrated in several courses in a program, and experience has shown that a three-step approach can be beneficial: 1) introduction, 2) teaching, and 3) application.

In ethics education, the assessment can be in the form of a reflective essay or an argumentative text where students must take a stand on an issue. A challenge here may be to convince the students that the assessment does not assess their own norms and values, but their knowledge, skills, and insights. This can be done by clearly communicating that it is how well the argument is formed that is going to be assessed and not the results of the argument itself. The differences between education for sustainable development and ethics education also have a large impact on the assessments chosen. In ethics education, a teacher can expect that students take a stand for their own opinions, while in education for sustainable development, students are usually not expected to argue against the norms and values for sustainable development in society.

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8.2
TEACHING ETHICAL DECISION MAKING TO STUDENTS AS 21ST-CENTURY PROFESSIONALS

Roland Tormey

Key concepts for sustainability education

- University education needs to teach students to take responsibility for the judgements they will make when working as professionals.
- Ethical behaviour results from the interplay between cognitive and emotional factors, and as a consequence, both need to be addressed in ethics education.
- Students need to learn to experience and regulate empathy and other moral emotions including anger, guilt, awe, embarrassment, and gratitude.
- Educational strategies that include having students actively work through dilemmas, engaging them in perspective taking, and doing empathy work appear to be more successful than more traditional means of teaching.
- The impact of ethics education may be effectively negated if the wider culture in the students' education tells them that ethics is somebody else's problem.

Introduction

The process of working towards sustainable development is one which deeply implicates the work of members of professions and, consequently, the education of professionals. Sustainability challenges are frequently 'knowledge' problems – ones which emerge from how professionals work, and ones which will only be solved by the application of the kinds of specialist knowledge which is the prerogative of university-educated professionals. While United Nations Educational, Scientific and Cultural Organization (UNESCO) has noted, for example, that each and every one of the Sustainable Development Goals requires solutions which are rooted in science, technology and engineering (2021, 58), sustainable development solutions also require specialist knowledge and skills in other domains including law, finance, economics, taxation, education, psychology, and public policy.

Although the term 'professional' is used in everyday speech in ways that encompass everything from professional footballers to medicine, and while the term has long been debated in the sociology of work (see, for example, Freidson 2001), in this chapter the term is used to refer to occupations that have a high degree of specialised knowledge and skill

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which is acquired through long periods of study and which is typically used in complex and uncertain circumstances that require a high degree of judgement. The specialist nature of professional knowledge and judgement typically means that assessment of the quality of professional work can often only be undertaken by other members of the profession. One feature of this claim to control over certain knowledge and skills is that it can be hard for non-professionals to successfully question the judgement of professionals, except in extreme cases. Because it can be hard to hold professions and professionals accountable for their judgements, one of the features of professions and professional education in universities has been that professionals are generally expected to be guided in their actions by a concern for the wider good: as Aileen Pierce has noted: "At the core of professionalism is the claim to subordinate or, at least moderate, self-interest in service of the public interest" (2006, 7; see also O'Flaherty and Doyle, 2014). Although this idea has long been part of the claim to professional status, it is one which has been identified as being increasingly relevant in the context of the contemporary challenges of sustainable development: as UNESCO's 2021 report on 'Engineering for Sustainable Development' identifies, for example, engineering solutions to sustainability challenges "consist not only of technological means, they are also accompanied by ethical codes, norms and standards to ensure that engineering practices are conducted responsibly" (2021, 58). The focus of this chapter is on how university lecturers and professors can educate professionals to maximise the likelihood that, when given the choice, they will take responsible decisions that reflect the needs of wider society and of our environment.

This chapter addresses three questions. First, what should be the goals of ethics education? While it may seem obvious that the goal is that people behave ethically, the understanding of the social and psychological processes that contribute to ethical behaviour continues to develop and hence so does our understanding of how education can affect this (this issue is also addressed in the Chapter 8.1 by Lundqvist and de Fine Licht in this volume). Second, what should be the methods of ethics education? While there are lots of creative suggestions as to how ethics can be taught and learned, these may or may not align with the goals of ethics education, and only some are actually backed up with evidence. Third, how does ethics education relate to the wider field of professional education within which it operates? Put simply, can ethics education make a difference if the rest of professional education is telling learners that ethics is not their problem? Many of the examples presented in this chapter are drawn from the engineering profession. Nonetheless, the points made typically apply to professional education more widely.

What is professional ethics education, and what are its goals?

Discussions on ethics frequently begin with offering some definition of the term. Ibo Van de Poel and Lambèr Royakkers's popular engineering ethics textbook (2011, 71), for example, offers a definition of 'ethics' as "the systematic reflection on morality", where morality is defined as "the totality of opinions, decisions, and actions with which people express what they think is good or right". Similar sentiments are found in ethics education in other professions (see Muriel Bebeau [2002] on ethics education in dentistry, law, and medical professions, or Joanne O'Flaherty and Elaine Doyle's work [Doyle and O'Flaherty 2013; O'Flaherty and Doyle 2014] on ethics education with, respectively, teachers and taxation professionals, for example). As awareness of sustainability challenges has risen since the 1990s, it has become increasingly accepted that sustainability questions, addressing both social and environmental concerns, are a fundamental part of professional ethics (see, for example, Wareham and Elefsiniotis 1996; Van der Poel and Royakkers, 2011). Reference to sustainability as a core value is now also a common part of professionals' ethical codes. For example, the Association of Computing Machinery (ACM) code is typical of many in its statement that "computing professionals should promote environmental sustainability both locally and globally" (ACM 2018).

These definitions see ethics education as being about a process; ethics is not so much about learning the right decision to make as learning how to make good decisions. Secondly they see ethics as a cognitive activity – the goal is to think through and evaluate moral decisions (rather than to do the right thing because it 'feels right', for example). Insofar as there is an action dimension to ethics, it arises from being able to study and reflect upon moral issues. In this formulation, 'right thinking' leads to 'right acting'. This is evident, for example, in the goals articulated by Charles Fledderman (2014, 11) in his engineering ethics textbook:

> The goal . . . is to sensitise you to important ethical issues before you have to confront them. . . . Moral autonomy is the ability to think critically and independently about moral issues and to apply this moral thinking to situations that arise in the course of professional engineering practice. The goal . . . is to foster the moral autonomy of future engineers.

This idea that the goal of ethical education is to foster moral autonomy that allows people to make up their own mind as to what is right and to then take action accordingly is deeply entrenched in Western rationalist cultural views about human nature which sees humans, at their best, as individuals whose moral actions derive from rational thinking (Haidt 2001; Solomon, 2008). This idea was influential for much of the 20th century in psychological studies of moral development, notably in the work of Lawrence Kohlberg, who "dominated the agenda of morality research [in psychology] for decades" (Rest et al. 2000, 382). Kohlberg's research led him to identify a number of different developmental stages through which children pass as they become adults and develop a 'mature' approach to thinking about moral issues. Kohlberg identified six stages which are generally recast as three *levels* (see for example, Kohlberg 1973), or as three *schemas* (Rest et al. 1999, 2000):

- *The pre-conventional level* is typically associated with younger children (although Kohlberg argued that all three levels can also be found in older children and adults). At this level, decisions as to how to respond to ethical questions are decided based on the risk of punishment or the possibility of reward for the decision-maker. The essential question at this level of moral reasoning is 'How does this affect me?'
- *The conventional level* is typically associated with adolescents who are now becoming aware of society beyond the narrow confines of their family. Decisions at this level are based on adherence to the rules, norms, and conventions (hence the name 'conventional' level) of their family, group, or nation. The essential question at this level is 'What is the rule?'
- *The post-conventional level* is typically associated with adults and, in particular, with highly moral adults. Decisions at this level are based on an attempt to articulate a moral value or principle which has some universal validity beyond the person's social group or context. This level is also referred to as the 'principled' or 'autonomous' level. The essential question at this level is 'What is the just thing to do?'

In the Kohlbergian worldview, the goal of ethics education is to move people towards post-conventional moral reasoning; for example, the term 'autonomous', used to describe the post-conventional level, is the same term used by Fledderman (2014) in the quote earlier to describe the goal of ethics education in a professional context. This illustrates Kohlberg's belief that philosophy and psychology were essentially pointing in the same direction; what philosophers saw as being the best form of moral reasoning was, for Kohlberg confirmed by his psychological research: "the philosopher's *justification* of a higher stage of moral reasoning maps into the psychologist's *explanation* of movement to that stage, and vice versa" (1973, 633, italics in the original).

Later researchers who followed in the tradition of Kohlberg, including James Rest, Darcia Narvàez, Muriel Bebeau, and Steve Thoma, adapted his stage and level model somewhat into what is referred to as a neo-Kohlbergian approach (Rest et al. 1999, 2000). Linked to this shift was the development of a pencil and paper psychometric test called the Defining Issues Test (DIT) which continues to be widely used to assess levels of moral reasoning (Rest et al. 1999) (and which will be returned to in later sections).

The linking of moral reasoning to sustainability decisions is perhaps less straightforward than might be assumed. While it might seem obvious that we would want people to autonomously apply universal principles about the greater good to sustainability decisions, much of the work on how people think about and learn about environmental sustainability has developed without substantial reference to the Kohlbergian tradition, which was the mainstream psychological framework for moral judgement for most of the late 20th century (Karpiak and Baril 2008). Nonetheless, there is evidence that post-conventional moral reasoning is linked to pro-environmental attitudes (Karpiak and Baril 2008).

There does also appear to be evidence that moral reasoning, as measured by the DIT, is linked to pro-social behaviours (See Doyle and O'Flaherty 2013 for a review). However, it has become apparent from empirical research over the last few decades that 'high' levels of moral reasoning is not sufficient to predict moral behaviour. This led those in the neo-Kohlbergian tradition to argue that Kohlberg's focus on cognition was insufficient and that ethics education needed to focus more widely on four integrated abilities if it is to give rise to effective moral functioning (see Narvàrez and Rest 1995; Bebeau et al. 1999; Bebeau 2002). This approach, generally referred to as the 'four-component model' identifies that in order to act ethically a person needs:

- *Moral sensitivity*, that is, the person needs first to recognise that an ethical situation exists. This involves being able to be aware of others who may be affected by a decision and to be able to recognise and interpret their feelings. This requires emotional empathy and cognitive perspective taking. Moral sensitivity is also partially based on professional knowledge – an engineer who understands how to effectively assess the risks to the public or to the environment arising from a product or process they design is in a better position to recognise potential ethical questions than one who does not.
- *Moral judgement*, which is the outcome of a process of moral reasoning and which requires an ability to identify relevant values or principles and to apply them to a situation in order to come to judgement. This is the component that was previously emphasised by Kohlberg and mainstream philosophy as being central to moral behaviour but is now, in the four-component model, seen as necessary but insufficient on its own.
- *Moral motivation*, which is the ability to prioritise moral values over other values such as career, personal pleasure, and institutional loyalties. The neo-Kohlbergians argued

that there are times when someone is aware that there is a moral issue and has come to a judgement as to what is the right thing to do, but yet does not do the right thing because it doesn't matter that much to them. Bebeau (2002) has argued that a deeply internalised sense of professional identity which is framed around a code or standards of ethics is a key component of developing moral motivation in professional ethics. Stefan Pfattheicher, Claudia Sassenrath, and Simon Schindler (2016) have also found that the emotion of compassion plays a role in motivating people to act in pro-environmental ways.
- *Moral character* (or *moral agency*), which refers to the ability to have the courage of one's convictions, to persist and to overcome obstacles which make it difficult to follow through on a moral judgement. For the neo-Kohlbergians this is typically framed in terms of individualistic psychological features (ego-strength), though a more situated understanding of human action would tend to reframe 'moral character' as 'moral agency' and identify that 'agency' needs to be understood as being as much a product of a person's social and organisational setting at a given time as it is a function of psychological features (see for example Biesta et al. 2015 on agency in the teaching profession).

A central idea of the four-component model is that fostering cognitive moral judgement alone is not likely to make a lot of difference to a professional's ethical behaviour. Rest and his colleagues (e.g. Bebeau et al. 1999) have argued that the four components should not be understood as being linear stages in a moral action decision, but rather the four interact with each other in producing moral behaviour. Hence, ethics education requires the fostering of all four processes of morality more or less simultaneously. This wider focus on developing abilities beyond autonomous ethical reasoning is evident, for example, in the goals identified by Van der Poel and Royakkers (2011, 2) in their popular engineering ethics textbook, which include moral sensibility (i.e. sensitivity), moral analysis skills, moral creativity, moral judgement, moral decision-making skills, and moral argumentation.

One of the important features of the four component model is that – in contrast to earlier approaches – it highlights that ethical behaviour results not from cognition alone, but from the interplay between cognitive and emotional or affective factors. Although Kohlberg's own work has been described as a sustained attack on what he saw as irrational emotive theories of moral development (Haidt 2001), a powerful counterpoint was developed by Carol Gilligan (1982) who argued that the rationalism at the heart of the Kohlberg model was linked to its individualism and that his prioritising of cold and rational moral judgements reflected a predominantly (although not exclusively) masculine way of thinking. Analysing examples of moral judgement interviews with children, she identified that whereas boys often made moral judgements through constructing a hierarchy of values and rules which might be thought to apply, girls more often focused on relationships and considered the problem in terms of how the social network as a whole should respond. Gilligan's work was influential in launching an idea of a feminist 'ethics of care' (see, for example, Nell Noddings 1988, 2012), an approach which grounded moral judgements not in the application of abstract principles, but rather in understanding the vulnerability of other people and the situated relationships within which people interact. The ethics of care approach has been described as providing "compelling foundations for environmental ethics" (Powys White and Cuomo 2017, 235). This idea has had more impact on some professions than others: its application in engineering, for example, has been limited (e.g. Pantazidou and Nair 1999; Riley et al. 2009), and 30 years after Gilligan's work was published, a care ethics approach to engineering ethics was described by Van der Poel and Royakkers (2011, 103) as being "still in its infancy". In professions like education, where human relationships are seen as a more central part of the professional identity, care ethics has been more influential (e.g., Noddings 1988, 2012; and see Tormey [2021] for a review on 'care' in higher education).

The recognition of the importance of empathy which is found in the neo-Kohlbergian four-component model reflects not only the relational critiques of feminist critics but also the work of social psychologists which focused on the role of emotional empathy in pro-social behaviour (see for example, C. Daniel Batson et al. 1981, 1988, 1997; Martin Hoffman 1989, 2000, 2008). Like the term 'professional', the term 'empathy' is one which is widely and often imprecisely used. The term is used, for example, to refer to the (cognitive) skill of being able to imagine what it is like to be in someone else's position (also referred to as perspective taking) and also used to refer to emotional experiences such as the distress which a person feels when faced with the distress of another person (emotional empathy or distress at another's distress) (Batson 2009; Hess and Fila 2016), as well as the related but distinct emotion of compassion (Haidt 2003). Emotional empathy was defined by Hoffman as "an emotional state triggered by another's emotional state or situation, in which one feels what the other feels or would normally be expected to feel in his [sic.] situation" (2008, 440). Hoffman highlights that empathetic distress, in particular, was found to be associated with pro-social or helping behaviour, but also that empathetic distress was not always associated with positive moral outcomes. The limits to the moral power of empathetic distress arise because people tend to empathise with those who are similar to themselves as well as with those who are present to them in the here-and-now. These features of empathy can limit people's pro-social responses to those who are different from them as well as those who are geographically distant. Furthermore, when empathetic distress becomes overwhelming, people may also focus more on their own feelings of distress than on the person with whom they are empathising (termed 'empathetic overarousal') (similar issues with disengagement may arise with eco-anxiety [Stanley et al. 2021]). This has important implications for moral education in that helping people learn to engage in perspective taking (in order to generate empathy as appropriate for those who are socially or physically distant from them) and facilitating them in learning to regulate emotion become identified as important elements of moral education.

This work on the role of emotions in moral reasoning has been further developed in the last two decades, focusing on a wider range of emotions beyond emotional empathy. Building on the work of the philosopher Martha Nussbaum (2001), for example, Sabine Roeser (2010, 2012) has argued that a wide range of emotions play an important role in making professionals aware of risk, "rather than being biases that threaten objectivity and rationality in thinking about acceptable risks, emotions contribute to a correct understanding of the moral acceptability of a hazard" (2012, 107). As in earlier periods, this philosophical work parallels empirical work in social and human sciences. The social psychologist Jonathan Haidt (2001, 2003, 2012), for example, has proposed that a wide range of 'moral emotions' (Haidt 2003) – anger, guilt, awe, distress at another's distress, embarrassment, and gratitude, to name but a few – play a role in shaping a person's response to moral issues, including environmental issues. Jonas Rees, Sabine Klug, and Sabastian Bamberg (2015), for example, have found that framing environmental damage in a way that makes human causes explicit led to greater reports of guilt in respondents and was, in turn, associated with spontaneous displays of pro-environmental actions, while Samantha Stanley and colleagues have found eco-anger to be associated with pro-environmental personal behaviour (Stanley et al. 2021). While Roeser sees emotions primarily as providing information which can be processed cognitively in coming to moral judgements, for Haidt moral judgements are typically emotionally driven. This is not to suggest that cognitive reasoning cannot play a part in moral judgement (Greene and Haidt 2002; Haidt 2003), but rather to argue that the influence of emotions in judgement is much more pervasive than simply providing insight which can be cognitively processed (see Jennifer Lerner, Ye Li, Piercarlo Valdesolo, and Karim Kassam [2015] for a wider review of the relationships between emotion and cognition in decision making).

Overall, then, what can meaningfully be said about the goals of professional ethics education? In the late 20th century a cognitive, rationalist, and individualist perspective largely dominated thinking on moral reasoning, and this was, (and to some extent still is), reflected in the goals of professionals ethics education. This is reflected in a focus on developing the knowledge and cognitive skills to be able to take rational and autonomous moral decisions. Over the last 20 years there has been an increasing focus on supplementing the focus on moral reasoning, with wider concern for other components of moral action such as ethical sensitivity, ethical motivation, ethical agency, and ethical imagination.

This begs the question as to what kinds of education methods can help to develop these kinds of attributes. This is the question to which we turn in the next section.

Ethics education methods

As Diana Martin, Eddie Conlon, and Brian Bowe (2021a) have noted, if the goals of professional ethics education have become somewhat fragmented, the same is true for the methods used to teach ethics to professionals. A range of different methods have been identified as being characteristic of ethics education including dilemmas, case studies, lectures, roleplaying and perspective-taking activities, news-story analysis, discussion and debates, watching films and videos, service learning, and field trips (see, for example, Justin Hess and Grant Fore 2018; Martin et al. 2021a). Indeed, the fragmentation and diversification of both goals and methods mean that there is a risk that teaching methods and teaching goals become misaligned, as teachers end up inadvertently using materials and approaches which were actually designed to achieve goals which do not match those of their class (Keefer et al. 2014). This section will describe some of the most commonly identified methods used in ethics education, the goals that they are aimed to address, and what evidence exists – if any – regarding their effectiveness.

Ethics lectures

As Marilla Svinicki and Wilbert Mckeachie (2014) have noted, the lecture is probably the oldest teaching method and remains the method most widely used in universities worldwide. It would therefore be surprising if lecturing was not widely used in professional ethics teaching. They identify that lectures are particularly useful for summarising information when an appropriate textbook does not exist, at adapting material to the interests and prior knowledge of a particular group of students, and at providing a structure and conceptual framework for students. While lectures can play a useful role in education, their value is perhaps over-emphasised within the culture of universities as a whole (Tormey and Isaac 2021, 127). At a minimum, there is good evidence that students, on average, perform better when they are required to actively process information and that, as such, interactive teaching gives rise to increased average attainment (see for example, Freeman et al. 2014) and to reduced inequalities between traditional and non-traditional students (Theobald et al. 2020) when compared to more traditional lecture formats. The economics of higher education and professional education, and the capacity of the lecture to target a large number of students with minimal human resources, means that the lecture is likely to stay with us for some time to come. Indeed, the restoration of traditional teaching approaches after the COVID pandemic has probably shown just how resilient the lecture format is within the culture of higher education. So the issue becomes how lectures can best be organised to ensure student learning.

In ethics education, the evidence suggests that lectures can contribute something to learning. Although in the 1980s Andre Schlaefli, James Rest, and Steve Thoma (1985) identified that the 'academic course' format was amongst the least effective in increasing students' scores on the DIT measure of moral reasoning, more recent evidence provides a slightly more positive picture of the lecture format, with a meta-analysis by Logan Watts and colleagues of 66 empirical studies of ethics instruction showing that lectures gave rise to better learning outcomes than service learning, book reviews, or essays and to similar levels of attainment as group discussions, role-plays, and self-reflection activities (Watts et al. 2017, 376). In line with the broader evidence on active learning, Watts et al. found that active training approaches generally gave rise to higher measures of learning than more passive approaches and that lectures were in general less effective than case-based methods (see also Antes et al. 2009; Waples et al. 2009). Specifically in the context of environmental learning, Judith van de Wetering et al. (2022) have also carried out a meta-analysis combining results from 169 studies. They found that traditional classes had a strong, positive impact on environmental learning and that the effect was not significantly different from that of less traditional forms of teaching (such as camps, field trips or investigation-based teaching).

Case studies

While lectures are pervasive in higher education in general, in ethics education, case studies are often identified as being the pedagogy of choice. In engineering ethics, for example, Hess and Fore (2018) found that case studies were among the most commonly used teaching methods, and it has been suggested that "there is widespread agreement that the best way to teach professional ethics is by using cases" (Harris et al. 1996, 94).

The key characteristics of case studies have been defined as (1) being based on real-life or realistic situations which allow students to vicariously face professional challenges, (2) they present contextual and technical information, and (3) they may have no simple solution in order to encourage students to engage in depth and develop different perspectives (Merseth 1994; Martin et al. 2021b). In professional education, case studies are generally identified as having first been introduced in legal education in Harvard in the late 1800s and were widely used in legal education by the early 1900s. The method spread to business education at around this time (Merseth 1991), before being later adopted in other professional domains including medical, business, teacher, and engineering education. There are, in fact, multiple approaches to case studies that differ in important respects:

- Case histories or case reports are typically based on real-life events and generally include both the context and the outcome of the case. This kind of case is very common in engineering education, which often focuses on disaster cases such as the *Columbia* and *Challenger* space shuttle explosions, the 1984 gas leak at the Union Carbide plant in

Bhopal, the Ford Pinto design scandal, the crash of ValuJet flight 592, and others. While case histories allow students to apply propositional knowledge to complex situations and also allow them to learn from mistakes, they often do not really provide much scope for perspective-taking and argument-building because the solution is often already clear to the students (i.e. most students identify quite quickly that blowing up the space shuttle or causing a plane crash is not good).

- Case problems are distinct from case histories in that they present an open-ended account of a problem without outcomes or resolution. In a teacher education setting, for example, case studies may involve a vignette of a teacher struggling with a particular challenge. Learners may work in groups to discuss and understand the case and to apply relevant theoretical perspectives and research evidence to proposing solutions. In a variant on this approach (the interrupted case method), students can be provided with additional information on the case as their discussion progresses, which may lead them to re-evaluate their initial assumptions and perspectives (this description is based on O'Flaherty and McGarr 2014).

Beyond the difference between case histories and case reports, case studies can differ in many other respects also, including whether the focus is on individual-level decisions (micro-cases) or on broad-based societal effects of the actions of the profession as a whole (macro-cases); whether the case is factual or fictional; if factual, whether or not the case is well known ('big news'); whether it is presented as historical or in the present tense; its length; the richness and embeddedness of the case; and the role of the student in the case development (see Martin et al. 2021b; Hess and Fore 2018).

Case-based instruction has been found to be effective as a component of ethics teaching. A number of meta-analyses of ethics instruction in both science and business, for example, have found that case-based learning has larger positive effects than many other teaching approaches (Antes et al. 2009; Waples et al. 2009; Watts et al. 2017). The meta-analysis by Logan Watts and colleagues (2017), for example, found that programmes which included a stronger focus on case-based instruction also tended to have above-average impact on ethics learning. In particular, they noted that longer cases seem to have more impact than shorter, that those with moderate complexity have more impact than both simple and complex cases, and cases with low to moderate realism have more impact than realistic cases which may involve highly emotive content such as multiple deaths. This is an important finding given the extent to which realistic cases of big news stories (e.g. case studies of *Columbia* and *Challenger* space shuttle explosions in engineering ethics) are ubiquitous in many ethics textbooks. The use of well-known cases that have resulted in numerous deaths may be so distant from the experience of most students that they generate emotional distance and emotional closure while at the same time their known outcomes limits the opportunities to develop reasoning and perspective-taking skills. In this respect, the evidence on a specific type of case problems – the dilemma – is worth considering.

Dilemmas

In the cognitive tradition of ethics education, the dilemma – defined as a situation which presents a difficult choice between two competing outcomes both of which are desirable (or undesirable) – played a central role (e.g., Galbraith and Jones 1976). This approach often emphasised collaborative discussion on the dilemma, which provided an opportunity for learners to make explicit their own assumptions, to have those questioned and challenged, to improve their ability to perspective-take via being exposed to others' points of view, and to build arguments. Given their centrality to the mainstream of moral education research towards the end of the 20th century, the dilemma method has been well researched, and there is good evidence that this kind of approach to moral education has a positive effect on students' scores on measures of moral reasoning such as the DIT (Schlaefi et al. 1985). Indeed, Schlaefi and colleagues (1985) found that dilemma discussion-based education had a more positive impact on measures of moral reasoning than other approaches which they studied.

Professional codes

One of the features which distinguishes professional ethics from ethics instruction more generally is that professional ethics has often already been formulated in professional codes and in formal interpretations of those codes (Harris et al. 1996). These professional codes not only mediate how broad ethical principles can apply in specific professional situations but can also be linked to a sense of professional identity and can thus contribute to the development of ethical motivation in learners (Bebeau 2002). Hence it is not surprising that, where codes exist, they have been seen to be pervasive in professional ethics education (e.g., Haws 2001).

The evidence on the impact of integrating standards or codes in education is a little mixed. Waples et al. (2009) found that when ethics education in business domains made explicit references to standards or codes, the impact on learning was higher than when standards were absent. Similar effects have been found in science and medical ethics education (Antes et al. 2009; Watts et al 2017). However, even if the use of professional standards or codes does seem to contribute to student learning in ethics education, it is worth noting that their use is not unproblematic. Codes developed by professional bodies often reflect the economic and organisational contexts within which professionals typically work. As such, they generally refer primarily to the responsibility of the individual member of the profession with respect to their clients and employers ('microethics'), rather than issues of equity in the profession, power imbalances in decision-making, and social and environmental impacts of professional practices ('macroethics') (Martin et al. 2021a; Rottman and Reeve 2020). Thus, even if codes can play a role in student learning of ethical content, they may be underpinned by an inherent conservatism which will limit their impact on sustainable development goals.

Empathy-based pedagogies

The growing focus on emotions in ethical decision making noted in the previous section has had some impact on more recent developments in ethics pedagogy. In sustainability-oriented ethics education, this is mirrored in references to developing empathy (Karpiak and Baril 2008) or to compassion (Pfattheicher et al. 2016). One way in which this has happened is in the integration of emotional content into ethics cases. Chase Thiel and colleagues (2013), for example, have found that the inclusion of emotional content in ethics case studies improved both participants' memory of the material and their ability to apply the same ethical principles to a different case. Cory Higgs and colleagues (2020) looked specifically at guilt, shame, and embarrassment and found that emotions of guilt and shame each changed the perceptions of the dilemma in question. Participants who felt shame, for example, reported highest levels of personal responsibility, while those who felt guilt saw the problem as more pressing. They note, "contrary to common thought, experiencing no emotion while in an ethical dilemma may actually result in cognitive processes that could lead to less ethical decisions" (2020, 53). The inclusion of emotional content is not unproblematic, however. Where cases have too much emotional content (such as large-scale cases of death and destruction), they may be overwhelming for learners (Watts et al. 2017).

A second way in which emotions have been increasingly addressed in ethics education is through the use of emotional processes to work through ethical questions. Justin Hess and colleagues (Hess and Fila 2016; Hess et al. 2017, 2019) have, for example, explored the development of empathy as part of an ethical decision-making process among engineering students utilising the scaffolded, interactive, and reflective analysis (SIRA) framework. They did find statistically significant increases in empathetic perspective-taking and, based on a reduction in empathetic distress, they inferred that students also developed enhanced emotion regulation skills. More generally Watts et al. found that including emotional processes in ethics education had a more positive impact on learning than the inclusion of cognitive processes or of values-oriented processes. Based on their analysis of empirical studies of learning, they concluded "Specifically, asking trainees to practice forecasting downstream consequences and the impact of emotions on their decisions proved of particular value" (2017, 380).

Other pedagogical approaches

As noted at the start of this section, there are many other pedagogies proposed for use in professional ethics education including role-play (Martin, Conlon and Bowe 2019), debates (Kim and Park 2019), service learning (Pritchard 2000), videos (Loui 2006), and challenge-based learning (Bombaerts et al. 2021). In some cases (role-play), the evidence shows positive effects on learning, while in others (e.g. service learning), the evidence so far shows little impact (Watts et al. 2017, 376).

Overall, however, it may be that rather than thinking in terms of 'effective' or 'less effective' pedagogical methods, it is more appropriate to think in terms of the goals of ethics education and the way in which these are linked to the pedagogies proposed. Moral sensitivity is likely to be enhanced by methods which draw learners' attention to consequences of decisions – including potentially unforeseen consequences. Hence case problem approaches and processes, which include forecasting, may be particularly appropriate. Moral reasoning seems to be improved by working through dilemmas in discussion with others and by perspective-taking activities. Moral motivation may be addressed through empathy-based approaches as well as through a focus on professional identity (such as through the use of professional codes). Throughout all these approaches, active processing of information and clear goals are more likely to be effective than situations in which learning is passive or learning goals are unclear (Tormey and Isaac 2021).

An underpinning idea in this section has been that there is evidence that ethics education can be effective if the methods are well chosen to match the learning goals and if they are well designed. But while ethics education can be effective, questions remain as to whether or not even effective ethics education will have much impact within the wider context of professional education. This question is addressed in the next section, taking engineering education as a particular example.

How does ethics education fit in professional education more generally?

In his introduction to UNESCO's 2021 report on engineering, the president of the World Federation of Engineering Organisations (WFEO), Gong Ke, strikes an optimistic tone about the role of engineering in the struggle for sustainable development:

> Engineering has helped solve our daily problems and our production needs by applying scientific knowledge, technical methods, design and management principles. Indeed, engineering . . . has been a prime contributor to the survival of humankind on Earth and to improving our quality of life.
>
> *(2021, 10)*

This optimistic tone is one that is familiar in many statements and documents about engineering by engineering bodies across the globe (Downey 2012, 2014). Such statements are examples of what Gary Lee Downey has called *normative holism*, a philosophy that draws an equivalence between engineering work and human progress *in general* (as was noted in the introduction, similar claims to being in service of the public interest are widespread in other professions also). For Downey, this belief has a paradoxical effect of meaning that, because engineering contributes to human progress as *a whole*, engineers are released from responsibility to question the political and social impacts of *specific* engineering decisions. This has implications for the education of the next generation of engineers, as engineering educators are in turn released from responsibility for ensuring engineers have the capacity to assess the effects of specific engineering actions. Questions which might be seen as questions of power and politics become, by definition, 'not engineering'. Engineers are understood in this formulation as serving the greater good by not thinking about the greater good and by instead being what Wendy Faulkner has referred to as "nuts and bolts people" (Faulkner 2007).

The apparent dominance of this ideology in engineering and engineering education perhaps helps to explain why engineering ethics education seems to have such little impact on the ethics of engineers, especially when compared to other professional domains. While research on the development of moral reasoning, for example, generally finds that measures of moral reasoning (such as scores on the DIT) increase with education (Bebeau and Thoma 2003), numerous studies with engineering students have found that the pattern for engineering students appears different from that of other disciplines: Joanne O'Flaherty and Jim Gleeson (2014), for example, compared the moral reasoning development of engineering students with that of students from a range of other disciplines including education, computer science, business, science, and humanities. While the measured moral reasoning of all student groups increased, the increases were small for engineering students and less than for all other disciplines. Other studies have found that the measured moral reasoning of engineering students either remained unchanged or actually *declined* over the course of their engineering education (Monzon et al. 2010; Tormey et al. 2015). Indeed, while Harding et al. (2013) found moral reasoning measures for engineering students increased during their education, they also found that they had made no gains in their ethical knowledge and that they were reporting higher rates of unethical (cheating) behaviour.

Numerous authors have tried to explain why engineering education seems to be such an outlier from education more generally when it comes to the development of moral reasoning. Tormey et al. (2015) have suggested that the focus in the early stages of an engineering programme on competition to succeed and on solving narrowly defined mathematically based problems with single correct answers may contribute to a decline in moral reasoning by students. Similarly Erin Cech (2014) argues that engineering education represents a 'culture of disengagement' whereby engineering students learn over time that to 'think like an engineer' means learning to define problems in solely technological terms and, as such, "public welfare considerations get *defined out* of engineering problems, [and] excluded from the realm of responsibility that engineers carve out for themselves" (2014, 48 emphasis in the original). Johanna Lönngren (2021) similarly found that engineering students learn to see ethics and ethical reflection as being in conflict both with ways of thinking of their 'core' disciplines and with the practicalities of their future professional life. She argues that students' disengagement from engineering ethics over the course of their studies is not actually a function of 'lack of interest', but rather the result of the way in which students (and professors) are enculturated to understand 'engineering' during the course of their studies.

This is not to suggest that all engineering ethics education is always ineffective: Barry and Ohland (2012) identify that there is a statistically significant relationship between the number of ethics courses engineering students have and their performance on an engineering-specific standardised ethics and business practices test (even if the relationship is not straightforward or linear). But even if engineering ethics education can be effective, it is unlikely to be effective if it is treated as disconnected from the rest of engineering education. In a review by Colby and Sullivan (2008, 331–332) of engineering ethics education practices in the United States, for example, they concluded that "strong curricular continuity in ethics coverage does not appear to be typical in engineering education" and that "It was commonplace in our site visits for faculty, even department chairs, to be unaware of whether or how their program supports its students' ethical-professional development".

It is worth noting that engineering education may be something of an outlier here when compared to other professional disciplines. Nonetheless it does raise the question as to how well the messages of ethics and sustainability education aligns with or conflicts with the messages of professional education more widely. What the case of engineering education shows is that it is not necessary for the culture of professional education to be actively hostile to the messages of ethics education for it to negate the effects of ethics education. Rather the impact of ethics education will be effectively negated if the wider culture of education tells students that ethics is somebody else's problem.

Conclusion

The work of professionals is central to the work of sustainable development. Because of their expert status, progress towards sustainable development goals will require the development of a number of capabilities in student professionals.

First they need to be able to recognise sustainability and ethical issues when they arise (ethical sensitivity). For example, a professional engineer who does not know where a particular material comes from and how it is disposed after use lacks the environmental ethical sensitivity to recognise an issue exists with the choice of material in a product. Methods like case problems, interrupted case problems, and forecasting approaches, alongside traditional teaching, may be most relevant for developing such sensitivity.

Professionals also need to make good decisions (ethical judgement). Judgements about which materials to use and how to use them, for example, may well have an impact on those who work in a company, as well as on users of the product, on those involved in material extraction at a geographical distance, and potentially on future generations at temporal distance. The skill of being able to make good decisions in the context of competing values may well be developed by the use of dilemmas in discussion with others and through perspective-taking activities in ethics education.

A third learning goal is to develop in students enough of a sense of care to follow through on their judgement (ethical motivation). This implies learning to focus on the emotions they experience when confronted with sustainability and ethical questions. This requires situations which enable them to experience empathy, compassion, and perhaps guilt, or anger, and which allows them to develop the ability to process these emotions constructively. It may also include a focus on professional ethics codes and on professional identity.

A fourth learning goal is to develop the skills to be able to work within their organisational setting to achieve their goals (ethical agency). Activities that may be relevant here are those that will help them develop the ability to work effectively with others, to negotiate, and to be resilient. Case studies of how decisions are taken within organisations may be particularly relevant for this goal, as well as adequately scaffolded team work.

But professional ethics education does not exist in a vacuum, and the success of ethics education will be dependent on whether or not the wider culture of professional education communicates that ethics is – or is not – important to their professional identity.

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8.3
SUSTAINABILITY LEADERSHIP AND THE PROTECTION OF THE COMMON GOOD

Sam Wilson and Michele John

Key concepts for sustainability education

- Viewing sustainability through the lens of the common good helpfully surfaces the complexities, challenges and controversies of leadership and governance for sustainability.
- Fundamentally, the common good refers to those tangible and intangible 'goods' that serve all members of a community. Typically, the 'goods' that comprise the common good require collective action to ensure their provision and protection (e.g., clean air, access to clean water, unpolluted marine and waterway environments, global climate change management, biodiversity protection and public health systems). As such, the common good can be positively or negatively impacted by leadership decisions and actions across all levels and sectors of society.
- Although acting for the common good is vital, agreeing on what constitutes the common good is not straightforward because it is riven with differences of opinion about: (1) the goals and outcomes that ought to be pursued; (2) the processes and procedures that ought to be used to realise these goals; and (3) the extent to which we should build upon, or destroy the past, in order to realise the common good. The common good is thus paradoxical.
- Sustainability leadership must embrace the complexity and the paradoxes of the common good, viewing these paradoxes as central components of the sustainability transition challenge.
- Sustainability education and education for sustainability leadership should prepare students to see and understand the paradoxes of the common good. It should also introduce students to the processes that exist to knit together plural perspectives in our search for common ground and the common good.

Introduction

Serious cracks are beginning to appear in the capacity of our communities and ecosystems to sustain our well-being (Lovelock, 2009). In the context of concerns about the end of a safe operating space for humanity (Rockström et al., 2009; Steffen et al., 2015), there

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are strong calls for human societies to evolve to preserve the social and ecological systems that underwrite human civilisation (Hawken, Lovins, & Lovins, 2000). The preservation of these social and ecological systems could include common goods like access to clean air and water, biodiversity protection, climate change management and protection and conservation of our natural environments including oceans, waterways and terrestrial parks and green spaces. As our understanding of the value of these interlocking social and ecological systems has increased, so too has our appreciation of the need to address what John Barry (2012) aptly called 'actually existing unsustainability' and discover safe, just and sustainable ways of living within our planetary boundaries (Jackson, 2011; Raworth, 2017).

It is clear that sustainability and the sustainability transition are more than just buzzwords for the 21st century (see chapters 3.6, 3.7 and 7.6 in this volume). Rather, fostering sustainability and facilitating low-carbon and sustainability transitions is a necessary function of leadership and governance to meet the challenges of our age – termed the Anthropocene (Crutzen, 2006) – to regenerate and sustain our planet's resources so that future generations can survive and flourish. Accordingly, leadership scholars have sounded the call for greater sustainability and sustainability leadership (Edwards, 2005; Goldman Schuyler, Baugher, & Jironet, 2016; Redekop, 2010; Scharmer & Kaufer, 2013; Senge et al., 2008).

However, the concept of sustainability is paradoxical. On one hand, it has the quality of being familiar and commonplace. And yet, on the other hand, it is difficult to articulate in a precise or comprehensive way. For example, when we pause to reflect on the interlocking pillars of environment, economy and society, we quickly discover that sustainability is more complex, expansive and elusive than we initially imagined. Similarly, the concept of sustainability leadership or, better, leadership *for sustainability*, resists easy definition. Instead of the typical adjective plus noun combination that characterises most approaches to leadership (e.g., *ethical* leadership), leadership for sustainability foregrounds its object – namely, ensuring the ability of people to co-exist and flourish on Earth over a long time (see Chapter 1.7 in this volume).

As noted throughout this volume, and in the sustainability literature more generally, scholars of sustainability often reference the concept of the 'common good' (see Chapters 1.1, 3.2, 4.3, 5.4, 6.4, 8.3 and 8.4 in this volume). This is evident, for example, in injunctions for people to adopt a 'common good mindset' (Tavanti & Wilp, 2021) or to act for the common good. In the context of leadership, this injunction is exemplified by the metaphor of the honeybee and the beehive and corresponding beehive approaches to sustainability leadership (Avery & Bergsteiner, 2011). However, despite this, the common good dimension of sustainability is rarely examined (Tavanti & Wilp, 2021), and when it is, its meaning is assumed to be self-evident. Moreover, when definitions of the common good are offered, they are typically narrow or partial, reflecting a specific school of thought or ideology, ignoring the uncertainty and contest regarding its meaning.

In this chapter, we show that the meaning of the common good is not self-evident. Further, we propose that concern about the diverse meanings of the common good, in general, and as they relate to sustainability in particular is not some esoteric or philosophical flight of fancy that is ultimately irrelevant to sustainability and sustainability education. Rather, we contend that reckoning with these diverse conceptions of the common good is, or ought to be, of central concern. We propose that harnessing the diverse, even contradictory meanings of the common good is central to our ability to address 'actually existing unsustainability' for the simple reason that, whenever important perspectives on the common good are excluded from collective decision-making, governance failure inevitably results (Verweij et al., 2006).

In this chapter, we argue the following. First, in complex, pluralistic societies, there is no single, determinate common good (Sluga, 2014), but rather a diversity of often-competing conceptions of the common good (Mansbridge, 2013). This fact is somewhat obscured when we refer to the social pillar of the sustainability as ‘social’ but is readily apparent when we unfold it to reveal politics, ethics and morality, religion, history and culture. Second, people’s conceptions of the common good influence how they perceive human nature (Pojman, 2006) and organise and justify social relations, as well as how they make sense of and attempt to solve the problems encountered in the world (Verweij et al., 2006). Third, although each perspective on the common good is partial and incomplete and often exists in uncomfortable tension with other perspectives, each perspective nevertheless contains wisdom that is lacking in the others (Verweij et al., 2006). Fourth, each time one of these perspectives is excluded from collective decision-making in shared power contexts – those in which no one is in charge (Crosby & Bryson, 1992) – governance failure inevitably results (Verweij et al., 2006). Fifth, because successful solutions to wicked problems tend to involve experimental combinations of these different perspectives (Grint, 2010a; Verweij et al., 2006), leadership for the common good must necessarily tolerate and accept the paradoxes of the common good as normal, rather than deviant, and reconceive the paradoxes of the common good as opportunities to be embraced rather than problems to be solved (Bolden, Witzel, & Linacre, 2016).

In this chapter, we invite the reader to take a bird’s-eye view of leadership for the common good as it relates to the possibility of discovering more sustainable ways of living. Consistent with this aim, and consistent with the turn towards ‘diagnostic practice’ in the search for the common good (see Sluga, 2014), we invite the reader to join us ‘on the balcony’. As explained by Heifetz, Grashow, and Linsky (2009), the metaphor of ‘getting on the balcony’ above the ‘dance floor’ fosters the type of distanced perspective that is necessary to see what is really happening in a system. The purpose of this chapter is to invite readers onto the balcony so that they can see that the ‘common good’ is a surprisingly complex concept whose diverse meanings need to be understood and reckoned with in the practice of leadership and governance for the common good.

Given this purpose, we necessarily screen off several important issues that, although important, are beyond the scope of this chapter. First, of the interlocking pillars of sustainability, environment, economy and society, our focus in this chapter is on society, especially its political, ethical, moral and cultural aspects. The reason for this is straightforward: addressing prevailing unsustainability and fostering sustainability requires leadership, and real leadership, as Heifetz and Linsky (2002) argue, surfaces conflict, challenges long-held norms and beliefs and demands new ways of doing things. All of this occurs in the social realm. Given that the fields of sustainability are highly normative – replete with prescriptions about the values, norms and practices that *should* be honoured or enacted (see Section 2.4, Chapters 8.1 and 8.2 in this volume) – here, we assume the role of educator, helping existing and emerging leaders recognise their normative blind spots. Second, because our intention is to offer an overview of leadership for the common good in shared power contexts, we neither examine nor advocate for specific leadership styles. Instead, our intention is to illuminate the assumptions and perspectives that need to be understood as part of the praxis of leadership for the common good. Our hope is that, armed with these insights, readers will be able to better understand what perspectives on the common good are included and, importantly, intentionally or unwittingly excluded in any given approach to leadership for the common good. Finally, because the conceptions of the common good presented in this chapter may not be universal, it is necessary to situate these ideas historically and culturally. This focus of this chapter is on the liberal democracies of the Western world, in general, and English-speaking nations (e.g., United States, UK, Canada, Australia, New Zealand) in particular: countries in which it remains unfashionable to think and talk about shared interests and the common good (Bauman, 2000; Giddens, 1991; Judt, 2010; Saul, 2009).

This chapter begins with an overview of the concept of the common good, illuminating the long pedigree of the concept and its irreducibility to a single normative principle or set of principles. Next, an account of the paradoxes of the common good is offered, delineating four main types of paradoxes that characterise the common good. Consideration then turns to leadership for the common good, where we highlight its suitability for the discovery of common ground and for fostering agreement about the common good and the need for collective action in shared power contexts. Finally, the implications of this approach for sustainability education and education for sustainability leadership are explored.

The common good

As observed by Etzioni (2004), for people not conversant with political philosophy and political theory, the 'common good' is a self-evident concept. Similar comments could be made for related concepts, such as the 'common weal', 'public interest', 'public good' and 'greater good'. Fundamentally, the common good refers to those tangible and intangible 'goods' that serve all members of a given community. Moreover, the term itself may refer either to the interests that members have in common or to the facilities that serve common interests (Hussain, 2018). However, this simple formulation obscures more than it reveals. The common good is, in fact, a complex normative concept with long and contested history, replete with diverging and often contradictory meanings (Mansbridge & Boot, 2022). We contend that these diverse meanings must be appreciated as a precondition for the conceptually and morally imaginatively work of leadership for the common good and sustainability in complex, pluralistic societies.

The common good has deep roots in the history of philosophical and religious thought. Plato (1975), for example, imagined an ideal state in which private goods and nuclear families would be relinquished for the sake of the greater good of a harmonious society. Aristotle (1984, 2013) defined it in terms of collective or communally shared happiness, whose key constituents were wisdom and virtue. Throughout the centuries, and often drawing on the Greek and Roman tradition (see Etzioni, 2015), Christian theologians such as Augustine (1983) and Aquinas (1981) examined the common good, the meaning of which was centred on the word and worship of God. Theories such as these, which define the common good in relation to a higher purpose, such as God, are described as *unitary* theories of the common good (Mansbridge, 2013).

More sustained engagement with the concept occurred in the 17th century with the rise of social contract theory (Hobbes, 1924; Rousseau, 1913), which held that people ought to forfeit their absolute freedom to live as they wish for the security of shared life in a community. Around this time, conceptions of the common good shifted from concerns with moral virtue and an ideal moral vision of the good society towards more pragmatic considerations of the material well-being of individuals (Jaede, 2017). Subsequently, 18th- and 19th-century thinkers, such as the philosopher and political economist Adam Smith (1961) proposed that the common good is not a collective social goal (e.g., about the good society) to be pursued, but rather the aggregation of individual goods. Similarly, philosophers such as the utilitarian Jeremy Bentham (1952) viewed the common good as the sum of all individual goods and argued that if every man and woman were free to maximise pleasure and avoid pain, the 'greatest happiness of the greatest number' would result. Subsequently, the philosopher John Stuart Mill (1940) modified Bentham's utilitarianism to develop a theory of moral individualism predicated on enlightened self-interest that would lead people to put the general good above their own particular pleasure (Macridis & Hulliung, 1996). Theories such as these that highlight the conditions that benefit all or most members of society, which everyone could agree on regardless of their circumstances, are called *aggregative* theories of the common good (Mansbridge, 2013).

Consistent with the modern turn towards a concern for material well-being, the 20th century witnessed growing interest from economists in 'public goods' and 'common pool resources' – also called 'common goods' – which can be endangered by social choice, famously described by ecologist Garrett Hardin (1968) as the 'tragedy of the commons'. Public goods are goods that are non-rivalrous and non-excludable, which means that the consumption of the good by one person does not reduce the amount available for others. It is difficult or impossible to exclude anyone from using public goods. Public goods include tangible goods (e.g., the public road system, public parks, public schools, museums and cultural institutions, public transportation) and intangible goods (e.g., courts and the judicial system; police protection and public safety; civil liberties, such as freedom of speech and freedom of association; the system of property; representative democracy). On the other hand, common pool resources are simply non-excludable, which means that it is difficult or impossible to exclude anyone from using them. Common pool resources include clean air, clean water, oceans and fisheries. Unlike common pool resources, which begin at full provision, public goods require the members of a community to contribute some form of capital (e.g., time, money, effort) to create and sustain them over time (Parks, Joireman, & Van Lange, 2013). Approaches that conceptualise the common good as those goods that all share *qua* members of a community reflect the *civic* account of the common good (Mansbridge, 2013).

The 20th century witnessed several contributions from economists to these civic conceptions of the common good, with particular emphasis on understanding the relationship between the economy, society and the environment, as reflected in the work of Herman Daly and John Cobb, Jr (1989). Related to this, and drawing on Herman Daly's (1973) hierarchical model of the relationship between well-being, society, economy and nature, Donella Meadows (1998) outlined a framework of means and ends that relates natural resources to human well-being through human, social, financial and built capital. In this framework, natural capital is theorised as the 'ultimate means' upon which human well-being depends. Financial capital and built capital are conceptualised as 'intermediate means'. Human capital and social capital are theorised as 'intermediate ends'. Finally, human well-being and flourishing are conceptualised as the 'ultimate ends' of human activity. Notwithstanding the limitations of this framework – its hierarchical structure and anthropocentrism are singled out as problematic (AtKisson & Hatcher, 2001) – its heuristic value is clear: human well-being is dependent on the well-being of the whole. This period also witnessed new discoveries into how to avert the tragedy of commons, exemplified by Elinor Ostrom's (1990, 2010) work on polycentric governance. As observed by Mazzucato (2023), work such as

Ostrom's demonstrates that common goods are the product of collective interactions and investment that require shared ownership and governance models. In the domain of philosophy, the common good received renewed impetus with John Rawls's work on justice as fairness (1971).

In addition to *unitary* theories, which define the common good in relation to a higher purpose, *aggregative* theories, which define the common good in terms of the conditions that everyone could agree on regardless of their circumstances, and *civic* approaches, that construe the common good as those public and common goods that all share *qua* members of a community, there is yet another tradition of theorising about the common good; namely, the *procedural* approach. As explained by Mansbridge (2013), procedural theories of the common good equate it with the outcome of particular practices, processes and procedures. Consider, for example, procedural justice, which focuses on the fairness and the transparency of the processes by which decisions are made. Deliberative democracy is another example of process-oriented approach to discovering the common good. Yet another approach is what Sluga (2014) calls 'diagnostic practice', an alternative to normative theorising that revives the idea of the philosopher, or expert more generally, as a participant in a public exercise of searching for shared meaning, common ground and a shared notion of the common good. These ideas also find expression in such practices as transformative scenario planning (Kahane, 2012), which centres the practice of learning by doing to help communities mired in conflict transform how they approach one another and the problematic situations of which they are part.

Although the concept of the common good has been subject to normative theorising for millennia, it is an 'essentially contested concept', leading scholars to argue that there is no single, determinate good (Sluga, 2014) and that, at any rate, a single normative conception of the common good is inappropriate in complex, pluralistic societies (Mansbridge, 2013). In an illuminating grand sweep of millennia of Western thought about the common good, the philosopher Hans Sluga (2014) writes:

> we can envisage the common good in very different ways, as high and low, as wide and narrow. We can speak of this common good in the language of justice, of freedom, security, order, morality, happiness, individual well-being, prosperity, progress and what have you. We can, moreover, envisage the community for which the good is sought in different ways: as tribal, local, national, international, or even global, as egalitarian or hierarchical in its order, as traditional or freely constituted, as unified or divided. And we can finally envisage the search itself in various ways: as organised or spontaneous, as guided or cooperative, as deliberate or merely implicit, as successful or thwarted.
>
> *(p. 2)*

Understood in this way, the common good is not a single thing, but rather more an umbrella term for several interlocking concepts and conditions that underpin the survival and flourishing of life. The common good is as much about process as it is about outcomes (Wilson, 2023). Nevertheless, as observed by Mansbridge and Boot (2022), scholars from many traditions and schools of thought concur that the uncertainty and contest regarding the meaning of the common good should not prevent individuals or communities from trying to act for the common good or from developing a politics in which the common good, conceived always as contested, plays a central role (see, also, Sluga, 2014).

If there is no single, determinate good, and if the search for the common good always occurs in the context of uncertainty and complexity, it is necessary to reckon with the paradoxes of the common good. In the context of sustainability, these insights suggest that in the search for the common good, we must be both curious about and cognisant of these paradoxes and be prepared to view them as opportunities to be embraced rather than as problems to be solved (see, e.g., Bolden et al., 2016). This is no mean feat: it is personally, socially and institutionally demanding. This will be the focus of the penultimate section of this chapter. First, though, it is necessary to identify and make sense of the paradoxes of the common good.

Paradoxes of the common good

It has long been recognised that historical conceptions of the common good are characterised by a raft of conceptual and normative contradictions and tensions. For example, Plato and Aristotle held that there is no tension between private and public goods, whereas the Christian formulation of the common good recognises a tension between private and public goods (Etzioni, 2015). Moreover, aggregative theories of the common good – exemplified, at the extreme, by libertarianism – are at odds with communitarian conceptions that hold that the common good does not merely amount to an aggregation of all private or personal goods in a society (Eztioni, 2015).

Other tensions among extant conceptions of the common good relate to their foci. For example, conceptions of the common good that focus on public goods and common pool resources give primacy to the *what* of the common good. By contrast, approaches that focus on the processes and procedures through which the common good is realised give primacy to the *how*. Yet other approaches are concerned with the question of *whose* interests are counted as part of the common good (see, e.g., Nussbaum, 2006) – an important consideration in light of the fact that most conceptions of the common good in the Western tradition are silent on the common good as it relates to nonhuman species and the natural world (Wilson, 2016).

Notably, none of these perspectives on the common good are right or wrong *per se*. There is truth in each of these perspectives: each contains elements of wisdom that are missed by the others. Moreover, each perspective provides an expression of the way in which a considerable proportion of society feels we should live with one another (see, e.g., Verweij et al., 2006). Thus, although these diverse perspectives and theories point to often contradictory perspectives on the common good, they are all nevertheless in some sense true. They exist simultaneously, persist over time and, ultimately, need each other. Characterised thus, the common good has all the hallmarks of paradox, defined as contradictory, yet nonetheless true elements that exist simultaneously and persist over time (Lewis 2000). Such elements seem logical when considered in isolation, but irrational, inconsistent and absurd when juxtaposed (Smith & Lewis, 2011).

Drawing on the logician Willard Quine, leadership scholars Richard Bolden, Morgan Witzel and Nigel Linacre (2016) describe these paradoxes as *antimony* paradoxes, which are distinguished from *veridical* paradoxes (which appear absurd but turn out to be logically true) and *falsidical* paradoxes (which appear to be false and, upon analysis, turn out to actually be false). Notably, and this is especially relevant given our focus on sustainability transitions within Anglophone liberal democracies, Bolden and colleagues observe that people in Western cultures find these paradoxes especially hard to understand and accept.

When confronted with an antimony paradox, the first impulse of many people is to try to resolve it; to reconcile the conflicting statements so that they agree, removing the apparent contradiction (Bolden et al., 2016). However, the central point to be made about antimony paradoxes is that they are not opposites that can be reconciled (e.g., dialectically; see Smith & Lewis, 2011) or puzzles to be solved; they simply *are* (Bolden et al., 2016).

Nevertheless, the paradoxes of the common good must be acknowledged and reckoned with in the search for the common good. As noted earlier, people's conceptions of the common good influence how they perceive, organise and justify social relations. These conceptions also influence how they make sense of and attempt to solve the problems encountered in the world (Verweij et al., 2006). From a sustainability perspective, there are many common goods that are inextricably linked to our long-term global future including climate change management. Later, climate change management is used as an example in highlighting both the paradoxical challenges and role of sustainability leadership in our protection of, or in acting for, the common good.

The divergent conceptions of the common good that are encountered in complex, pluralistic societies create contradictory demands, which become increasingly salient and persistent as environments become more volatile, uncertain and complex (Lewis, 2000). Crucially, leaders' responses to the tensions and paradoxes of the common good may be a fundamental determinant of the fate of our society. Thus, a core focus of sustainability leadership must be to constructively work with the paradoxes of the common good.

According to management scholars Wendy Smith and Marianne Lewis (2011), paradoxes can be categorised into four basic types: paradoxes of performing, organising, learning and belonging. Performing paradoxes emerge in the context of a diverse stakeholders and result in competing strategies and goals. Organising paradoxes arise as complex systems create competing designs and processes to achieve a desired outcome. Learning paradoxes surface as dynamic systems adjust, adapt, change, renew and innovate, which raises questions about whether to build upon, abandon or destroy the past to create the future. Belonging paradoxes arise in the context of competing values, roles and memberships. These different types of paradoxes are examined next.

Paradoxes of performing

Performing paradoxes emerge in the context of diverse stakeholders and result in competing goals and outcomes. Consider, for example, Meadows' (1998) framework that related natural resources to human well-being through human, social, financial and built capital. Although all capitals are important, and although it is important to maintain stocks of all capitals, doing so is not straightforward because the goal of maximising one type of capital (e.g., financial) is often in tension with the goal of maximising other types (e.g., natural). This societal-level tension is recapitulated at the organisation level, such as between the goals of profit and social responsibility (Margolis & Walsh, 2003). The common good is associated with many other goal-related paradoxes. For example, as observed by Sluga (2014), we can speak of the common good in the language of justice, freedom, security, order, morality and happiness. Whereas some goals are compatible (e.g., security and order), others may be incompatible (e.g., freedom and order). Moreover, apparent agreement (e.g., about equality) can mask competing goals (e.g., equality of opportunity vs. equality of outcome).

Paradoxes of organising

Organising paradoxes arise as complex systems create competing designs and processes to achieve desired goals and outcomes. The paradoxes of organising call attention to the divergent but legitimate processes that can be recruited in the search for the good. We can envisage the search for the common good in various ways: as cooperative or competitive, as centralised or decentralised, as organised or spontaneous, as guided or cooperative, as traditional or freely constituted or as deliberate or merely implicit (Sluga, 2014). Moreover, we can imagine the search for the common good as ordered by distinct social forms – as individualistic, egalitarian or hierarchical (Sluga, 2014), with corresponding differences in approaches to organising. The crucial insight to bear in mind is that these approaches are all legitimate, exist simultaneously, persist over time and, ultimately, need each other. As seen with the aforementioned paradoxes of performing, the organising paradoxes observed at societal level are recapitulated at the organisational level, such as the long-recognised tension between collaboration and control (Sundaramurthy & Lewis, 2003).

Paradoxes of learning

Learning paradoxes surface as dynamic systems adjust, adapt, change, renew and innovate, which raises challenging questions about whether to build upon, abandon or destroy the past in order to create the future. In essence, this reflects the tension between continuity and change, which is experienced by complex adaptive systems from individual humans all the way up to societies. The political arena is the domain in which the drama between continuity and change is played out most obviously, as reflected in political ideologies that seek to conserve or incrementally build upon tradition and those that strive for progress by destroying the past.

Paradoxes of belonging

Finally, in terms of belonging paradoxes, which pertain to the nature of self and identity, consider the paradoxical tensions that exist between the individual and the collective (Murnighan & Conlon, 1991). So fundamental is this paradox that leadership scholars Donelson Forsyth and Crystal Hoyt (2011) call it the 'master problem' of social life. Moreover, even when a collectivist perspective is assumed, belonging paradoxes do not disappear because community boundaries can be ambiguous. We can envisage communities as tribal, local, national, international or even global and as unified or divided, with distinct values, needs, interests and identities (Sluga, 2014). In this intergroup context, merely being human is no guarantee of inclusion in the moral circle, as infrahumanisation and dehumanisation research readily attests (Haslam & Loughnan, 2014).

In addition to these performing, organising, learning and belonging paradoxes, a host of paradoxes emerge at the intersection of these categories. Decades of research in the social sciences have revealed that, beneath the rich diversity of human cultures and ways of life, human activities and ways of life are patterned by a limited set of basic social and cultural modes (Fiske, 1992) or forms (Verweij et al., 2006): egalitarianism, hierarchy, individualism and fatalism.

Notably, these four social forms, or ways of life, represent diverse ways to conceive the relationship between the common good and the good of individuals. For example, individualism values freedom and autonomy and conceives the good life as one not strongly constrained by duty to other persons but nevertheless open to association as an individual's perceived interests demand. Of the theories of the common good outlined earlier, the individualist way of life reflects an aggregative view. By contrast, egalitarianism values individual freedom but is also characterised by commitment to the group and identification with other group members. Egalitarianism thus contrasts markedly with individualism. The egalitarian way of life reflects neither an aggregative, procedural nor unitary view of the common good, but rather a *communitarian* conception that contends that strong individual rights (e.g., to liberty) go hand in hand with strong obligations to the community and the common good (Etzioni, 2004).

Importantly, these modes or forms not only affect how people organise and justify social relations but also how they interpret and attempt to solve the problems encountered in the world, such as global climate change. To illustrate this, it is helpful to draw on the work of Verweij and colleagues (2006; Verweij, 2006) to describe how climate change is seen through the lens of egalitarianism, hierarchy and individualism, respectively. Given that fatalism does not seek to act on the world – all events are predetermined and therefore inevitable, negating agency – the fatalist story will not be presented here.

First, seen through the egalitarian lens, the climate change story is one of profligacy (Verweij et al., 2006; Verweij, 2006). The setting of this story is a world in which nature is fragile, an intricately connected web of life. The villain in this profligacy story is the fundamentally inequitable structure of advanced society with its unquenchable thirst for profit and economic growth. Given that, in this story, the environment is precariously balanced on the brink of a precipice, the answer is not found in expanding already bloated bureaucracies but in radical decentralisation, in devolving decision-making down to the grass-roots level.

Second, seen through the hierarchy lens, the climate change story is one of lack of global planning (Verweij et al., 2006; Verweij, 2006). The setting of this story is a world in which nature is stable until pushed beyond discoverable limits and in which society can be reliably managed by firm, long-lasting and trustworthy institutions. The underlying problem in this story is the lack of global governance and planning that would rein in and steer global markets and protect the global commons. Given this, the solution is to expand transnational decision making and environmental governance. The villains of the story are those individuals, governments and enterprises sceptical of the view that the solution to climate change consists of global intergovernmental treaties and action based on scientific planning and expert advice.

Finally, seen through the individualistic lens, the climate change story is one of business as usual (Verweij et al., 2006; Verweij, 2006). The setting of this is a world that is as benign, bountiful and resilient, a world able to recover from any exploitation. To individualists, the noise around climate change is just another attempt by naïve idealists (the egalitarians) who erroneously believe the world can be made a better place and by international bureaucrats (hierarchy) looking to expand their own power, budgets and influence. The story's villains are the egalitarians and the bureaucrats who create the problem through their meddling and interference in free enterprise and the proper functioning of free markets. It follows that the solution to climate change is to let people and enterprise freely interact without interference from activists and the state.

Crucially, despite representing contradictory modes of social organisation and contradictory ways of perceiving and addressing complex problems, egalitarianism, hierarchy, individualism and fatalism exist simultaneously, persist over time and, ultimately, despite their contradictions, these four ways of life need each other; they are unavoidably interdependent. Schwartz (1991) characterises these interdependencies thus:

> Each way of life undermines itself. Individualism would mean chaos without hierarchical authority to enforce contracts and repel enemies. To get work done and settle disputes the egalitarian order needs hierarchy. Hierarchies, in turn, would be stagnant without the creative energy of individualism, uncohesive without the binding force of equality, unstable without the passivity and acquiescence of fatalism. Dominant and subordinate ways of life thus exist in alliance, yet this relationship is fragile, constantly shifting, constantly generating a societal environment conducive to change.
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> *(Schwartz 1991, 765)*

Understood in this way, the paradoxes of the common good are unavoidable in pluralistic societies. Moreover, these paradoxes are all for the good: something to be harnessed through constructive communication and negotiation (Verweij et al., 2006). Each of these perspectives distils certain elements of experience and wisdom that are missed by the others and provides an expression of the way in which a considerable proportion of the populace feels we should live with one another and with nature (Verweij et al., 2006). Most importantly of all, and this is a central contention in the context of a book about sustainability education, each perspective needs all the others for the discovered solutions to complex problems to be durable. Each time one of these perspectives is excluded from collective decision-making in shared power contexts, governance failure inevitably results (Verweij et al., 2006). These insights have profound implications for leadership for the common good, in general, and sustainability leadership, in particular.

Sustainability leadership and the search for the common good

To this point we have argued, first, that in complex, pluralistic societies, there is no single, determinate common good, but rather a diversity of often-competing conceptions of the common good. Second, people's conceptions of the common good influence how they organise and justify social relations, as well as how they make sense of and attempt to solve the problems encountered in the world – including those of sustainability. Third, although each perspective on the common good is partial and incomplete, each perspective nevertheless contains wisdom that is lacking in the others. Fourth, each time one of these perspectives is excluded from collective decision-making in shared power contexts, governance failure inevitably results. In this penultimate section of the chapter, we argue that because successful solutions to wicked problems tend to involve experimental combinations of these different perspectives, leadership for the common good must necessarily tolerate and accept the paradoxes of the common good as normal, rather than deviant, and reconceive the paradoxes of the common good as opportunities to be embraced rather than problems to be solved.

According to Crosby and Bryson (1992), leadership for the common good is required precisely in complex, 'shared power' contexts in which no single actor or institution has the authority or capacity to govern or manage the complex challenges encountered in these contexts. These contexts, which Bryson and Crosby call 'weak regimes', are characterised by weak agreement among stakeholders about the principles, norms, rules and decision-making procedures that guide behaviour and expectations. This aptly describes the context in which sustainability transitions occur. Shared power contexts are riven with the types of performing, organising, learning and belonging paradoxes described earlier, and many more besides. Notably, this characterisation of shared power contexts has all the hallmarks of what other scholars have called complex contexts (Kurtz & Snowden, 2003; Snowden & Boone, 2007) or, with more of an emphasis on the problems encountered in these contexts, complex (Kahane, 2004), adaptive (Heifetz et al., 2009), wicked (Rittel & Webber, 1973; Grint, 2010a) and super wicked (Levin et al., 2012) problems.

Wicked problems (such as sustainability) and the complex contexts (Kurtz & Snowden, 2003; Snowden & Boone, 2007) in which they are encountered are characterised by flux, uncertainty, ambiguity and unpredictability. As explicated by Grint (2010a), whereas experts are typically ascribed responsibility to solve tame problems – familiar problems with known solutions – and authorities tend to be granted social licence to use coercive command and control in the context of critical problems or crises, responsibility for wicked problems falls to the actors involved in, or caught up in, the problem. Under these conditions, what is required is *leadership*, which calls on leaders to ask wise and perhaps challenging questions rather than simply provide answers or organise processes (Grint, 2010a; Snowden & Boone, 2007).

Understood thus, leadership is complex; it involves influence without authority and the ability to foster a sense of common ground among diverse, perhaps divided, stakeholders, persuading them to assume a sense of shared responsibility for shared problems, mobilising them to act collaboratively and to do so voluntarily because they believe it is the right thing to do (Grint, 2010a). However, as Heifetz and Linsky (2002) argue, this is extremely challenging and not without personal and professional risk because leadership surfaces conflict, challenges long-held norms and beliefs and demands new ways of doing things.

Real leadership is immensely challenging for a host of reasons, not least because the complex contexts that require leadership are characterised by deep uncertainty and unpredictability, unknown unknowns and many competing, perhaps contradictory, ideas (Snowden & Boone, 2007). As should be very clear by now, in pluralistic societies, the common good is replete with myriad competing and contradictory ideas. Although there are guidelines to inform the leadership and facilitative practices that can be utilised to find common ground and address complex problems (see, e.g., Kahane, 2012, 2021; Scharmer, 2016), it is vital to note that there are often no 'right' answers or solutions per se. There are no good or best practices or elegant technical solutions. Rather, complex contexts are the domain of 'next practice' solutions, 'clumsy' emergent solutions that are discovered via experimentation (Kahane, 2004; Snowden & Boone, 2007; Verweij et al., 2006).

In the context of this growing appreciation of complexity and the need for approaches to leadership that are alive to complexity (Colander & Kupers, 2014; Heifetz et al., 2009; Uhl-Bien et al., 2007), there is an emerging appreciation of the paradoxes of leadership (Bolden et al., 2016). There is a corresponding appreciation of the need to escape the idea that, when faced with paradoxes, we must choose one perspective and reject the rest or otherwise attempt to reconcile contradictory elements rather than accepting the paradoxes are not puzzle to be solved (Bolden et al., 2016; Smith & Lewis, 2011; Verweij et al., 2006). Thus, it is becoming increasingly clear that an approach to leadership for the common good that can help facilitate the sustainability transition requires constructive engagement with both the paradoxes of leadership and the paradoxes of the common good.

What are the principles to bear in mind as part of the praxis of sustainability leadership? We suggest that there are at least five basic principles that should be considered in the search for the common good.

Principle 1: embrace the paradoxes of leadership

Leadership is full of paradoxes, and understanding these paradoxes is also central to the understanding of leadership (Bolden et al., 2016). For example, Linacre (2016) suggests that leaders are caught in a spatial and temporal paradox that requires them both to be 'here' and 'elsewhere'. Leaders are also caught up in a social paradox: they must be part of the group, but at the same time, their status sets them apart (Grint, 2010b; Linacre, 2016). Moreover, leaders must manage in the present, but at the same time, they must also think constantly about the future (Linacre, 2016). This paradox is also reflected in Heifetz and colleagues' (2009) insight that leaders must be on the 'dance floor' but also be on 'on the balcony'. Leaders must be also agents of change and agents of continuity (van Knippenberg et al., 2008). Leadership is full of paradoxes, and these must be embraced to make sense of and successfully lead in contexts of complexity and uncertainty, which epitomise the current sustainability transition.

Principle 2: use all styles, and be beholden to none

Leadership for the common good is not defined by or reducible to any single philosophy or ideological perspective, recognising the need for plural perspectives to create sustainable solutions to complex problems. Furthermore, given the diversity of communities for which the common good is sought, leadership for the common good is neither constrained to specific social contexts, such as communities or organisations, nor constrained to specific sectors, such as the government, business or not-for-profit sector. Leadership for the common good must be enacted within and across all interlocking levels, institutions and sectors using an array of temporary and enduring individual, shared and distributed leadership practices (Crosby & Bryson, 1992). Thus, to foster and facilitate social transformation, leaders must be strive to be less an expert in their action logics and more an alchemist (Rooke & Torbert, 2005): able to orchestrate all styles and beholden to none.

Principle 3: Be open to heterodox views on the common good

In complex, pluralistic societies, there are reasonable differences of opinion about what is the right, just or fair thing to do. These differences of opinion relate to a host of phenomena, including goals and outcomes, the processes through which goals are realised, identity and belonging and the extent to which we should build upon or destroy the past to create the future. Pluralistic societies are thus characterised by plural perceptions about the common good. However, despite the ease with which it can be asserted that sustainability involves the creation of safe and just social systems that operate within planetary boundaries, it is not always obvious what that this means or how this is to be achieved in the context of these plural perceptions. It is therefore imperative to be tolerant of and open to plural and perhaps heterodox views on the common good, particularly as they pertain to current sustainability challenges.

Principle 4: cultivate both/and thinking

The practice of leadership for the common good calls on us to overcome any Manichaean tendencies to parse the world into opposites and to instead live with the tensions and paradoxes that inevitably attend life in complex, pluralistic societies. As argued by Bolden and colleagues (2016), living with paradox requires us to do something that, in descriptive terms, is quite simple; namely, accept that there is no black and white, no right and wrong, and that two logically incompatible positions might well be true. However, practically, living with and leading in the context of paradox is quite difficult. In order to achieve long-term sustainability, leaders, and indeed all who are involved in addressing the complex challenges of sustainability, need to eschew either/or thinking and instead cultivate a capacity for both/and thinking.

Principle 5: embrace 'clumsy' solutions

Shared power contexts call on all stakeholders involved or caught up in a complex challenge to hold their worldviews and preferred diagnoses and treatments more lightly and, better, to suspend them, as if from a string for dispassionate contemplation, as Kahane and colleagues 2012, 2021) have learned from decades of helping communities and societies solve their tough problems. The corollary of this, to address complex challenges and discover sustainable solutions, it is vital to eschew 'elegant' solutions – those that reflect the perspectives of single worldviews and perspectives on the common good – and instead embrace 'clumsy' solutions – those that experimentally combine different perspectives – which better reflect the messy reality of the search the common good in complex, pluralistic societies (Grint, 2010a; Verweij et al., 2006).

Global citizenship and the common good

'Global citizenship' is a developing discourse that could play a significant role beyond governments and corporations sustainability leadership.

Hughes (2022) notes that 'Global citizenship is building the future on a shared sense of humanity and responsibility, as every country is inextricably linked to one another through cause-and-effect interrelationships'.

Oxfam (n.d.) defines global citizenship as the 'social, environmental, and economic actions taken by individuals and communities who recognise that every person is a citizen of the world'. They suggest global citizenship is about how we all share a common humanity, and we need to take an active role in our community's and work with others to make our planet more peaceful, sustainable and fairer. Oxfam notes that global citizenship is about citizens getting involved in their local, national and global communities, voicing their opinions and ensuring that they have the power to act and influence the world around them (https://www.oxfam.org.uk/education/who-we-are/what-is-global-citizenship/).

Quilligan (2016) asserted that a broadly shared worldview of common goods is vital to the democratic future of the planet and noted that since the 1980s, national and state governments globally have concerned themselves principally with increasing the rights of private property, free markets and free trade. Quilligan also noted that the importance of discriminating common goods from public goods is crucial in recognising our essential rights to the commons as global citizens. He also suggested that people's rights to global citizenship are not acknowledged or affirmed because citizen representation is largely vested in the state and often does not go beyond the state level, and therefore the idea of an active citizenship with identity and purpose is gravely weakened. He noted that this challenge is then made even more difficult at a global citizenship level.

With the advent of neoliberalism, the public sector now refers, not to citizens self-providing their own resources for their collective benefit, but to the institutions of government provisioning that claim to improve individual well-being through private market goods which are still called public goods. In a mystifying sleight of hand, the resources we use in common are identified as public goods and then deregulated and turned over to the private sphere for production and distribution.

In this way, goods that were once managed as commons or public goods – water, food, forests, energy, health services, schools, culture, indigenous artefacts, parks, community zoning, knowledge, means of communication, currency, and ecological and genetic resources – have either been privatised outright or remain public or common goods in name only. (Quilligan, 2016)

Quilligan suggested that public or common goods could be citizen managed via self-organised and participatory systems of common property, social charters and commons trusts grounded in the sovereign rights of citizens to their common goods.

Mannion et al. (2011) noted that global citizenship education started with the convergence of lineages of environmental education, development education and citizenship education. They suggested that as global citizenship is something that constantly needs to be achieved, citizenship education should therefore also emphasise the process of citizenship itself.

Parker et al. (2004) expanded on the 1997 global citizenship curriculum framework developed by Oxfam (n.d.) and included the following key issues for higher education:

- Take account of complex multiple identities of people today.
- Develop curricula that develop understanding of complex local and global issues.
- Develop skills, competencies and understanding in order to become actors in a complex world at local, national and global levels (within ourselves, as well as our students).
- Acknowledge the interrelatedness and connectedness of knowledge and to develop transdisciplinary ways of working.
- Question the validity of current dominant forms of knowledge that have contributed to the present unsustainable world.
- Engage with different forms of knowledge (for example, local and indigenous knowledge) (see also Chapters 5.6 and 7.6 in this volume).

Quilligan (2016) also importantly highlighted the potential role of global citizenship in protecting shared global common goods and the role it could play in transforming the global economy and creating globally representative governance. (see also Chapters 7.5 and 8.5 in this volume).

Given the increasing modern pressures from citizen stakeholders and non-governmental organisations (NGOs) across a variety of common good issues like climate change and marine protection, it is perhaps to be expected that global citizenship will increasingly play an important role in protecting the public/common good and is likely to become an increasingly vocal driving force for both increased sustainability leadership and sustainability governance in the future.

Implications for sustainability education

There are several implications from the perspectives we have offered for sustainability education, in general, and leadership development, in particular.

First, as noted widely in this Handbook, there needs to be a strong reawakening in sustainability education, sustainability leadership and sustainability governance for our common future and a corresponding commitment to protecting and preserving the health of socio-ecological systems that underpin human well-being. This will require a deep re-engagement with the idea of the common good and the inherent responsibilities of the 'commons' for the common good and our common future.

Second, the central implication of this chapter is that sustainability education and leadership development programs should prepare students to perceive the paradoxes of the common good and to understand that, in pluralistic societies, there are reasonable differences of opinion about what is the right, just or fair thing to do. Among other things, these insights suggest that the practice of leadership for the common good and the possibility of sustainability, requires an ability and willingness among people to overcome the tendency to separate the world into opposites and to instead live with and learn from the paradoxes of the common good.

Third, defining the common good is also challenging, with narrow or partial definitions typically provided that ignore the uncertainty and contest regarding its meaning. Sustainability education must include strong reference to the various perspectives and values held in relation to the common good and focus on processes to support constructive, equitable and open engagement in the learning and solution development for sustainability challenges. For example, recent years have witnessed the emergence of fascinating new ideas about new kinds of learning zones that could overcome the problem of learning from each in the context of the tensions and paradoxes that cause people to speak past rather than to each other (Beech et al., 2022).

Fourth, sustainability education must include reference to the various interdependent perspectives that frame our understanding of both the common good and sustainability and the important role of leadership and governance in protecting our common good for both current and future generations.

Fifth, students in the sustainability transition must have the skills to 'manage their own wellbeing, relate well to others, make informed decisions about their lives, become citizens who behave with ethical integrity, relate to and communicate across cultures, work for the common good and act with responsibility at local, regional and global levels (see Chapter 5.4 in this volume).

Sixth, sustainability education must recognise the importance of clumsy solutions – solutions that creatively combine opposing perspectives on what the problems are and how they should be resolved. Such an approach is essential in addressing complex problems such as climate change, and many others besides. To this end, sustainability education should introduce students to methodologies such as theory U (Scharmer, 2016) and transformative scenario planning (Kahane, 2012) that are expressly designed to help stakeholders in shared power contexts find common ground and develop a shared sense of the common good.

Seventh, students should be introduced to a worldview of common goods and be encouraged to recognise the importance of the management of public/common goods with global citizen representation.

Finally, in this sustainability transition, we need to acknowledge that education and knowledge are global common goods that are essential to the sustainability transition. A report by UNESCO (2015) on the topic of reimagining education as a global common good asserted that:

> The authors propose that both knowledge and education be considered common goods. This implies that the creation of knowledge, as well as its acquisition, validation and use, are common to all people as part of a collective societal endeavour. . . . Knowledge is an inherent part of the common heritage of humanity. Given the need for sustainable development in an increasingly independent world, education and knowledge should, therefore, be considered global common goods. Inspired by the value of solidarity grounded in our common humanity, the principle of knowledge and education as global common goods has implications for the roles and responsibilities of the diverse stakeholders.

Conclusion

In the context of concerns about the end of a safe operating space for humanity, there are calls for human societies to evolve to preserve the socio-ecological systems that underpin our long-term welfare and well-being. Viewing the concept and challenges of sustainability through the lens of the common good provides a way to perceive and constructively engage with the underlying tensions and paradoxes of sustainability. The common good lens also highlights the importance of an approach to leadership that is alive to the social complexity of sustainability and has the wisdom and capability to harness this complexity. Critically, acknowledging that there is no single, determinate common good and accepting that the common good is naturally riven with tensions and paradoxes invite existing and emerging leaders to understand the paradoxes of the common good as sites of learning about plurality of perspectives that need to be woven together in order to discover sustainable solutions to our complex problems. Ultimately, if there is to be a reawakening of concern for our common future, this will require a deep re-engagement with the idea of the common good.

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8.4
CORPORATE SOCIAL RESPONSIBILITY AND RESPONSIBLE LEADERSHIP EDUCATION

Kanji Tanimoto

Key concepts for sustainability education

- The current era of sustainable development is resulting in a sustainability revolution, with governments and businesses called to provide increased responsible leadership.
- New roles and models of business responsibility are being developed with increasing expectations from stakeholders and the community.
- Leadership models are focusing on the development of stakeholder capitalism and increasing levels of corporate social responsibility (CSR) to guide business strategy and provide more responsible leadership and management.
- Teachers as educators are critical links in this sustainability transition and must be prepared to develop their own understanding of CSR and the changing responsibilities for modern businesses in order to be able to effectively teach CSR.

Introduction: a sustainability revolution

In a *New York Times* article from November 22, 2014, "black elephant", a term coined by the London-based investor and environmentalist Adam Sweidan, was introduced as a combination of a "black swan" – an unlikely, unexpected event with enormous ramifications – and an "elephant in the room" – a problem that is visible to everyone but remains unaddressed by anyone, despite everyone knowing that one day it will have vast, black-swan-like consequences. Global warming, natural disaster and infectious disease are typical cases of a black elephant phenomenon. We are able to forecast the high risk of them occurring at some point in the future. Everyone, however, believes that such things are not current political issues, nor will they happen now, and is likely to ignore them consciously or subconsciously. Once such things happen, however, they have the potential to cause significant damage to society and to markets. We must recognize which matters we should give priority and how business should allocate managerial resources to not only make business resilient and sustainable but also make the planet more sustainable. Over the last couple of decades, international discussion on how sustainable development can be achieved has developed with intensity.

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At this point, let us reconfirm the meaning of sustainable development. It is generally defined, in accordance with the Brundtland Report (World Commission on Environment and Development, Our Common Future, 1987, commonly referred to at the 'Brundtland Report') as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Currently, we need to take into account not only the 'present–future time axis' but also the 'developed country–developing country axis' and the 'environmental–social axis' in defining sustainable development, as shown in Figure 8.4.1. The situation that developed countries acquire wealth by sacrificing developing countries is not sustainable. Sustainable development issues contain not only environmental ones but also social ones including poverty, human rights, and such.

We are living in the age of a sustainability revolution, which is a turning point in human history in the same way as the industrial revolution and digital revolution. We should have an analytical perspective on sustainable development from a long-term view with recognizing that economic, environmental, and social concerns are mutually related.

Elkington (1997) advocated the 'triple bottom line' (TBL) concept which is an accounting framework with three dimensions: economic, environmental, and social (Figure 8.4.2). TBL embraces the notion of focusing on economic (profit), environmental (planet), and

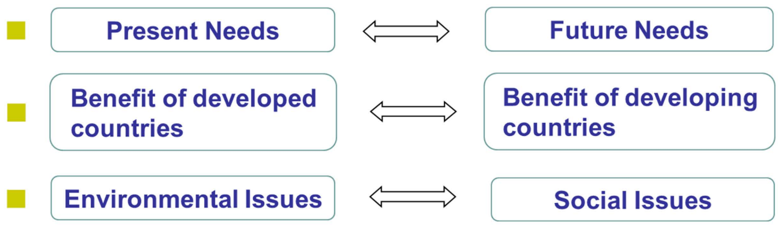

Figure 8.4.1 Definition of sustainable development.

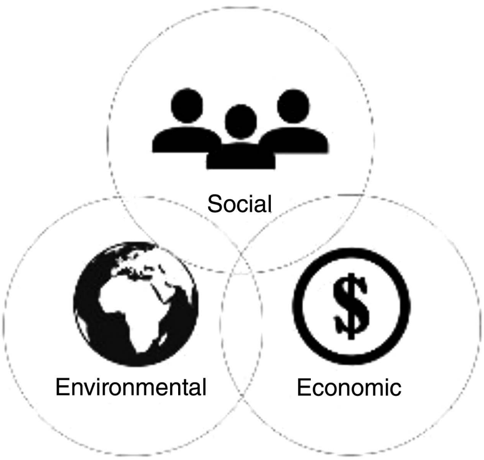

Figure 8.4.2 Dimensions of the triple bottom line.

social (people) spheres. It offers a broader base to evaluate business performance in a comprehensive way.

However, he concludes that TBL has failed to bury the single bottom line paradigm of capitalism despite being discussed for more than a quarter of a century (Elkington 2018). Sustainability sectors have actually grown to generate more than 1 billion US dollars in annual revenues in the world. TBL is not just an accounting tool, however. Its stated goal is system change: pushing toward the transformation of capitalism. It was originally intended as "a genetic code, a triple helix of change for tomorrow's capitalism" (Elkington 2018). TBL does not measure performance in terms of profit only but also in terms of the health of our planet and the well-being of its people.

As the well-known social entrepreneur, Mr. Yvon Chouinard, one of the founders of Patagonia, has said, "Without a healthy planet there are no shareholders, no customers, no employees" (Chouinard 2005). "Patagonia (is) always considering the impact our business has on employees, customers and communities – and on the health and vitality of natural world" (https://patagonia.com/ownership/). Indeed, we must acknowledge that no business can be done on a lifeless planet.

Who should take the sustainability initiative?

We are faced with a fundamental problem: Who should tackle the challenges of sustainable development and take the sustainability initiative? Governments, international organizations, non-governmental organizations (NGOs), or businesses? According to the 2020 GlobeScan–SustainAbility Leaders survey, NGOs (59 points) are rated the most positively for leadership on sustainable development, followed by research/academic organizations (49 points), citizen-led mass social change movements (46 points), the United Nations (40 points), and multisectoral partnerships (35 points).

In the survey, national governments were seen as lacking in leadership (8 points). National governments have, to begin with, traditional roles and limitations. We need to recognize that there are certain problems which cannot be covered effectively by a national government playing a regulatory role. Most notably those issues which are 'too large' (global/cross border)' for a single national government, such as climate change, and those issues which are 'too small' (local/minor), such as support for under-served populations with diverse values to manage.

Despite the performance of the private sector being seen as poor in the survey (17 points), in recent years, business has been expected to do more as a sustainable and innovative leader. The potential of innovation is recognized as the most important factor in tackling sustainability issues in the next phase of the sustainability age. What is needed is an innovative way to approach these issues in collaboration with relevant stakeholders.

New roles and responsibilities of business

The expected roles and purpose of business have changed over time. In the context of the sustainability revolution, the purpose of business is not just to maximize the financial value for shareholders by conducting core business as in a classical economic model but also to increase the total value of the corporation for all relevant stakeholders through due care of environmental and social concerns in business operations (see Section 6, Fröhlich, in this volume).

Corporate social responsibility (CSR) has been expected of companies for the past couple of decades. Since around 2000, international CSR standards and norms have been developed and implemented, including the United Nations Global Compact, the ISO Social Responsibility Guidance, the Principles of Responsible Investment, and global reporting standards including the Global Reporting Initiative (GRI) and International Integrated Reporting Council (IIRC). While it is true that in recent years, all corporations have been required to be responsible to all relevant stakeholders and that CSR has become a popular term in global business, CSR remains subject to differing interpretations and misunderstandings.

Let us now review the concept of CSR. This is not a simple task, as Matten and Moon (2008) have suggested that the CSR concept is based on various elements. First, CSR is defined differently by different groups of people. Rasche et al. (2017) compiles five conceptualizations of CSR: normative perspective (ethical obligation), integration perspective (economic, social and environmental expectation), instrumental perspective (economic self-interest), political perspective (providers of public goods), and emergent perspective (permanent issue of CSR management).

Secondly, CSR overlaps with other relevant concepts such as business ethics, sustainability, and accountability. Sustainability is a larger concept, as we learned in the preceding section. Accountability means that a corporation must be accountable to stakeholders. Business ethics mainly focuses on human behaviors in an organization and ethical dilemmas in the decision-making process. This was developed based on stakeholder theory led by Freeman (1984). Business strategy and operation should be accountable to relevant stakeholders.

Thirdly, as CSR is a dynamic phenomenon, the concept of CSR varies with times and regions. However, CSR has been developed and accepted in a global market for the past couple of decades around the world. The core concept of CSR has converged on the following definition. It is neither merely philanthropy nor compliance. CSR must be embedded into the very core of management (Tanimoto 2010; Rasche et al. 2017). European Commission (2002) defines CSR as follows: business needs to integrate the economic, social, and environmental impact in their operations. CSR is not an optional 'add-on' to business core activities, but about the way which businesses are managed.

Carroll (1979) has provided the CSR framework called the 'CSR Pyramid', which includes four types of responsibility: economic at the formulation of the pyramid and legal, ethical, and discretionary (philanthropic) at the peak of the pyramid. However, this simple model has been criticized, as CSR is intrinsically requested in the process of economic activity.

The core concept of CSR has essentially two dimensions (Tanimoto 2010). The first is doing business responsibly, that is, integrating the concept of CSR/sustainability into management processes. The second is contributing to the community, that is, approaching social issues via core business and philanthropic activities (Table 8.4.1).

For example, a pharmaceutical company, such as Novartis, could describe their CSR strategy just in accordance with the similar idea (Figure 8.4.3). The left side is 'Doing business responsibly' and the right side is 'Contributing to the community'.

Waddock and McIntosh (2009) claim that corporations which integrate sustainability into their management processes are demonstrating a shift in managerial mindset on the role, purpose, and impact of multinational corporations on society. Similarly, the previously referenced Elkington (1997) insists that TBL is a concept intended to transform the single bottom line paradigm of capitalism. CSR is not just a tool for enhancing corporate

Table 8.4.1 Definition of CSR

(1) Responsible Management: Doing Business Responsibly	
Way of	**Incorporating Social Fairness, Ethics and Environmental Considerations into Management Practices**
Management	Approach to Compliance and Risk Management Approach to the Creation of Values (Innovative Approach)
(2) Social Contribution: Contributing to the Community	
Social	**Development of Social Goods and Services and Social Business**
Business	**Approach to New Social Issues (Social Innovation)**
Philanthropy	Community Support with Management Resources
	Approach to Strategic Philanthropy

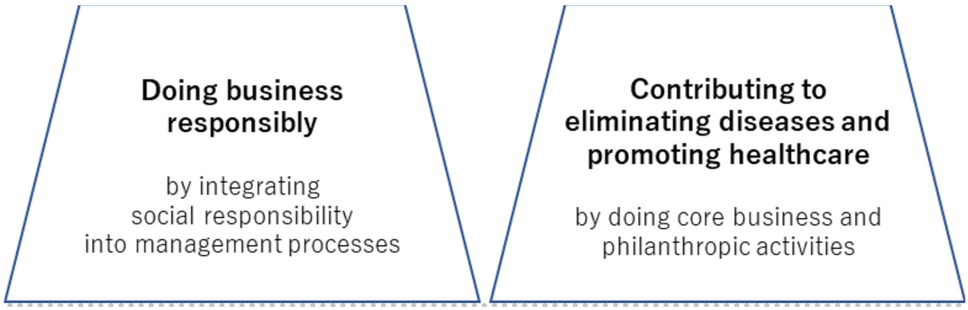

Figure 8.4.3 Pharmaceutical company's CSR strategy.

reputation in the market. Rather, it is important to use discussion of CSR to reconsider and rebuild the basic discipline and purpose of a company in the market. CSR should be a step towards achieving change in the traditional capitalistic market society.

The first CSR boom emerged in the United States in the 1970s (Steiner 1971; Davis and Blomstrom 1971; Jacoby 1973; Nader et al. 1976). Social movements which fought against the Vietnam War and South African apartheid and advocated for civil and consumer rights also targeted big business, making an appeal for responsible operation. CSR failed to take root in business strategy at that time, and faded away after the oil crisis towards the end of the 1970s. At that time, Friedman (1962) and the Chicago School of Economics had a strongly dissenting view toward CSR; managers should be concentrated on maximizing profit in the market.

The second boom took place globally in the 1990s in an environment markedly rather different to that of the first. The classical market structure was changed and globalized. Globalization brought with it such negative effects as societal inequality, climate change, and resource scarcity over the borders caused by unsustainable economic activity (Moon 2014; Lawrence and Weber 2017; Rasche et al. 2017). In the face of such negative impacts, the values held by people changed. Civil society organizations (NGOs) have grown and become networked as third-party monitors of business activities and products and have provided information otherwise unavailable to the general public. The behavior of individual consumers and investors has also gradually changed in the market, shifting to a preference for green or ethical products and investment in responsible companies (Gonzalez et al. 2009;

Devinney et al. 2010; do Paço et al. 2013). Institutional investors have also been changing their investment strategy in response to the global sustainable development movement over the past two decades (Louche and Lydenberg 2011). Recently, these institutional investors have taken positive steps towards making responsible investments, with a particular focus on environmental issues such as climate change, social issues such as human rights, and corporate governance issues (environment, social, and governance investment). The total assets of institutional investors which have signed up to the UN Principle for Responsible Investment (PRI) stood at 103.4 trillion US dollars in 2020.

As shown in Figure 8.4.4, company activity is greatly affected by consumers' buying power and investors' investing power through positive and/or negative sanctions in the market (Tanimoto 2019). Increasingly, companies are trying to respond to changing markets and to be accountable to their stakeholders.

Many companies are incorporating this trend into their strategic marketing planning (Ottman 2010). While not all consumers are fully conscious of green or ethical products, or indeed of a sustainable style of living, the fact remains that the idea of green consumerism has been increasing at high speed for the past two decades (National Geographic and GlobeScan 2014; Ratcliffe and Coulter 2015).

Recently Business Roundtable, an association of chief executive officers (CEOs) of leading companies in the United States, redefined the purpose of a corporation in a 2019 statement, which represented a rethinking of shareholder-ism and a commitment to meeting the needs of all stakeholders – that is, customers, employees, suppliers, communities, and shareholders – by creating long-term value. In 2020, too, the association pointed to the importance of these commitments again in the light of the coronavirus pandemic, emphasizing that businesses should invest in employees, support local communities, and strive to achieve multi-stakeholder capitalism.

Also in 2020, the World Economic Forum also noted the need for a shift away from shareholder capitalism towards stakeholder capitalism, which takes responsibility for a wider range of stakeholders, including society in general. In a post-coronavirus era, this is exactly the argument that will apply, and the resolution for such a shift is now being tested in practice.

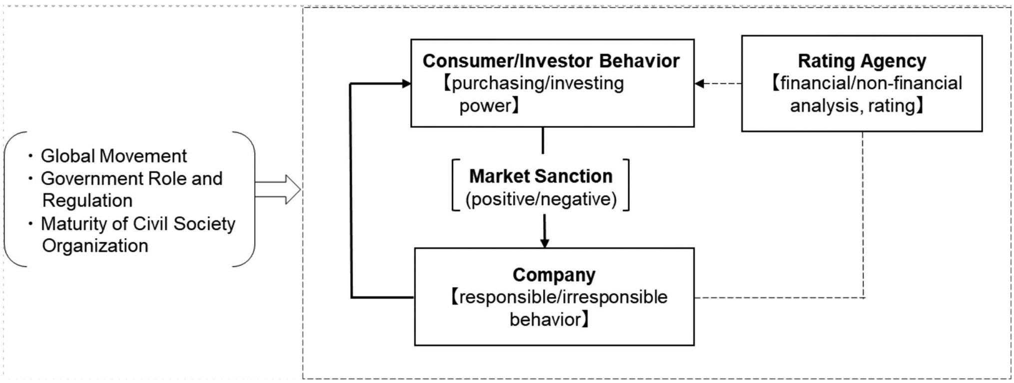

Figure 8.4.4 Market mechanism: positive/negative sanctions.

Stakeholder capitalism has been discussed repeatedly in history in terms of the question 'who owns a company?' During the CSR boom and after the financial crisis, shareholder-ism was criticized and stakeholder-ism, which advocates for the role of business being a benefit of all stakeholders, proposed as an alternative. The fact is, however, that shareholder value and stakeholder value are not inherently conflicting. As it stands now, in order to create shareholder value, CEOs must commit to building good relationships with relevant stakeholders in the market now.

At present, various discussions about and attempts on the redesign of market institutions are in progress. Management is not automatically transformed just by signing up to international CSR guidelines and norms. Rather, CEOs must review their companies' purpose and attempt to strategically embed CSR and sustainability into their management processes in response to new market movements if they are to contribute to build a sustainable society. In such a process, these CEOs need to commit to reconstructing both organizational institutions and culture (Tanimoto 2016).

Another significant trend is partnership beyond sectors. At present, no single sector is capable of resolving local and global social and environmental problems. Recently, collaboration between sectors has been developing in relation to setting international standards and tackling sustainability issues (Hirschland 2006; Fransen 2012; Gitsham and Page 2014; Tanimoto 2019). CSR initiatives, such as the UN Global Compact and the GRI, work to define and implement programs with relevant stakeholders: business, NGOs, national governments, and international institutes. Under such initiatives, stakeholders commit to work together in mutually beneficial ways to accomplish goals that they could otherwise not achieve alone (Sloan and Oliver 2013). They voluntarily co-create and commit to a platform in order to set a norm and then comply with it. As this is a self-defined, self-managed, and self-regulated system, it is a case of "self-organized collective choice", as described by Professor Elinor Ostrom, a Nobel Prize laureate in Economics (Ostrom 1990). Multi-stakeholder initiatives go beyond the dichotomy of traditional approaches to sustainable development issues: that is, voluntary approach versus mandatory approach (Tanimoto 2019). Under such initiatives, companies do not simply comply with a rule set by a third party, but rather voluntarily adapt a standard set by a multi-stakeholder initiative of which they are also a member. As such, business leaders are required to involve in the collaborative process of defining and implementing the standard to which they are then held.

A new leadership style

Most companies are busy adapting to the rapid changes impacting today's business environment: globalization, digitalization, and sustainability. Such companies are always pressed to respond to newly emerged rules and norms in the market. Some companies have moved positively to create new business models. Unilever, Danone, and Patagonia, for instance, are renowned for their sustainability management, achieved by incorporating sustainability thinking into their business operations and by demonstrating tangible results both internally and externally. On the other hand, many companies still have a considerable gap between what they claim in CSR statements and what they do in actuality. Despite this, in a truly sustainable market society, business leaders should have a clear purpose and philosophical faith backed with integrity.

So, then, what is expected of new leadership now? Those expectations encompass the following four elements (Tanimoto 2018), as shown in Figure 8.4.5.

1. Visionary: to lead diverse people to common sustainability goals, while nurturing sustainable mindsets. The sustainability mindset consists of four factors; ecological worldview, system thinking, emotional intelligence, and spiritual intelligence (Rimanoczy 2020).
2. Empowering: to empower people not to control. A leader should give people both opportunities and the means to achieve common goals.
3. Collaborative: to bring people who have different values and ideas together and to collaborate with one another in order to achieve common goals.
4. Innovative: to create sustainability innovation, untethered to conventional ideas, in order to make things better in the long term. Businesses should work in collaboration with relevant stakeholders to develop sustainability innovation for tackling complicated sustainability issues.

Future leaders must learn strategic and innovative meanings and applications of CSR and sustainability management in the globalized market:

- How do they strategically embed CSR and sustainability into the management process?
- How do they constructively contribute to SDGs

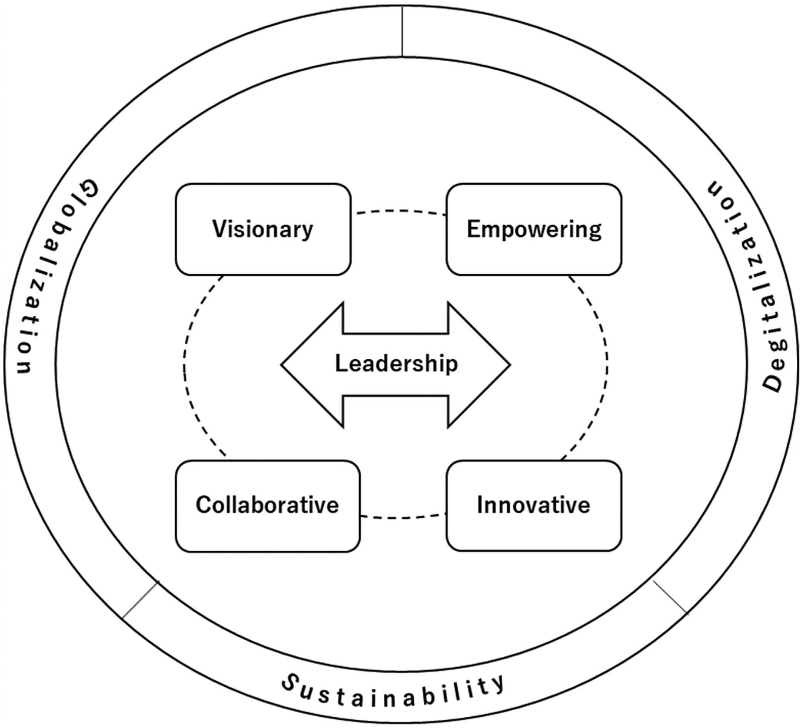

Figure 8.4.5 New leadership style.

- How do they create new business models and sustainability innovations?
- How do they collaborate with relevant stakeholders to tackle sustainability issues?

Building responsible and sustainable business models will earn the long-term trust of stakeholders. Responsible competitiveness is a key concept for businesses in the sustainability transition. Future leaders are required to do business responsibly and sustainably in alignment with globally accepted standards of CSR. Some Japanese managers say that we should put up an 'antenna' to catch the latest global CSR standards and rules. However, companies should committedly lead the discussion on how to make businesses more socially responsible and create new paths to a sustainable society, not just blindly following global trends.

In the words of former UN Secretary-General Ban Ki-moon, "the long-term viability and success of business will depend on its capacity to manage environmental, social and governance concerns, and to create sustainable value through innovation and new business models adapted to a changing global environment" (PRME 2008).

Principles for Responsible Management Education (PRME) is a UN-supported initiative founded in 2007. It is a global platform for universities and educators to develop the future leaders needed to balance economic, social, and environmental goals. PRME's stated vision is "to create a global movement and drive through leadership on responsible management education", while its mission is "to transform management education and develop the responsible decision-makers of tomorrow to advance sustainable development" (https://www.unprme.org/about).

In order to align better with the sustainability revolution and to nurture responsible leadership, traditional teaching methods in university education need to be changed. Business schools need to work on in integrating the concepts of CSR and sustainability into entire courses and entire curricula, rather than just setting up new, stand-alone courses (Molthan-Hill 2014; Kolb et al. 2017; Tanimoto 2018; Fröhlich and Kul 2020; (see Chapter 6.1 in this volume) Fröhlich, in this volume). In this sense, the approach must be similar to that for actual management processes. That is, CSR needs to be integrated into all the activities of all the related departments, rather than pigeon-holed as a CSR department matter. Figure 8.4.6 shows the development process of such an education program.

Stage 1 comprises simply adding CSR/sustainability topics onto an existing course. Stage 2 is establishing a new but stand-alone course for CSR. Stage 3 is embedding CSR into modules and related courses. Stage 4 is integrating CSR into the entire curriculum.

Most universities are currently at either stage 1 or 2. More recently, some business schools have managed to embed CSR/sustainability in the mainstream of business education over the last decade and moved up to the stage 3 by creating unique curricula, across all courses, which include sustainability.

According to the Global Action Programme on Education for Sustainable Development (UNESCO 2014), students need certain core competencies in order to become responsible and sustainable leaders: critical and systemic thinking, collaborative decision-making, and taking responsibility for present and future generations (see Chapter 4.5 in this volume) Fukukawa, in this volume.

To this end, a new pedagogy has been developed, intended to foster responsible leaders in the sustainability transition.

Under this pedagogy, students not only study sustainable business knowledge but also learn communication skills with a focus on holistic and diverse views, global and

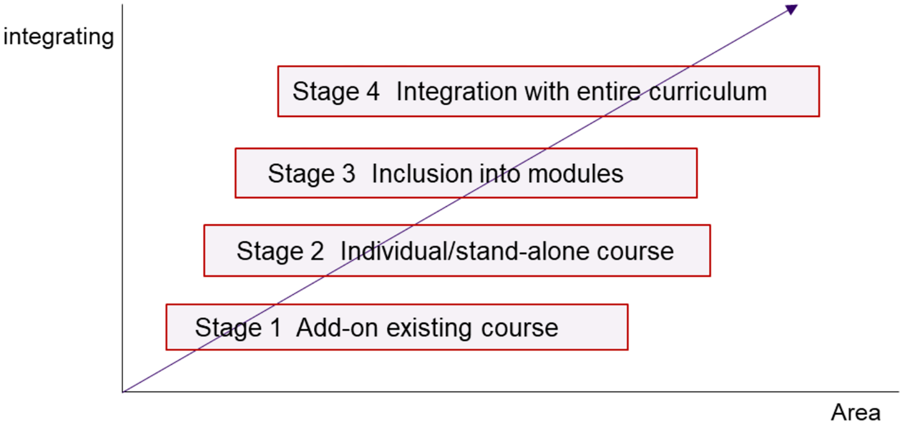

Figure 8.4.6 Integration of CSR/sustainability into a course, module, or curriculum.

sustainability mindsets, and entrepreneurship. This holistic learning approach distinguishes studying and learning (Winne and Hadwin 1998), where learning is an active and reflective construction process of change, rather than simply understanding or memorizing something (Hermes and Rimanoczy 2018).

In parallel with classroom-based learning, students need to cultivate a social sense of reality outside of the university. For that, opportunities for field-based experiences, such as internships and volunteering both at home and abroad, should be provided to students. Students will learn how to combine theory and practice in their chosen field as well as to expand their international networks. Teaching methodology is also shifting from case study to experimental learning. Case study is good for learning how to make decisions based on data analysis, but this only forms part of the learning circle. The other parts focus on experiences in order that students might establish a general criterion in decision making that has consequences in reality (Alcaraz and Thiruvattal 2010). Students learn the responsibilities and ethics of these consequences through their own experiences. In this sense, the role of the teachers is to get students closer to reality.

Rieckmann (2018) outlines the importance of sustainability competence-based education for students and summarizes the following key sustainability competences as necessary for thinking and acting in a way that will work to promote sustainable development:

1. System thinking competency: the ability to recognize and understand relationships, to analyze complex systems.
2. Anticipatory competency: the ability to understand and evaluate multiple futures and to create one's own visions for the future.
3. Normative competency: the ability to understand and reflect on norms and values.
4. Strategic competency: the ability to collectively develop and implement innovative actions.
5. Collaborative competency: the ability to learn from others.
6. Critical thinking competency: the ability to question norms, practices and opinions.
7. Self-awareness competency: the ability to reflect on one's own role in the local community.
8. Integrated problem-solving competency: the overarching ability to apply different problem-solving frameworks to complex sustainability problems.

Students are required to develop a wide range of competencies to be responsible leaders. At the same time, teachers should develop their own perspectives to provide quality education for students.

In 2013, the Association to Advance Collegiate Schools of Business (AACSB) revised their accreditation standards, requiring business schools to address, engage with, and respond to current and emerging corporate social responsibility issues (e.g., diversity, sustainable development, environmental sustainability, and globalization of economic activity across cultures) through policies, procedures, curricula, research, and/or outreach activities (Eligibility Procedures and Accreditation Standards, p. 7). Every business school is now required to provide CSR education and to conduct research on CSR. AACSB also set another requirement on business schools, namely, to foster and promote societal impact on the betterment of society in 2020. Businesses are expected to address broader economic, social, business, and environment issues at a local, regional, national, and international scale. The AACSB states that business education is a force for good in society and can make a positive contribution to society, and finally that business schools' curricula must contain some components relating to societal impact.

Lastly, comprehensive sustainability management curricula should be provided for future leaders at business schools, with teachers also revising any long-standing content in their lectures and teaching method in order to adapt to the sustainability revolution (see Section 5, Gough, this volume).

Conclusion

As the world has changed drastically and demanded sustainable development over a couple of decades, the roles and responsibilities of businesses also have evolved. Future leaders must learn how to do business responsibly and contribute to the sustainability revolution in collaboration with stakeholders. These leaders will be expected to have new understanding and competencies in corporate social responsibility. Business education should evolve the curriculum and pedagogy along with the sustainability movement. Teachers are critical 'change agents' in the provision of education and will play a critical role in educating within the sustainability revolution. Rieckmann (2018) claims that teacher knowledge and competencies will be crucial for restructuring educational processes and educational institutions toward sustainability. Teachers must adequately develop their own competencies, namely, understanding global trends and discourses on CSR and the significance of the SDGs, developing an interdisciplinary and global world view, incorporating the concept of CSR and sustainability into mainstream curricula, and developing action-oriented pedagogy to help reinforce the imperatives of the sustainability transition (UNESCO 2017). Put simply, students and teachers alike must learn about the new roles, leadership responsibilities, possibilities, and the challenges facing business in the sustainability transition.

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8.5
DEMOCRACY DEFICIT OR GOVERNANCE DEFICIT
The dilemma of transnational decision-making

Jürgen Bröhmer

Key concepts for sustainability education

- It is important to understand the role of transnational legal frameworks and their inherent challenges in sustainable development.
- Competencies in the conduct of international relations are necessary to understand and use to optimize the implementation of the Sustainable Development Goals.
- Transnational decision-making poses particular challenges for achieving the Sustainable Development Goals
- The legal and transnational frameworks involving sustainable development principles should be integrated into sustainability education teaching at various levels and subjects, e.g., international and domestic politics, international and domestic law, and international relations.

Introduction: "translating" sustainable development policy into legal and regulatory decisions

What is and what is not sustainable and what can be subsumed under sustainable development is a difficult question. Sustainability can only partially be defined by methodologies of the natural sciences. Beyond the natural sciences lies the political domain, i.e., what is politically possible in the concrete circumstances and what can be transformed into law and regulation. Law and regulation are not everything. Evidence shows that a sustainable future will not be achievable without profoundly changing economic and cultural attitudes. Failure is not an option; the consequences for future generations will be dire. Legal and regulatory frameworks will be essential in achieving higher sustainability levels. Domestic (national) legislation and regulation alone will not be sufficient; transnational decision-making will be necessary to achieve sustainability goals. Herein lie significant challenges.

This chapter attempts to shed some light on the difficulties of transnational decision-making. It is written from the perspective of an international and constitutional lawyer, not from the point of view of educational expertise. However, teaching public international and constitutional law in law schools in Australia, Europe, and Asia reveals the

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difficulty and the necessity of trying to create a profound understanding of the problems involved. The principles of sustainability and sustainable development, their evident linkage to climate change, and the perhaps less obvious linkage to international trade and finance provide illustrating examples. I will have to leave it to educational experts to determine how these matters can be integrated into the various levels of learning. That said, it is possible to integrate these concepts on all levels of learning – from classes dealing with politics, social studies, and law in secondary schools, to political science or sociology courses on the university level, and to specialized courses offered in the sciences, where environmental law and regulation or sustainability concepts are discussed in an attempt to embed the specialized natural science focus in a broader political and sociological framework.

Democracy and transnational decision-making

The status quo

The idea of democracy is simple at its core (but only there). The legislative branch usually authorizes executive decision-makers to act within the scope provided for in the legislation. Generally speaking, legislation consists of acts of Parliament defining the scope of executive actions or legislation that delegates the power to determine the scope of the authorization to the executive but retains some right of oversight, including the power to retract or overrule the delegated power. The legislators answer directly to the members of the community affected by the authorized decisions as relevant binding law. Suppose the community members do not like what is being authorized, i.e., legislated, they can then install a different majority in the hope of achieving different policy outcomes, i.e., different authorizations for executive decision-making more in line with the expectations of the members of the community. In some instances, it is also possible that the community members directly authorize such actions, bypassing specialized institutional authorization such as parliaments. This is common in smaller organizations; it can also be found in lower-level hierarchies of multilevel governance systems and occasionally even on the highest level of multilevel governance systems, with Switzerland and its system of direct democracy being the prime example.

The term community can be used generically for any institution where decisions with tangible effects are made. It could be an organized choir or a sports club. It could be a corporation pursuing commercial objectives. All of these institutions are organized similarly in that the executive decision-making is linked back and ultimately answers to those who make up that particular community, be it the members of the sporting club or choir or be it the shareholders as owners and, depending on the underlying philosophy, other recognized stakeholders, for example, the employees of a corporation if they have special rights, for example of representation in the governance institutions (Jäger et al. 2022; ILO). The communities at issue in this paper are the roughly 200 nation-states (UN membership 2023) and similar entities (UN non-member states) that make up the international community.[1]

Under the current international order, nation-states are regarded as sovereign entities. The legal understanding of sovereignty means no institutional entity is hierarchically superior to the nation-state. Contrary to an all-too-common usage of the term sovereignty (in the media, but not only there), the sovereign status does not mean that the nation-state is above the law. On the contrary, sovereignty is the core principle of public international law, and nation-states enjoy sovereignty as members of the international law community. Therefore, legal obligations incurred by states under public international law, such as treaty obligations or obligations flowing from customary international law, are not limitations of a state's sovereignty. Instead, they must be understood as expressions of that sovereignty.

In that sense, states are similar to individuals: the freedom to enter into contracts, which create obligations for the parties, is the ultimate expression of personal autonomy. The autonomy of individuals is the corresponding attribute to the sovereignty of states. Therefore, the freedom to contract is a core attribute of freedom in our societies: it gives individuals the right to shape and manage their legal sphere with others. The freedom to contract is the prime expression of the individual's personal autonomy; the freedom of states to voluntarily enter into legal obligations with other states or international persons is the prime expression of their sovereignty. A contract entered under duress is void; so is a treaty between states unless it is based on the state parties' free will (VCLT-Art. 52 1974).

For this reason, the notion of consent is so foundational in international law because the principle of consent is the translation of the notion of sovereignty into the real world. No state can become a party to any treaty without proactively signing and ratifying the instrument. Customary international law is different in that settled state practice does not require all states to have proactively demonstrated such practice. Still, by persistently objecting, every state can keep customary international law from coming into existence or amending its content. The states are the masters of international law: that is what sovereignty means in the legal sense.

In a world where public international law essentially functions as a normative framework securing the coexistence of the various states, the consent condition for creating international law was a sufficient link between the transnational sphere of the community of states and the national sphere of sovereign states.

The new challenges

Over recent decades the world has witnessed profound, if at times subtle, changes in international governance. Whereas public international law continues to serve as a legal order for organizing the mere coexistence of the states, the element of cooperation and collaboration between states has gained much more importance. This is evidenced by the rise of international organizations in general and international organizations with decision-making power in particular (Schimmelfennig et al. 2021).

This rise of international organizations is due to problems and challenges that cannot be addressed sufficiently nationally. Tackling these problems requires some degree of international governance. With international governance comes international – or, to use a more generic expression – transnational decision-making. Transnational decision-making can only exist if the transnational body that exercises these decision-making powers has been authorized by the collaborating states to exercise such powers. Logic dictates that any power yielded to a transnational institution is a power that does not anymore belong to the state which has yielded it: it has shifted to the transnational level to the degree that it has been yielded and for the time that it has been yielded.

Examples of such transnational decision-making can be found in international trade, finance, and economics. The World Trade Organization (WTO), as well as regional, bilateral, or multilateral free trade agreements, wield such powers vis-à-vis the respective parties of the underlying treaties. Another example is the International Monetary Fund (IMF) and the notorious conditionality attached to its emergency loans. The protection of the environment and the climate further illustrate the issue. Anything to do with sustainable development that involves transnational decision-making is a case in point and a very good one because sustainable development is not an isolatable, single issue. Instead, sustainable development goals transcend into many policy fields. International trade and the discussion of, for example, carbon border adjustment measures are one isolatable and technocratic example.

Institutionally, the European Union (EU), with its degree of political integration that comes close to that of a federated state and with its constitutional crises of late, provides valuable insight into these challenges because it is the only transnational entity with state-like powers: still a club of sovereign states and still an international organization in the legal sense but one that has transnationalized political and legal decision-making to a degree that very much resembles a federal state. The EU is the world's standard bearer in transnational power pooling to tackle transnational policy issues. So much so that, to various degrees, counterforces are now arguing for the renationalization and the weakening of transnational decision-making. With Brexit, these forces scored their first significant victory.

Policy areas most relevant for transnational decision-making

Climate change

The efforts to seek more collaboration in combatting climate change are perhaps the most significant example. It is evident that combatting climate change, from lowering greenhouse gas (GHG) emissions (mitigation) to adaptation measures, cannot be achieved by national policies alone. A transnational framework will be necessary if this problem is going to be addressed with any hope of achieving a measure of success. To imply that climate change as the ultimate sustainability problem could be tackled effectively merely by coordinating national efforts is not a maintainable position. That is not to say that climate change can only be tackled transnationally. It will require both – and perhaps foremost – national policy decisions, but it will also require transnational decision-making. The definitional approach to the various types of emissions and their classification as scope one, two, and three emissions (World Economic Forum 2022) illustrates that. So-called scope three emissions capture all emissions in a value chain from the perspective of a single entity such as a company. The scope three emissions of a coal producer in Queensland will cover the carbon footprint of everything required to extract the coal to the burning of this coal and the resulting carbon emissions in China or elsewhere. The transnational impact of this approach to emission allocation is evident, as is the transnational regulation necessary to address these emissions.

One part of that framework will have to be the creation of international legal obligations for states regarding GHG reductions and steps to be taken and financed to protect the most exposed populations. To the degree that such international obligations are created, national decision-makers are legally no longer in control of the relevant policies.

Climate change is an illustrating example for a second reason as well: the scope and extent of the necessary transnational decision-making itself is and will remain controversial. That is not surprising as the decisions to be taken internationally are no less political than on the national level. However, on the national level, these decisions are in a continuous feedback loop of democratic legitimization.

The Paris Agreement illustrates the problem impressively (UNFCCC 2015). To the chagrin of many (but by far not all), the Paris Agreement did not prescribe obligatory ("hard law") emission reduction targets to be met. In that regard, the agreement is limited to so-called "soft law", i.e., legally sounding language that, when interpreted, does not spell out breachable obligations. It did, however, obligate the states to formulate, report, and cyclically revise (upwards) such emission reductions. These self-imposed emission reduction targets were named "nationally determined contributions" (NDCs) (UNFCCC 2015, Paris Agreement, Article 3). The naming was not coincidental. The constitutional situation in the United States was the main reason for shying away from the creation of breachable international emission reduction obligations. International treaties can be concluded by the United States only if the US Senate agrees with a two-thirds majority (US Constitution, Article II.2.2). No proposal containing legally obligating emission reduction targets, for which domestic legislation would have been required, could have achieved this high-threshold qualified majority. Therefore, the Obama administration could only agree to an outcome that, under domestic constitutional law, could circumvent the need to ratify the Paris Agreement as an international treaty by the US Senate. So-called "executive agreements" do not require the participation of the upper house of Parliament in the US. Executive agreements rely solely on powers the Constitution has vested in the president (Dalton 2005, 780). As a result, the Paris Agreement could not (and did not) contain anything that required legislation or created financial obligations because the president controls neither legislation nor the purse. One consequence of this structure was that the subsequent office holder, Donald Trump, could revoke the executive agreement as easily as President Obama had the power to sign on and that President Biden could reinstate it again when he assumed office (White House 2021; Blinken 2021).

The setting of GHG emission targets of any significant nature will, directly and indirectly, have significant impacts on the content of all kinds of national policies concerning all sectors of the economy, from energy to transport and from coal to urban planning. One only has to look at the major climate change policy plans, for example, of the EU or Germany (EU-Commission 2019; German Federal Ministry for the Environment et al. 2016; Bröhmer 2020), to gain an idea of the scope of these plans and the profound impact on many national policy areas and, perhaps equally significant, on budgetary considerations both of government and private households. The German government decided at the end of April 2023 that fossil fuel–based heating systems can no longer be installed in private homes from next year. This will have a tremendous impact as there are only a few viable alternatives, the main one being heat-pump systems, which not only raise efficiency issues, especially in older buildings but will add between EUR 20,000 and 50,000 to the cost of a new heating system. Even if much of that cost will be subsidized, homeowners and renters will be left with hefty expenses.

International trade

The current difficulties in the multilateral international trading order, i.e., the difficulty in achieving meaningful advances on the multilateral agenda of international trade, are further examples of the difficulties of transnational decision-making and the consequences of the resulting governance deficit. In 2001 the WTO embarked on what became known as the Doha Development Agenda to further develop the multilateral trading system. The problems encountered, from agriculture to developing and least developed nations, were too big to be successfully tackled during a time of increasing criticism of multilateral policy approaches and resurging nationalism and populism (Jones 2021; Churche and Findlay 2022). One result of this impasse has been the proliferation of almost countless bilateral (between two states) and plurilateral (between several states) free trade agreements to the point that whatever trade liberalization has been achieved is now so complex, complicated, and administratively expensive that increasingly business is bypassing these agreements altogether because the benefits from the agreements are not worth the cost of extracting the benefits (Kloewer 2016).

Two issues are perhaps good examples to illustrate the transnational decision-making problem. Many of these new free trade agreements do not just address issues "at the border", i.e., the level of customs duties payable on the importation of certain products and their reduction. They specifically want to address "behind the border" issues impacting trade. "Behind the border" lies the realm of the state and the national decision-making process in the form of legislation and regulation. To the degree that such free trade agreements themselves undertake to impact the scope of national decision-making "behind the border", they inherently limit the decision-making scope of the domestic (national) process. Environmental or safety regulation often is part of the "behind the border" agenda in such treaty negotiations. Genetically modified foods, food additives, and the production or treatment of certain foods are examples in this area; these examples all have sustainability aspects.

Investor-state dispute settlement (ISDS) is a second illustrating example. ISDS is about investors from one country investing in a host country. ISDS clauses in treaties protecting such foreign investments (mainly to entice foreign investors to invest their capital) give these investors access to international arbitration as a forum to seek redress from the host country if subsequent regulatory changes in the host country impact the investment. Such ISDS clauses can be found in many so-called "bilateral investment treaties" (BITs), in the investment chapters of free trade agreements, and other treaties. The scenario often plays out in the context of legislative or regulatory changes in the host country that could impact the investment undertaken to a degree rendering the investment economically useless with a similar effect to outright expropriation. For example, a corporation could build and operate a nuclear or coal-fired power plant in another country in line with local law (the investment). Subsequent national legislation or regulation could then outright prohibit the further operation of this nuclear or coal-fired power plant or place such heavy restrictions on these installations that their further operation is economically no longer viable. Those critical of ISDS lament the interference of such transnational decision-making instruments (the investment or trade treaty containing the ISDS clauses) with democratic decision-making processes in the host country. The threat of being subjected to potentially considerable damages in commercial arbitration proceedings between the foreign investor and the host state could have chilling effects on the political processes in the host state. The foreign investor will often be a multinational corporation, and if the host state is a poor developing country, the political implications are even more apparent. Sustainability legislation – and ultimately all environmental or climate change regulation falls into that category – in areas such as energy policy, transport, or infrastructure are easily affected because international investors are often active in these areas.

Brexit

On an institutional level, the conflict between transnational and traditional nation-state–based decision-making has come to the fore notoriously as the underlying (main) reason for Brexit, i.e., for the United Kingdom leaving the European Union (EU) on 31 January 2020, 47 years after having joined the European Economic Community (EEC) on 1 January 1973. The drivers for the successful referendum were many; many different concerns affected those voting in favor of leaving the EU. However, the slogan "take back control" stood out as one, if not the central, argument used in various contexts. One example was the opinion that the UK could negotiate better free trade agreements on its own, whereas it had no power to do so as a member state of the EU. A second core motivator was the immigration of EU citizens into the UK. Free movement is a core right of EU citizens, and the Leave proponents wanted to regain control of national borders to be able to alone determine who gets to come into the UK and who must stay away. This, too, is at its core a "take back control" issue and, as such, an expression of dissatisfaction with the fact that in all those areas where the EU has jurisdiction to legislate or regulate – and there are many – Westminster is no longer in the exclusive "driver's seat".

Interestingly, the loss of power through transnational decision-making is not the only way of power loss that creates pushback. The notion of (human) rights, i.e., subjective and procedurally pursuable individual guaranteed spaces of personal autonomy not accessible for regulation and limitation even by a unanimous legislator, is another way to reduce power from those that otherwise hold it. This approach is often explained as limited government. The limit is to government power, and governments sometimes do not like it. Despite some "de-escalating" developments recently, there remains a chance that Brexit I might be followed by Brexit II – the withdrawal of the UK from the European Convention of Human Rights (Alleweldt 2019; Cowell 2021). The loss of power is also why Australia does not have a Bill of Rights. Opponents argue that such a bill would reduce legislative power, thus limiting democracy.

The illustrating case of the supranational European Union (EU)

The "supranational" (Lindseth 2017) EU is a template for the problems connected with transnational decision-making. As we speak, the conflict with Poland and a recent – comparatively minor – conflict with Germany and its Federal Constitutional Court (GFCC 2023) have put in question one of the core foundations of the transnational decision-making process – the supremacy of EU law over the law of the member states when and in so far as there are norm conflicts. That supremacy is necessary to maintain legal unity and to prevent a falling apart of the EU due to member states following EU law only if it suits them.

From its inception, what is now the EU and what started in 1957 as the EEC (EU-Founding Treaties 1957) had as one of its governing institutions a court – what is now the Court of Justice of the EU (CJEU). From its inception, the CJEU was given the power to interpret the provisions of the founding treaties (TEU), and the Court inferred from the founding treaties what is the only logical conclusion: if one creates a treaty-based legal system and, as part of it, a Court with the power to interpret the law created by and under these treaties, then that law must be equally relevant in all member states as interpreted by the CJEU. For that to happen, that law must be hierarchically supreme and, in case of norm conflicts, prevail over all laws of the member states:

> By contrast with ordinary international treaties, the EEC Treaty has created its own legal system which, on the entry into force of the Treaty, became an integral part of the legal systems of the Member States and which their courts are bound to apply. By creating a Community of unlimited duration, having its own institutions, its own

> personality, its own legal capacity and capacity of representation on the international plane and, more particularly, real powers stemming from a limitation of sovereignty or a transfer of powers from the States to the Community, the Member States have limited their sovereign rights, albeit within limited fields, and have thus created a body of law which binds both their nationals and themselves. The integration into the laws of each Member State of provisions which derive from the Community, and more generally the terms and the spirit of the Treaty, make it impossible for the States, as a corollary, to accord precedence to a unilateral and subsequent measure over a legal system accepted by them on a basis of reciprocity. Such a measure cannot therefore be inconsistent with that legal system. The executive force of Community law cannot vary from one State to another in deference to subsequent domestic laws, without jeopardizing the attainment of the objectives of the Treaty.
>
> *(CJEU 1964, Costa v. ENEL)*

The logic behind this is straightforward, but the political implications have ramifications to this day and are presently creating a potentially destructive constitutional crisis in the EU. The supremacy of EU law was never entirely accepted unequivocally by the member states in theory but, until recently, was always upheld in practice. The German Federal Constitutional Court (GFCC) always claimed that whereas the CJEU has the ultimate power to interpret the EU treaties and EU (legislated) secondary law, the ultimate power to decide which powers Germany had surrendered to the EU remained with the German court. The CJEU is the master of the treaties, but the GFCC is the master of the German laws ratifying these treaties. The two instruments – treaty and domestic ratification legislation of the treaty – are, of course, identical, but they are still different instruments. Potential conflicts between the two sets of instruments were always avoided because the GFCC refrained from taking the last step and quashing EU legal acts for (allegedly) overstepping the powers transferred by Germany to the EU.

However, more than once, the GFCC made no secret of the fact that it had severe difficulties with the CJEU. The first test was around the protection of fundamental human rights. They can be found in the constitutional bills of rights of the EU member states and the European Convention of Human Rights, another international organization of which all EU member states are also members. In the famous first "as long as decision", the GFCC held that for "as long as" the EU does not possess an adequate legal human rights instrument to protect individuals against unjustified infringements by EU acts, the GFCC would have to ensure that protection in Germany (GFCC 1974). Twelve years later, the GFCC rendered the second "as long as" judgment stating that the CJEU had, in the meantime, developed an adequate human rights protection level and that for "as long as" that is the case, the GFCC would not have to exercise its role as a guardian of fundamental rights in Germany regarding EU acts (GFCC 1986). It should be noted that both of those statements are conditional, i.e., the GFCC did not "surrender" the GFCC's self-perceived supremacy, which stands in stark contrast to the CJEU's understanding of the relationship between the two legal spheres.

Since then, the GFCC has increased its pressure. First, by using more threatening language in its judgments. The famous Maastricht decision of the GFCC, while coming to an EU-friendly conclusion by holding the new treaty (and with it the Euro as the new future currency) to be constitutional, maintained the GFCC's threat that it would not hesitate to qualify EU legal acts to be *ultra-virus* and thus void in Germany (GFCC 1993).

To this defense line against potential *ultra vires* acts attributable to the EU, the GFCC's judgment on the constitutionality of the Lisbon Treaty added a further line of defense – the so-called *identity review*:

> Furthermore, the Federal Constitutional Court reviews whether the inviolable core content of the constitutional identity of the Basic Law pursuant to Article 23.1 third sentence in conjunction with Article 79.3 of the Basic Law is respected (. . .). The exercise of this review power, which is rooted in constitutional law, follows the principle of the Basic Law's openness towards European Law (*Europarechtsfreundlichkeit*), and it therefore also does not contradict the principle of sincere cooperation (Article 4.3 Lisbon TEU); otherwise, with progressing integration, the fundamental political and constitutional structures of sovereign Member States, which are recognized by Article 4.2 first sentence Lisbon TEU, cannot be safeguarded in any other way. [. . .] This ensures that the primacy of application of Union law only applies by virtue and in the context of the constitutional empowerment that continues in effect.
>
> *(GFCC 2009)*

For the GFCC, transnational democracy is inherently limited, and national democracy remains the norm. The GFCC's identity alarm sounds when matters of citizenship, use of force, serious encroachments on fundamental rights, or significant budgetary implications are at issue. The exact demarcation line remains unclear. It is plausible to assume that the fuzziness of the demarcation is partially unavoidable. However, it is not entirely unwelcome. The fuzziness ensures that any doubt can be funneled into legal proceedings that allow the GFCC to step in if it regards what is brought before it as excessive, i.e., as "*ultra vires*" in the narrow sense or as threatening the constitutional identity of Germany.

A judicial hand grenade: the GFCC and "quantitative easing"

In 2020, the GFCC gave up its decade-long acquiescence to the EU's claim to absolute supremacy of its law over that of the member states. It used a highly technical and equally controversial monetary policy matter, commonly referred to as "quantitative easing" or QE. Critics refer to QE as money printing and point out inflationary dangers. Low interest rates hurt pensioners or savers, driving them into higher-risk investment options. These concerns had led to legal challenges to this policy in Germany before the GFCC. Before reaching its final decision, the GFCC, as mandated by the EU treaties, submitted its critical view to the CJEU under the preliminary rulings procedure. The GFCC warned the CJEU that it has serious concerns about the compatibility of the European Central Bank's (ECB) acts with the EU treaties. On 20 May 2020, the GFCC, after the CJEU had rendered its preliminary ruling in favor of the ECB for the first time, went into open conflict with the EU and declared the CJEU's judgment as being *ultra vires*. In the eyes of the GFCC, the CJEU's decision affirming the compatibility of the ECB's actions was "not comprehensible", and the CJEU's decision was, therefore, not covered by the EU Treaties and hence "*ultra vires*" (GFCC 2020).

Of course, the accusation of acting "incomprehensively" is an insult. Legally, it marked the first time an important national court went into open rebellion and rendered a decision departing from the foundational principle of the supremacy doctrine of EU law. Practically, the GFCC's deviation and, thus, rejection of the EU law supremacy doctrine had no effect at all. The matter was closed when in June 2020, the German Federal Parliament revisited the matter and, together with instruments provided by the ECB, resolved that the proportionality concerns expressed by the GFCC were now resolved and the GFCC in a different but related matter endorsed this view expressly (GFCC 2021). But the genie was out of the bottle. The supremacy of EU law had been openly rejected by one of the national judicial powerhouses of the EU. The nationalist dark forces were watching closely and with glee. A pillar of transnational decision-making is under threat again.

The bombshell: Poland, the rule of law, and the EU

The right-wing government in Poland has been pursuing policies domestically that are widely regarded as undermining the fundamental values of the EU as expressed in Article 2 of the Treaty of the European Union (TEU), which speaks to the foundational values of the EU, in particular, the concept of the rule of law (TEU, Article 2). The conflict with Poland (Cameron 2022) goes back to reforms instituted by the Polish government from 2015 onwards concerning the selection and supervision of judges and resulting powers to interfere with the independence of the judiciary. The conflict had already led to the opening of the so-called Article 7 TEU procedure against Poland, which could, in the extreme case, lead to the suspension of Poland's participation rights (not its obligations) in the EU institutions. One of the main concerns was the annulment of the judicial nominations to the Polish Constitutional Tribunal after the 2015 parliamentary elections in Poland and the appointment of new judges (EU Commission 2017). On 15 July 2021, the CJEU issued a judgment in which it declared that Poland had violated the TEU and the guarantees implicit in it concerning the independence and impartiality of the Disciplinary Chamber of the Polish Supreme Court, *inter alia*, "by allowing the content of judicial decisions to be classified as a disciplinary offence involving judges of the ordinary courts." (CJEU 2021) In other words, the CJEU took issue with how Polish judges can be subjected to disciplinary threats and sanctions merely for reaching the "wrong" conclusions.

The Constitutional Tribunal of Poland reacted on 7 October 2021 with a judgment that threw the gauntlet at the EU and created a major constitutional crisis for the EU (Petersen and Wasilczyk 2022). In it, the Constitutional Tribunal brazenly attacks the EU legal order by declaring Articles 1 and 19 TEU incompatible with the Polish Constitution and thus invalid (in Poland) insofar as these EU legal norms include the consequence that "the [Polish] Constitution is not the supreme law of the Republic of Poland, which takes precedence as regards its binding force and application" and insofar as these EU treaty provisions, therefore, mean that "the Republic of Poland may not function as a sovereign and democratic state".

The Polish Constitutional Tribunal's decision can only be characterized as a "judicial insurrection". The decision turns the relationship between member states and EU law on its head not only by flatly and generally declaring the supremacy of domestic constitutional law but by doing so with regard to the fundamental principle of the rule of law.

The example of Brexit and the whole complex of the EU and its constitutional structure and problems extend well beyond the narrower notion of sustainability in the sense of a subject matter–related concept. Both examples deal with institutional problems; subject matter issues such as a particular policy are not overly relevant and are used more as illustrating examples. A notorious example is the infamous Brexit bus claiming vast amounts of monies could be freed for the UK's National Health Service.

What is much more important is the institutional aspect of the principle of sustainability itself. It appears that the principle is not often looked at from this perspective. Decision-making processes and the necessary institutions themselves need to be sustainable. If they are not, the institutions will weaken or disappear altogether. If that happens, substance-based sustainability policies will likely suffer. Not inherently and always because it is conceivable that the same policy might find acceptance "at home" even if it were being opposed as a transnational policy. The feeling of being controlled is more challenging to sell than the feeling of being in control, even if the outcome is the same. But it is not the likely outcome. Proponents of policies of national preference tend to sit on the more removed ends of the political spectrum, right and left, and less so in the broad centrist middle. Names like Trump, Orban, Kaczynski, Le Pen, or Erdogan are openly playing this card. Many others are, perhaps less vocally and perhaps less comprehensively, at least sympathetic to such ideas. Yet others are merely waiting for their day to come. The sheer size and military or economic power (or both) of some countries, for example, Russia, China, India or the United States, makes it hard for them to accept and participate at equal footing in any co-operative transnational system that they do not fully control.

What follows?

The governance/legitimacy dilemma of transnational decision-making remains a major, if not the major, legal challenge in effectively tackling transnational problems. There are currently no silver-bullet solutions to this problem. The instrumentarium to address the problems of transnational decision-making is extremely limited. If and insofar as transnational decision-making is a necessary policy tool, abstention from it will result in potentially catastrophic governance deficits. Climate change is but one illustrating example. If, even in a closely integrated body like the EU, the conflict between the national center and federal periphery poses such difficult problems, how will the world be able to come together to achieve meaningful policy outcomes to address pressing and complex policy problems, for example, all those collectively referred to under the heading of Sustainable Development Goals?

If one looks at the problem from the perspective of federal or quasi-federal entities, the principle of subsidiarity is the most "prominent" instrument to balance the powers of the center and those of the periphery. That principle seeks to allocate decision-making to the lower tiers unless decision-making there cannot achieve the necessary results. The principle of subsidiarity is one of the foundational principles of the EU, and its idea is well expressed in Article 5.3 TEU:

> Under the principle of subsidiarity, in areas which do not fall within its exclusive competence, the Union shall act only if and in so far as the objectives of the proposed action cannot be sufficiently achieved by the Member States, either at central level or at regional and local level, but can rather, by reason of the scale or effects of the proposed action, be better achieved at Union level.
>
> *(TEU)*

This is an important constitutional principle, but its inherent and unavoidable weakness is that it will often be controversial at what level of decision-making objectives can be achieved "better". However, there are no persuasive criteria for what is "better" or "worse", especially not in the political arena. A person considered a climate change sceptic or an opponent of free trade will invariably be less inclined to support multilateral approaches in these policy areas than someone of the opposite persuasion. It is safe to say that the history of all federally organized structures has been that of a pendulum swinging from favoring more centralized to more decentralized decision-making. Currently, the international community and, with it, many federal entities appear to favor decentralized decision-making.

There is another reason for this: in federally organized states, transnational decision-making tends to come at the expense of the lower constituent entities of the federal state. The state will often be represented in the transnational context by a member of the federal government. Any participation of the constituent entities in national decision-making processes is at risk of falling by the wayside if the requisite policy matters shift to the transnational level. If Australia were a member of a transnational body such as the EU, the federal government in Canberra would acquire all legislative power necessary to meet its obligations under the external affairs power in section 51(xxix) of the Commonwealth Constitution. The Australian states would lose all of the powers previously held by them without a seat at the table, as their representation would be in the hands of the center in Canberra.

Concepts of democratizing transnational decision-making run into a myriad of problems. It is practically difficult, if not impossible, to democratize the proceedings in the UN General Assembly or the UN Security Council or any large international organization. The link to the individual member states is invariably achieved through national representation. In practice, that will be achieved through the executive branches of the respective central governments. Transnational decision-making, therefore, tends to take a particular toll on national parliaments that regard themselves as the seat of democratic legitimization. The more decision-making power is vested transnationally, the more critical the legitimization of the decisions becomes. Too little legitimization and the acceptance of those decisions suffers in tangible ways. The resulting governance deficit is then a consequence of the unsustainability of the decision-making framework (if there was one) or the cause of not setting one up in the first place.

The judicialization of transnational decision-making by subjecting the decisions to transnational courts is not without risk. In the EU, the constitutional framework with enumerated powers, the principle of subsidiarity and a well-functioning CJEU have not been able to avoid the problems described earlier. Even highly developed and established constitutional systems are increasingly having visible difficulties grappling with the, as some perceive it, overstepping of power by the courts, especially the supreme or constitutional courts. The United States has been struggling with this conflict for a long time; Israel is perhaps the latest illustrating example, with thousands of people protesting judicial reforms in the streets.

Judicial review is critical in supervising the exercise of power, but its major shortcoming lies in its inherent technocratic approach. It is akin to the rule of experts, where objective expertise is thought to create the necessary levels of legitimacy. Nobody in their right mind would deny the importance of expertise in decision-making. However, the assumption that empowering experts could create more acceptable policy outcomes is naïve at best. Judicial decision-making relies on acceptance even more than political decision-making. For example, it is unclear and, in fact, rather unlikely that highly controversial questions around climate change policy measures that can impact many people's daily lives can be decided by judicial organs trying to overcome and compensate for political decision-making deficits. Human rights–based legal challenges to force better climate change policies are, in that sense, not without risk.

Conclusion

Sustainability and sustainable development are – not only but to a significant degree – political concepts designed to influence the outcome of political processes and thus to influence and perhaps even predetermine decision-making processes. Political decisions, including those seeking to implement sustainable development goals, require legitimacy to attract acceptance; acceptance is a prerequisite for compliance. The principal instrument for achieving legitimacy today is still national decision-making, as lamentable as that may be. This reality is embodied in the concept of sovereignty.

National decision-making, however, is increasingly insufficient and needs to be complemented by transnational decision-making, i.e., political decisions reached in collaborative form by several (nation-)states in legally binding ways to create obligations. These transnational forms of decision-making face legitimacy challenges because they are inherently not national. In democratically organized states, the legitimacy problems flow from the fact that such decisions inherently diminish the role of the parliaments by strengthening the executive branches.

The interplay of constitutional and international law concepts is crucially important if one wants to understand how political goals such as sustainability can be translated into effective policy on the ground.

The relationship between policy goals and their concrete translation into tangible action, understanding the factors necessary to achieve effectiveness by creating legitimacy and acceptance, and the additional difficulties arising from the increasing necessity of transnational decision-making require educational attention. These concepts must be integrated into all forms of political-legal and sustainability-focused education.

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SECTION 9

Leadership in the sustainability education transition

"We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect".

(Aldo Leopold. Cited in the Foreword 'A Sand County Almanac'. Oxford University press. 1949)

This section considers the important role of universities in both sustainability ethics, values, and governance leadership and in sustainability education development through curricula and pedagogical innovation, new course development, and formal commitment to investment in sustainability curriculum. This section also discusses the importance of focusing on social and political agendas in sustainable development.

It explores the role that universities can play in developing 'future-ready graduates'. This role incudes curriculum and pedagogical development in sustainability education as well as reference to the support mechanisms required to ensure university leadership in this area.

Balser (see Chapter 9.1 in this volume) suggests that university leadership in sustainability education should include fostering scholarship in sustainability studies, new program development in sustainability education, and societal outreach and community engagement, which influence policies and transform behaviours and attitudes.

The role of university leadership in sustainability education is paramount and should be focused on a whole-of-institution response to sustainability education development and delivery, not just an institutional response to 'greening' campus infrastructure.

The Stockholm Declaration in 1972 formalised educational interest in environmental education. The Talloires Declaration in 1990 was the first higher education commitment to sustainability and environmental literacy, with a focus on teaching, research, operations, and community responsibilities in universities. The 'International Green Gown Awards' were initiated in 2004, together with the United Nations Environment Programme (UNEP) to recognize exceptional sustainability initiatives being taken by universities and colleges. The Times Higher Education Impact Rankings, which started in 2010, include a metric for ranking university research, stewardship, outreach, and teaching against the Sustainable Development Goals (SDGs).

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The role of faculty engagement in pedagogical development of sustainability and environmental studies is also important, as is the need for centralised planning and development of sustainability education content and pedagogy. The incorporation of sustainability into university graduate capabilities is another important driver for sustainability education development. In addition, extending sustainability education and research community of practice within the university is a valuable way of engendering commitment and ownership across the campus for sustainability education programs. Centralised planning of sustainability education targets and goals related to teaching and learning outcomes is also critical. Professional development programs for all staff in sustainability education and curriculum development would also greatly assist in the building of capacity in sustainability education.

Kuzich (see Chapter 9.2 in this volume) notes that to be effective educators in sustainability, academics require four kinds of knowledge: disciplinary content knowledge, sustainability content knowledge, pedagogical knowledge for the discipline, and pedagogical content knowledge for sustainability.

In this section, specific focus is given to sustainability education development and innovation across the world including in the United States, (see Chapter 9.1 in this volume) Australia, (see Chapters 9.2, 9.3, and 9.4 in this volume), India (see Chapter 9.5 in this volume), Indonesia (see Chapter 9.6 in this volume), Europe (see Chapter 9.7 in this volume), and China (see Chapter 9.8 in this volume). The role of sustainable development competencies is also explored in relation to European engineering education.

The important role of systemic thinking is also highlighted in connecting the various discourses in sustainability education that are provided and the need to cover the many separate, but equally important, multidisciplinary dimensions of sustainability education.

9.1
UNIVERSITY LEADERSHIP THAT ENABLES SUSTAINABILITY EDUCATION AND SCHOLARSHIP

Teri C. Balser

Key concepts for sustainability education

- Institutional, or operational, sustainability is different from academic sustainability.
- Institutional sustainability is under direct central control and faces fewer barriers to implementation than academic programs.
- Academic aspects of sustainability are controlled by individuals or faculty and by institutional factors such as governance and organizational structure.
- Barriers to implementing academic programs for sustainability are found at the individual level and at the institutional level.
- Individuals determine who they engage with and how they deliver their classes. They need to be supported in their efforts by the central administration.
- University culture and tradition are often barriers. Universities are organized around disciplines and tend to value "pure" rather than applied scholarship. There is a need to legitimize and operationalize engaged scholarship.
- Universities contribute to sustainability through discovery and research as well as through degree programs and classes. There is a need to better recognize and reward these efforts.
- Degree programs and classes need to include the space and types of pedagogy that build agency, so that students become responsible citizens in the world – taking action that effects positive change.

Introduction

The need to better understand sustainability and the environment has long been recognized (see Chapter 7.1 in this volume). In Section 7, Dr Tyler presents a historical overview of environmental studies and "environment." She recognizes the start as the 'conservation movement' in North America extending from the 1940s, through the 1950s and early

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1960s. During this time, university environmental studies programs were focused on literature and works such as Rachel Carson's *Silent Spring*, *A Sand County Almanac* (Aldo Leopold), and even Wendell Berry's works on land and land ethic. Other authors recognize two 'waves' of environmentalism that followed the conservation movement. The first, arising in the 1970s from concerns about runaway growth, was epitomized by the work of scholars such as Donella Meadows and Paul Ehrlich. Meadows's 1972 work, *Limits to Growth*, in particular set the stage for consideration of what comes after growth, birthing a second wave of environmentalism. The concept of 'sustainable development' came with the release of the World Commission on Environment and Development's report "Our Common Future" in 1987 (see also Tyler, Chapter 7.1, Macedo, Chapter 3.6, and Gough, Chapter 7.1 in this volume, and McGrail 2011 for additional detail).

As public attention and concerns related to conservation and environmental sustainability have arisen and evolved from the 1940s to now, so too have university programs, and research institutes emerged and changed in response to a growing need for environmental and sustainability education and research. In North America, environmental studies and environmental science programs led the way, with the first bachelor of science degree in environmental studies established at the New York State College of Forestry at Syracuse University in the 1950s, followed by a Middlebury College undergraduate degree program launching in 1964. A bit later, in the early 1970s, places like Dartmouth College (where Donella Meadows was a professor) and University of Wisconsin-Madison (home of Aldo Leopold) launched programs and institutes.

It can thus be argued that for nearly 75 years environmental education, ideally leading to an environmentally literate citizenry, has been recognized as essential to planetary sustainability.

Yet have we been successful? Are people more environmentally literate now than they were? Arguably, and unfortunately, they are not, by and large. In 2020, degree programs in environmental studies or environmental science in the United States had 9,869 graduates (Data USA 2022a), with a growth rate of 3.71%. Contrast this to business degrees in the same year: 840,116 degrees awarded, albeit with a –0.413% growth rate. Clearly, it will take some time to reach high levels of environmental literacy from environmental studies or science majors alone (Wolfe 2001). An alternative is university-wide requirements for graduation, which has potential but is still limited in scope (Moody and Hartel 2008). Another option for increasing environmental awareness and literacy is to embed environmental content across the broader curriculum. This has been called for but has been slow in progressing (Haigh 2005). A fourth option for extending the reach of environmental education is to offer single, introductory or foundation courses for students across all majors and that satisfy general education requirements (Wixon and Balser 2012). However, such integration of environment into general education has also seen slow adoption.

These are all viable ideas, yet they have had limited success. Both university governance and academic incentive structures act as barriers to innovation and expansion of environmental education and literacy. Degree programs, graduation requirements, and general education are subject to university governance and curriculum approval processes, while embedded content is dependent on the willingness of individual instructors or program coordinators.

This has been the case for environmental education, but in the past couple of decades, the focus in higher education has shifted increasingly from environmental studies and environmental education to sustainability, encompassing the different concepts of sustainability science and scholarship, sustainability education, education for sustainability, and education for sustainable development (Haigh 2005; Wiek, Withycombe and Redman 2011; Yarime et al. 2012). The definitions of each vary. For the purposes of this chapter I focus on sustainability scholarship (research and discovery), sustainability education, and institutional sustainability as distinct yet overlapping categories where university leadership can have an impact. I consider education for sustainable development to be a sub-category of sustainability education, subject to many of the same challenges and barriers, and thus will not address it separately.

Gough (see Chapter 7.2 in this volume) provides an excellent overview of the transition from the emphasis on environment to sustainability. It is largely coincident with the emergence of national and international declarations and policies related to environmental sustainability beginning in 1972 with the Stockholm Declaration. Wright (2002) provides an analysis of the various declarations in sequence, their adoption by postsecondary institutions, and consequent outcomes or actions. She tracks and details the emergence of both the concept of education for sustainability and the responsibility of physical institutions to behave sustainably. In effect, the shift in emphasis from environmental studies to sustainability corresponds to a change in focus from academic programs alone to consideration of greening the entire university enterprise (UNEP 2014). In other words, in addition to teaching about the environment or sustainability, university operations and grounds themselves must also be sustainable. Institutional sustainability and sustainability education thus became overlapping but important concepts (Figure 9.1.1). The significance of this distinction lies in the relatively straightforward nature of institutional sustainability versus sustainability education. Institutional sustainability tends to sit under university operations, facilities, and grounds, and as such is not subject to shared governance or faculty-driven decision making (Wright 2002; Brinkhurst et al. 2011). In addition, the metrics associated with institutional sustainability projects are fairly simple to obtain, tend to have revenue and grants associated with them, and deliver a clearer picture of 'success.' On one hand, this is a good thing. Many positive developments in campus sustainability have resulted from an emphasis on operational sustainability. On the other hand, institutional sustainability has arguably overshadowed or distracted from the more complex and challenging work of education, curriculum, and pedagogy, leaving institutions behind in outcomes related to these areas (Wright 2002; Timmerman and Metcalfe 2009).

Also of note, the change in focus from environmental studies to sustainability has not been uniformly positively received. Some believe that it has resulted in the marginalization

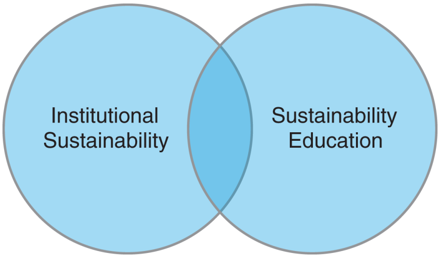


Figure 9.1.1 Higher education involvement in sustainability has two areas with overlapping goals and activities, but with differing levers and institutional controls.

or decentring of environmental education in favour of social issues or social justice (see Chapter 7.2 in this volume; González-Gaudiano 2006). González-Gaudiano (2006), referencing Suavé (1996), even goes so far as to point out that there are those who feel sustainability education to be “in harmony with the dictates of neo-liberalism” (Suavé 1996). A thorough analysis of this argument is outside the scope of this chapter, but I raise it here as a highlight to another of the barriers to effective innovation and adoption of sustainability across the university curriculum: vagueness of purpose and ambiguous definitions (González-Gaudiano 2006; Timmerman and Metcalfe 2009).

Controversy notwithstanding, sustainability education is intended to be an umbrella or framework that encompasses environmental education. It is therefore reasonable to ask whether sustainability education is also subject to the same barriers and challenges and whether it has been any more successful in accomplishing its academic goals.

And what are those goals? One goal might be an increase in the number of graduates with credentials in sustainability. If we look again at Data USA, we see that in 2020 sustainability studies had 2,645 graduates, with a 20.6% growth rate (Data USA 2022b). Graduate attainment is clearly growing, but the numbers are still very low. Another objective might be measurable progress against the UN Sustainable Development Goals (SDGs). Here we might look at the rise of the Times Higher Education Impact Rankings as a way to measure increased attention on, and attainment of, the SDGs. Developed in 2018 and launched in 2019, the Impact Rankings attempt to capture the impact of universities on society by measuring their progress against the SDGs Times Higher Education 2022). The idea has caught on, and the fourth edition of the rankings, published in 2022, included more than 1,500 institutions from 110 countries and regions. The Impact Rankings ask universities to report on the extent to which they are embedding and embodying the various SDGs and what the outcomes are they have achieved for each. The value and importance of rankings in general as a means for creating action is a somewhat controversial topic, but the increase in engagement does imply a growing awareness of sustainability goals as valuable.

However, graduates and rankings aside, the ultimate goal of sustainability education is arguably the same as that for environmental education – the production of environmentally and sustainability literate and active citizens in order to support the maintenance of life on the planet indefinitely. This means fostering scholarship and discovery in sustainability studies, new program development in sustainability education, and outreach to all aspects of society that influence policies, behaviours, and attitudes. It is a bold goal, and a critical one.

How do we get there? As with environmental education, there are barriers and challenges. Sustainability, unlike environmental education, also has a focus on operational or institutional sustainability, such as net zero buildings, LEED certifications, or utilities reduction programs (University of Calgary 2022). These are distinct in their purpose and nature from sustainability scholarship or education, and generally fall under central control, outside of faculty governance policies and processes (Yarime et al. 2012). They can become a detriment to sustainability education or scholarship if the focus on institutional sustainability distracts from, or overshadows, academic initiatives – or if a campus believes that institutional greening is all that is needed and fails to do more (Wright 2002). Institutional sustainability is attractive: the direct top-down control makes it easier to see gains or successes in implementing policy (Timmerman and Metcalfe 2009). And it is easier to gain board- or executive-level approval for initiatives related to university operations, as these are often linked to savings or financial gain (Moore et al. 2005).

The bigger challenge is to embed or operationalize sustainability education and scholarship. An overfocus on operational sustainability can pull attention and resources from academic efforts, but there are also a number of other barriers and challenges to sustainability scholarship and education. Next I outline a number of them and consider ways to overcome them.

Barriers and challenges

Numerous authors have broached the topic of barriers to wide-scale adoption of sustainability scholarship and education, many of whom have already been cited here. Moore (2005a), in a case study focused on the University of British Columbia, lists four barriers: disciplinarity, competition, misdirected evaluation, and unclear priorities. Michael Crow (2010) likewise identifies entrenchment in disciplinary silos as a barrier and calls for wholesale institutional transformation to truly effect change related to sustainability and sustainable development. The need for large-scale university reform or transformation, whether focused on disciplinarity, curriculum, or governance, is a theme also echoed in the work of Pidlisnyuk (2010), Brinkhurst et al. (2011), Kurland (2014) and Kuzich (see Chapter 9.2 in this volume). Moore et al. (2005) identifies a need to reimagine the reward structure and recognition of work in sustainability education and scholarship.

In all, barriers and challenges can be categorized as individual, institutional, or intrinsic (Table 9.1.1), with each category requiring distinct approaches and strategies. On an individual level the motivation, attitude, or experience of a given instructor can influence sustainability in the academic mission (Haigh 2005; Chawla and Cushing 2007; Timmerman and Metcalfe 2009; Pappenfuss et al. 2019). The faculty role in pedagogical innovation and sustainability education leadership is critical and will be explored further later.

Barriers and challenges that manifest at the institutional level may be financial, structural, or cultural. Financial and structural hurdles are fairly straightforward. Financially, if an institution is committed to sustainability and sustainability education, it can choose to invest in operational sustainability and green campus programs or in educational programming related to sustainability of environmental education. The extent to which a university is committed to sustainability education versus simply operational sustainability is directly indicated by its budget and strategic plan (Moore et al. 2005)

Structural barriers include university governance and organization. Moore et al. (2005) describe how the organization of universities into disciplines not only prevents the type of curricular collaborations necessary to address sustainability challenges (as described by Crow 2010) but also determines funding allocation. There is thus both a financial and structural disincentive for transdisciplinary programs. Other structural barriers include overly complex or cumbersome approval processes for new programs and/or promotion and tenure processes that fail to recognize or value interdisciplinary work.

Cultural barriers include disciplinarity and disciplinary identity, as well as attitudes toward applied or engaged scholarship. To start, sustainability work is inherently transdisciplinary (Crow 2010). This sits in contrast to the historical dominance of academic disciplines. The identity of scholars or academics is typically bound to their discipline or field, and their first loyalty is often to a disciplinary professional society. They are evaluated (judged) by their disciplinary peers and promoted by their departments, schools, or colleges on the basis of disciplinary productivity. Small wonder, then, that they are reluctant to engage in work that has no clear disciplinary foundation. This is true of all inter- and

Table 9.1.1 Barriers and challenges at different levels

	Barrier/challenge	*Example*	*Consequence*
Individual	Attitude	Instructor is dismissive or resistant to learning new things	SE is not valued or incorporated into classes
	Experience/ knowledge	Instructor is unaware of basic concepts in sustainability or EE	SE cannot be taught properly
	Motivation	Instructor lacks incentive to teach sustainability or faces disincentives	SE will not be embedded or integrated into classes or programs
Institutional	Financial	Resources are denied or unavailable	Inability to introduce or increase ESD programming
		Budget models allocate funding to disciplinary programs	Competition among units and failure to support sustainability education
	Structure	University is organized around disciplinary departments and decisions are disciplinary	Reduces likelihood of collaboration, promotes allegiance to the discipline
		Governance model for new program approvals is overly complex or cumbersome	Approvals take too long or don't happen at all
		Promotion criteria do not support engagement in transdisciplinary or applied scholarship	Disincentive to participate in sustainability scholarship or education
	Culture	Sustainability is not valued or is resisted in some way	Sustainability as a concept is resisted or attacked
		Disciplinary organization creates perception of competition or antagonism between/among units	Reduced engagement in sustainability activities
Intrinsic	Nature of sustainability education	Transdisciplinary, complex, shared – doesn't sit neatly in one area	No one 'owns' it and thus no one is responsible
	Purpose	Extrinsic focus or applied (not valued by traditional academe)	Traditional scholars resist or dismiss it
	Alignment	Definitions or terms are contested or unclear	Confusion about what it is and why it's important

transdisciplinary work but seems to be a particular barrier for sustainability scholarship and education (Moore et al. 2005; Crow 2010).

This reluctance may be explained the fact that sustainability is not only inherently transdisciplinary but is also inherently translational, or 'applied.' Academic culture has long looked down on application, treating it as 'second-class' scholarship. The fundamental point of sustainability is its applicability to human and planetary life, but it takes a particular type of scholar to embrace this in the face of what Michael Gibbons calls "Mode 1" knowledge production – or "pure" ivory tower–generated scholarship (Gibbons et al. 1994).

To expand sustainability scholarship and foster sustainability education, we must instead embrace "Mode 2" knowledge production. This is knowledge generated within a broader, transdisciplinary, social, and economic context (Gibbons et al. 1994). We might also call it "community engaged scholarship." Ingrid Waldron's work on environmental justice in Nova Scotia provides a powerful example of community engaged work related to sustainability (Waldron 2018). Her research on the pollution and poisoning of Mi'kmaw and African Nova Scotian communities led to a successful documentary film, and ultimately looks likely to result in changes in federal policy (CBC 2021). The work has also been translated into a school lesson plan (Law Lessons 2022). This example illustrates the critical importance of community engaged work and is what sustainability scholarship is ultimately all about: affecting policy, education, and thus behaviour. But Waldron should not be the exception, and the work shouldn't require the attention of award-winning actors-as-producers to be effective. Every university can foster true community-engaged scholarship. The land grant university system in the United States is a case in point (Gavazzi and Gee 2018). 'Land grant' refers to the mechanism by which the federal government funded the creation of public postsecondary institutions. In 1862 the U.S. House of Representatives granted 30,000 acres of federally controlled land to each state for the purpose of financially supporting a system of public universities (Gavazzi and Gee 2018, 37). At that time, a college degree was largely restricted to wealthy, white, urban males (Gavazzi and Gee 2018, 43). The passage of the Morrill Act of 1862 was an attempt to rewrite the social "covenant" between colleges and communities to include rural areas and a broader range of learners – particularly those seeking degrees in agriculture, the "mechanic arts" (engineering), and military tactics. In effect, to create a university "of the people, by the people, and for the people" (Gavazzi and Gee 2018, 36). Of even greater relevance to this chapter, Gavazzi and Gee go on to say:

> we argue that the mutually beneficial relationship between the land grant university and the greater public good – seen explicitly in the terms of the array of benefits derived by community stakeholders and society itself – should guarantee that these precious resources, properly stewarded, will never be in danger of perishing from the earth.
>
> *(Gavazzi and Gee 2018, 37)*

This sounds quite a bit like a definition of sustainability, but more importantly also underscores the importance of the idea of *relationship* – the relationship between university and the public it serves. The idea of relationship, and the social contract, has evolved over time. Public assessment of university's worth has shifted more and more away from the public benefit of higher education (e.g. an informed, literate populace) to private benefits (e.g. career prestige and personal income). This has been accompanied by a reduction in public funding, placing substantial financial pressure on universities and students alike (the reduction in public funding is usually offset by increases in tuition and fees). Increasingly, higher education has become commercialized or corporate – to the dismay of many scholars and proponents of postsecondary education (Bok 2003; Spooner and McNinch 2018; Thorp and Goldstein 2018). With these shifts has come increasing emphasis on careers and employability, and the idea of students or learners as 'customers.' This mentality serves as a further barrier to sustainability education: the success of new programs is not reliant on their long-term value or value as a public good, but instead on their ability to compete for students and deliver short-term career benefits (Hungerford and Volk 1990; Chawla and Cushing 2007).

Both examples highlight the idea and importance of 'community engagement.' Ingrid Waldron's work is a specific example, and the evolution of the land-grant ideal provides another. In fact, in 2010 the Carnegie Foundation (founded by Andrew Carnegie in 1905 to create the first pension system for university professors and that later developed the Carnegie Classification for Research Intensity) developed a new classification, the Carnegie Classification for Community Engagement (Gavazzi and Gee 2018, 53–54). Applications for the classification demonstrate how community engagement is built into every aspect of the university's mission and functions.

All of this is simply a lengthy way to say that in order to foster true and lasting sustainability scholarship and education – beyond simply academic – a university must foster authentic community engagement. In the United States, in the land-grant universities, this takes the form of 'extension,' or outreach, as established by the Smith-Lever Act of 1914 (Gavazzi and Gee 2018, 40). For colleges or departments receiving Smith-Lever funding, extension is operationalized by assigning a percentage of a faculty member's workload in their employment contract. Their productivity and success are then evaluated as part of the regular tenure and promotion process, using criteria developed specifically for the type of engaged scholarship Extension work embodies. While this has a long history in the United States for land-grant institutions, it is only more recently that others have tried to develop a broader concept of scholarship, similar to the social-utility or service dimension inherent in the land-grant mission. The Gibbons et al. (1994) concept of Mode 2 knowledge production is one such, and perhaps more widely known is the model proposed by Ernest Boyer, then president of the Carnegie Foundation. In his 1990 book *Scholarship Reconsidered*, Boyer articulates four domains of scholarship: discovery, integration, application, and teaching (Boyer, 1990). The scholarship of discovery is the "classic" academic mode – a commitment to knowledge for its own sake and contribution to the body of human knowledge. This is akin to Gibbons's Mode 1 knowledge production. The scholarship of integration calls for putting "meaning to isolated facts" and building bridges or connections across disciplines. This is the type of work needed for sustainability scholarship. The scholarship of application represents a move away from Mode 1, or traditional scholarship, toward engaged scholarship, allowing social concerns to serve as a defining factor for investigation and calling for knowledge to provide tangible benefit to individuals as well as institutions. This is the domain arguably most needed for sustainability scholarship, and education, and is akin to Gibbons's Mode 2 knowledge production. Finally, the scholarship of teaching calls on university faculty members to treat their instructional craft with as much rigor and curiosity as they treat their efforts at research or knowledge production. This is essential for innovation and lasting impact in sustainability education.

Ultimately, the challenge is adoption of the concepts and also their operationalization as part of faculty evaluation for tenure and/or promotion. The Boyer model was never intended as a template for operationalization. It is too complex to attempt to build criteria around multiple dimensions. Neither is Gibbons et al. (1994) intended as a template. Both offer an intriguing perspective and a theoretical lens that has gained traction and/or recognition, but don't provide sufficient tangibility for more than use as a guiding principle.

What is needed is a way to operationalize the idea of engaged scholarship; to assign criteria that allow for recognition, evaluation, and acknowledgement of accomplishment. Figure 9.1.2 illustrates a simple two-dimensional framework for community-engaged scholarship that could be used as part of discussions or workshops to foster adoption and operationalization. The two axes reflect two dimensions of university scholarship, asking: 1) Who determines the topic or the need? Is it the researcher, or a stakeholder group? (In this

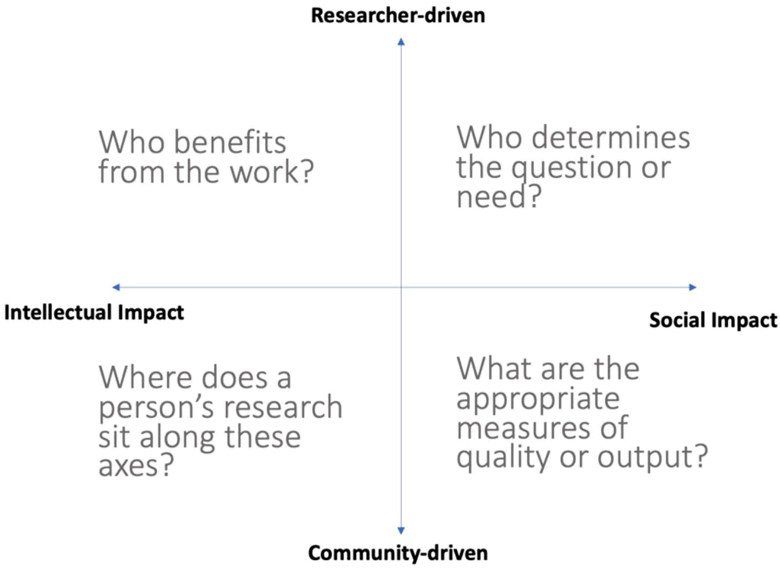


Figure 9.1.2 A simple framework for community-engaged scholarship.

case, I've shown community, but it could be students, industry, or government as stakeholder that is driving the work.) And 2) Who benefits from the work? Is it the researcher primarily, through intellectual impact? Or is there a broader societal impact? These key questions are shown above the horizontal axis. Below the axis are two questions related to operationalization and evaluation. Where does a person's scholarship sit (and thus what percentage of their workload should count as 'community-' or 'stakeholder-engaged'? And what are the appropriate measures by which to evaluate such work? Community-engaged work tends to take place on a longer time scale, relies heavily on long-term relationships, has fewer funding sources, and very different publication outlets as well as overall outputs. These are important questions to address, and once they have been, a barrier to sustainability scholarship can be removed.

To this point, the barriers discussed have been more focused on sustainability scholarship than sustainability education. This in some ways makes sense. Education and scholarship are intertwined in postsecondary education, and many of the barriers that inhibit sustainability scholarship likewise inhibit sustainability education. Thus we must remove the structural (incentives and rewards), cultural (disciplinarity and the primacy of Mode 1 knowledge production), financial (budgeting that supports and includes sustainability), and attitudinal (purity of disciplines and aversion to applied science) barriers to sustainability scholarship if we are to foster sustainability education.

Ultimately, that means whole-of-university transformation, arguably the most complex barrier – and equally arguably the most important (Moore et al. 2005; Crow 2010; Pidlisnyuk 2010). In order to increase the validity and volume of sustainability scholarship, we must recognize and reward it – which means altering promotion criteria. To alter promotion criteria, we have to not only alter academic culture (get past the primacy of disciplines), but we have to work our way through university governance systems (Kurland 2014). In some countries, such as the UK and Australia, that may also mean changing a national standard such as the Research Excellence Framework. In the United States or Canada, it means working through a shared or bicameral governance system whereby change in policy or procedure must work its way up through faculty councils, senates, and boards. In some cases, sustainability education accreditation may also be an issue (see also Chapters 3.2, 9.6, and 9.8 in this volume). In order to generate acceptance of changes to promotion criteria, we must also generate acceptance of a wider range of scholarship, one that includes community-engaged work, or Indigenous scholarship. To be successful in this, we must also foster a sense of academic humility and commitment to Mode 2 knowledge production, community engagement, and two-way partnerships.

In general, this type of transformation is driven by strategic planning and the vision of the president/chancellor or vice chancellor. But ideally it employs both bottom-up and top-down approaches. Leadership is needed from above, below, and the middle (Moore et al. 2005; Brinkhurst et al. 2011)! Executive support for initiatives and individual champions for the work. I describe the contribution and role of the various actors a bit more later.

Finally, a last set of barriers for sustainability scholarship and education can be called 'intrinsic,' or those posed 'existentially' by their nature. As discussed earlier, sustainability is inherently transdisciplinary and applied. It is also enormous in scope and alarming in purpose. The stakes are very high; this is work that is, in fact, intended to save the world (Chawla and Cushing 2007; Pidlisnyuk 2010). It requires a focus on social change that is outside of academic control. To be truly successful, sustainability scholarship and education must result in demonstrable change in behaviour across every aspect of human existence: politics, policy, law, education, capitalism, commerce, technology, etc. To say that this places a burden on education and scholarship for sustainable development is an understatement! Perhaps related to the enormity of the task, or at least complicating it, is vagueness in definitions and terminology as well as ultimate purpose of the work (see Chapter 7.2 in this volume; González-Gaudiano 2006). Further complicating things is the nebulous nature of how to measure success – in order to track institutional change, we need data, we need metrics and evidence of outcomes. There are countless arguments about the nature of data and danger of metrics (e.g. Schryvers 2020), but the fact remains that data are necessary. For example, how do we know our efforts are working? How do we know what graduates from programs in sustainability go on to do?

Addressing the challenges: leadership across the institution

No matter what the barrier, it takes leadership to overcome it. This can be the informal leadership of committed individuals on the faculty or staff, or it can be formal leadership from executive or senior levels. In this section I provide an overview of the role each can play in expanding and supporting sustainability scholarship and education.

The role of formal (senior and executive) leadership and governance

In the North American context, academic senior leadership includes deans and associate vice presidents or vice provosts. Executive leadership includes vice presidents and the president/chancellor or vice chancellor. Individuals in these roles have formal responsibilities that can influence the success of sustainability scholarship and education goals. These include roles related to university budgeting, policy, quality assurance, and governance (Box 9.1.1).

Box 9.1.1 Formal leadership and governance influence on sustainability

The senior and executive leadership portfolios

- Adopt declarations or sign charters on behalf of university (president)
- Drive fundraising efforts to support sustainability (president, deans)
- Drive strategic planning that includes sustainability (president, provost, deans)
- Oversee quality assurance; academic program and unit reviews (provost)
- Champion or call for new academic programs (provost, deans)
- Allocate university resources/budget for sustainability goals (provost, deans)
- Foster collegial and collaborative engagement among university stakeholders (all)
- Champion and support innovative ideas (all)
- Call for review of university policies and procedures to ensure alignment with sustainability goals (provost, president)
- Remove or lower barriers and disincentives to sustainability goals (president, provost, deans)
- Inspire, motivate, and influence culture and decisions (all)
- Empower faculty and students as change agents (president, provost, deans)

University governance (e.g., faculty, senate) influences sustainability with responsibility for

- Approval of new programs
- Approval of program or unit reviews
- Approval of policies and/or structural changes

Approval of criteria for tenure and promotion (initiated by deans or provost, and approved by faculty senate)

The role of faculty and staff

Formal leadership can influence the context for sustainability efforts, can call for initiatives, can request policy change, and can empower and reward champions. But ultimately it is the champions, the individuals and teams, who do the work. In sustainability *scholarship* their role is straightforward: they form the partnerships, seek the funding, and do the work in the field, with communities or in laboratories. However, their role in curriculum and pedagogical innovation is more nuanced.

In short, curriculum is 'owned' by the department, school, faculty, or university. Thus, as described earlier, university leadership and governance play a critical role in sustainability education by their control over curriculum development and approval. Content and pedagogy, in contrast, are generally 'owned' by the individual instructor. This individual instructional agency and efficacy is critical – instructors have tremendous influence on whether material in a given course is retained, acted upon, or has any impact at all. For sustainability education, it also matters whether instruction impacts attitudes and actions. We want our students to change. This is a greater challenge than passively delivering a content-focused large lecture class, and hoping students pass a three-hour final exam.

Curriculum and pedagogical innovation

At the start of this chapter, I articulated four ways that universities have sought to increase environmental awareness and literacy: 1) environmental studies or science majors, minors, or certificates; 2) inclusion as part of university-wide requirements for graduation; 3) embed environmental content across the broader curriculum; and 4) offer single introductory or foundation courses for students across all majors that satisfy general education requirements.

These same four ideas are also the actual means for increasing sustainability awareness and literacy. In addition, there is a fifth area specific to the broader goals of sustainability, related to the necessity of informal or 'outreach' education that benefits a broader range of learners. Rewritten, then, the list looks like this:

1. Sustainability studies majors, minors, or certificates
2. Inclusion of sustainability as part of university-wide requirements for graduation
3. Embed sustainability content across the broader curriculum
4. Offer single introductory or foundation courses in sustainability for students across all majors and that satisfy general education requirements
5. Provide programs of informal or public education that foster awareness and action related to sustainability

These are all part of university offerings or curriculum – yet the underlying learning goal, and the tangible need, is to effect wholesale societal change. This requires practitioners who are skilled and innovative at curriculum design as well as pedagogical delivery and public outreach or engagement.

Curriculum

Practically speaking, curriculum at a university includes the development of new degree programs or minors, certificates or microcredentials, continuing education or outreach programs, and courses that are part of general or core education. Curriculum might also refer to courses that are part of a larger programmatic whole. Curriculum also refers to the content and sequencing of content in a class or program.

Initiatives in sustainability education can be mapped onto a two-dimensional grid that illustrates the dimensions of sustainability in higher education (Figure 9.1.3.) The vertical axis runs from purely academic to purely operational. Sustainability curriculum falls on the academic side, while campus greening initiatives or utilities reduction programs would fall on the operational side. The horizontal axis illustrates the continuum from sustainability offered with a technical lens to a social or ecological lens. Programs developed in engineering or architecture would fall on the technical side. Programs in social or ecological sciences would fall on the other side. Programs developed for business might fall somewhere in between. There is value in knowing where on the map a given initiative falls in terms of resource allocation, strategic planning, or marketing. It is also important to consider where various initiatives sit in terms of controls, timing of implementation, and champions for them. Operational initiatives tend to be under central control with defined metrics and can happen relatively quickly, while academic initiatives are subject to academic governance or individual efforts and might take years to be approved and launched.

The framework in Figure 9.1.3 helps us map curriculum initiatives but doesn't address *what* is delivered in a given program. Not surprisingly, opinions vary, but some themes

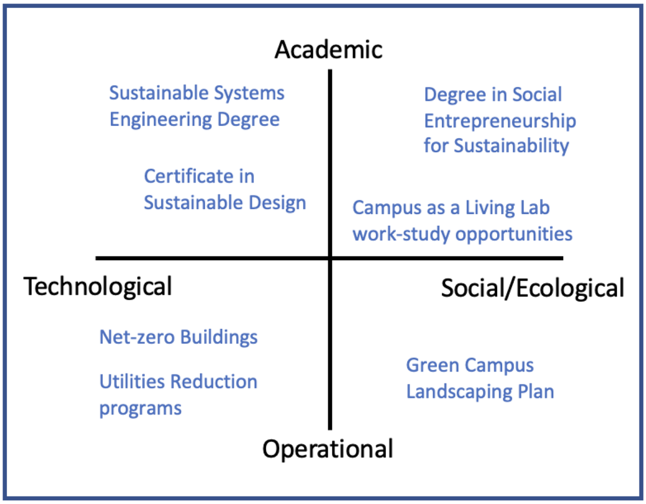


Figure 9.1.3 Dimensions of sustainability in higher education with example initiatives mapped to the quadrants.

emerge. In general it is agreed that the ecological and environmental problems we face are unique in scope and destruction, and as such we must create an "ecologically literate and environmentally sensitive populace," and thus curriculum must be designed so that students can (and will) extend or translate their learning beyond the classroom (Blumstein and Saylan 2007). This idea is reinforced by Kuzich (see Chapter 9.2 in this volume). Blumstein and Saylan (2007) offer seven ways to support this, such as emphasizing content related to consumption patterns, worldview, legislation, and critical thinking. Others feel that sustainability curriculum would be improved by greater inclusion of global or international, rather than local or regional, perspectives (Haigh 2008; Savelyeva and McKenna 2011).

Ultimately, in order to grow sustainability education and create literate and engaged citizens, curriculum needs to move beyond traditional approaches. Curriculum innovation can include the content that is included, the sequence of topics presented, or the 'structure' or extent to which content is taught in traditional degree programs or is made modular ('stacked' degrees or 'microcredentials'). Innovation can also include delivery; pedagogical models that engage and empower students and allow the translation of their learning into action.

Savelyeva and McKenna (2011) introduce a global seminar curriculum model to demonstrate a model of "participatory curriculum." The model is implemented from the top and bottom, both – facilitated by faculty and run by students from 40 universities around the world. It is their hope that the model represents an emerging shift towards a new paradigm in teaching and learning for sustainability.

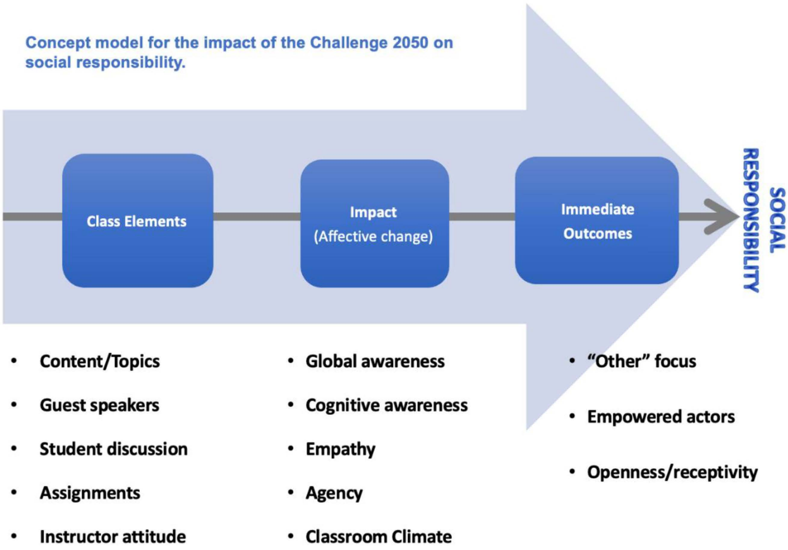
Likewise at the University of Florida, we developed a new program using the pedagogical model of challenge-based learning. The "Challenge 2050" had the intention to create agentic, literate citizens committed to sustaining human wellbeing beyond 2050 (Andenoro, Sowcik and Balser 2017; Balser, Bigham and Andenoro 2014). In particular, in the first course of the program, we used challenge-based learning rather than traditional lecture to engage and empower our students. Box 9.1.22 describes the Challenge 2050 and its results in more detail.

Box 9.1.2 Humanity's 2050 challenge

Complex and adaptive challenges threaten human wellbeing and sustainability. However our graduates often lack capacity and/or commitment to address these challenges. We offered a new course where students are given ownership of their learning in confronting an authentic and complex challenge. Students address the problem of how to feed 9–11 billion people sustainably by 2050 and present their solutions to state industry leaders.

One of the most important and exciting programs in the Challenge 2050 was a (then new) approach to college teaching and learning; a certificate in food security and global leadership that challenged students to work in teams, coached by industry and academic professionals, and propose a solution to the problem of feeding 9 billion people sustainably by 2050. Students learned about five interacting systems (food, environmental, economic, social, and health) and explored how various disciplines contribute to the challenge of sustainability. In addition, through course work that included interaction with industry representatives, individual study, and travel (both domestic and international), certificate students experienced the challenges faced in rural and urban areas and developed their personal capacity for leadership and entrepreneurial thinking. They also developed as professionals: by carving out a piece of the overall challenge and being held accountable at the end of their program for presenting a product/solution (e.g. a policy recommendation or a piece of research) to an authentic audience (a legislative committee, an industry board, a research panel).

The ultimate goal of the Challenge 2050 program was to prepare students to think critically about real problems and clearly communicate how products and processes affect sustainability. It was intended to create a workforce enabled to innovatively meet societal challenges, equipped with a skill set to be effective in the diverse workplace. The results were compelling. The design and delivery of the course influenced students' sense of social responsibility and their ability to take action. The model is shown in the figure.



Pedagogy

From the examples provided, it could be argued that innovative pedagogy is equally as important or more than innovation in general curriculum. Curriculum determines broadly *what* is taught, in what order, and when – pedagogy determines *how* things are taught and can have a profound impact on learning: learning that lasts, learning that is translated into action, and learning that leads to true change. This is what is needed; if we are to sustain human (and other) life on the planet, we need learning that leads to broad social change.

Importantly, unlike curriculum, pedagogy and pedagogical choices lie within the purview of the instructor. Pedagogical innovation, thus, is driven by the instructor. This is critical. A university senate may or may not approve a new program, or sustainability might or might not be part of a president's strategic plan, but no matter what, an instructor can choose to include content related to sustainability and can choose to deliver in an impactful way. However, this requires that instructors are aware of pedagogical options, and that they are literate themselves in the core concepts of sustainability (Cotton et al. 2007; Pidlisnyuk 2010).

Awareness (and use) of pedagogical best practices is the focus of the field of university faculty development (see Sorcinelli et al. 2006 for an overview and short history of the field). During the past 50 years or more, approaches to faculty development have evolved in response to external pressures. There is growing recognition of the need to transform our approaches to teaching to better reflect the rapidly changing world around us and the reality of how learning works (Handelsman et al. 2004). Sustainability education, with its need for transdisciplinarity and its high-stakes nature, is a perfect reflection of this need. Papenfuss et al. (2019) write that the goal of sustainability education is to "transform and emancipate" students, allowing them to become "innovators that change existing structures and systems." They argue that this requires pedagogies of transformation and emancipation, which are at odds with the traditional university focus on transmissive and instrumental pedagogy. Moore (2005b) likewise questions the readiness of universities to provide transformative experiences and new pedagogies, noting that these are necessary for sustainability education.

A comprehensive treatment of faculty development for pedagogical innovation is beyond the scope of this piece. Dozens of conferences and workshops are offered annually dedicated to the topic of pedagogy. There are tens of books published about the same. However, in brief, Box 9.1.3 indicates some of the choices an instructor has in designing courses. Any of these can be used to teach sustainability content and concepts. The examples given earlier by Savelyeva and McKenna (2011) and Balser, Bigham and Andenoro (2014) demonstrate active, experiential, participatory, authentic, and challenge-based pedagogy.

Box 9.1.3 Examples of pedagogical choices an instructor can make

- Active or experiential learning
- Service learning
- Flipped classrooms
- Case-based instruction
- Challenge-based learning
- Groups and group work
- Ungrading
- Concept inventories

Environmentally responsible behaviour

In the end, the goal of curriculum and pedagogical innovation for sustainability is to transform societal attitudes and behaviours. The focus should not be to employ graduates within a year of completion, but to create social actors capable of 'saving the planet.' This is embodied in a body of literature related to the concept of 'environmentally responsible behaviour (ERB),' or 'pro-environmental behaviour.' It is not as prominent in the discourse about sustainability, oddly. Ultimately, though, we want learners to take action – we want learning to influence behaviour. Hungerford and Volk (1990) review a number of models for behavioural change related to 'environmental citizenship.' The earliest models linking learning and behaviour predict simply that an increase in knowledge about the environment should lead to more awareness or a different attitude, and thus increased motivation to take action (Hungerford and Volk 1990). However, this is an oversimplification, and in 1986–1987 Hines, Hungerford and Tomera (1987) (cited in Hungerford and Volk 1990) expanded the model to include locus of control and personality factors along with action skills and knowledge to predict ERB. Finally, Hungerford and Volk themselves propose that ERB is predicted by three sets of variables. "Entry-level" variables include environmental sensitivity, or early experiences, attitude or orientation toward environmental problems, as well as actual ecological or environmental content knowledge. "Ownership" variables are related to a personal connection to environmental issues. Ownership requires in-depth knowledge of a subject and a sense of personal investment. Finally, "empowerment" variables are related to the extent people feel able to make change and take action. These include knowledge of action strategies and an internal locus of control.

These ideas are reinforced by Fremerey and Bogner (2014) in a case study looking at drinking water with year 9–11 students. They look at knowledge in three dimensions: system knowledge, action-related knowledge, and effectiveness knowledge. System knowledge leads to a factual, topic-focused understanding of environmental issues. Frick, Kaiser and Wilson (2004) define this as "knowing what," whereas action-related knowledge is "knowing how." Effectiveness knowledge is the ability to compare different options for action and choose the one most likely to succeed. The study by Fremerey and Bogner (2014) shows that system knowledge is important, but on its own is insufficient to impact behaviour. However, it affects action-related and effectiveness knowledge. The three are intertwined, and together they result in ERB.

Ultimately, the models and ideas must be incorporated into classes and curriculum. Chawla and Cushing (2007) provide a comprehensive overview of factors that lead to action on behalf of the environment. Notably, they include political and collective action. Their argument is that environmental educators must build learner agency by creating space in the curriculum and by using pedagogies that allow for practice and development of a sense of competency. This must extend from early childhood experiences and influential role models. In short, students must care, and their interest or caring must align with their ability to take action (their agency). But even more important, students must also learn a collective sense of agency. They must be exposed early on to political action and involved in democratic and collaborative decision making. They must learn to engage with peers and others around issues. This is especially critical for addressing the systemic and large-scale concerns we face in environmental change and also sustainability; institutions such as government and private industry are responsible for, and control, many of the levers (and problems) involved in addressing things like climate change. It is only by collective and political action that citizens have agency.

This returns us full circle, then, to the role of university educators. We have no direct control over early childhood experiences, but we do still have a role to play. Chawla and Cushing (2007) list ten areas where environmental educators can make a difference. These can be condensed into two categories: 1) act as a role model and mentor for students and 2) provide opportunities within the curriculum or class for students to practice taking action and building agency. Again, full circle, this requires the will and skill of individual faculty members and is enabled by engaged and supportive upper-level leadership. With that, we can achieve the transformation needed for higher education to contribute meaningfully to addressing sustainability.

Conclusion

We started with a consideration of the historical context and the shift from environmental education to ideas about and emphasis on sustainability as a broader concept. 'Sustainability' in the context of higher education encapsulates tangible operational activities, leading to 'green campuses' and also academic activities such as scholarship and discovery and academic programs. Operational aspects of sustainability have often taken centre stage, as they are an easier 'sell' to governing boards and university executive leadership. The results are tangible, and there is a direct line of control from the top downward. The academic aspects of sustainability, however, face notable challenges and barriers – at individual, institutional, and intrinsic levels. Lines of power and control are not straightforward. Faculty members individually determine how they teach in their classroom (pedagogy), whether they engage in outreach or collaborative scholarship, and whether they include sustainability or space for the development of sustainability-related skillsets and knowledge. University governance, accrediting bodies, and/or governments control curriculum and whether or not a new program is approved or whether there is space in the curriculum for experiential learning and practice of sustainability-related skills. Universities are structurally and culturally bound to disciplines. Traditional attitudes toward applied or transdisciplinary scholarship determine whether programs begin or succeed.

Ultimately, the leadership necessary to enable sustainability scholarship and education must come from both the faculty level, with individual champions and broad adoption of sustainability concepts and pedagogies, and from the university senior leadership, in terms of championing academic initiatives to the board or government, addressing policy barriers such as reward and recognition for applied or transdisciplinary work, and positioning sustainability prominently in the university strategic plan and budget. With communication and alignment on goals, the two together can make powerful strides forward in creating the knowledge and the citizens capable of transforming our approach to planetary sustainability.

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9.2
EDUCATING WITH SUSTAINABILITY LEADERSHIP IN MIND AT UNIVERSITY
Considerations for curriculum and pedagogy

Sonja Kuzich

Key concepts for sustainability education

- Education for sustainability (EfS) is a transformative approach to education that is futures orientated, premised on systems and transdisciplinary thinking and reflects a holistic understanding of sustainability, encompassing social, cultural, political, economic and environmental considerations.
- A growing role for universities is to educate for sustainability as a means to address wicked societal problems.
- There is no defined curriculum for sustainability; however, there are foundational principles, big ideas and competencies that can form an effective framework for teaching.
- Effective pedagogies for sustainability are those that support students to learn through cognitive (head), affective (heart) and experiential learning (hands). These enable transformative and emancipatory learning outcomes.
- An educator's worldview and mindset affect their curricular and pedagogical design.
- To be effective educators for sustainability, university academics require four kinds of knowledge: disciplinary content knowledge (D-CK) and sustainability content knowledge (S-CK) as well as pedagogical knowledge for the discipline (PK-D) together with pedagogical content knowledge for sustainability (PK-S). Together these are known as disciplinary and sustainability pedagogical and content knowledges (DASPACK).

Introduction

The combined challenges the world faces, including exosystemic collapse, threats to societal well-being, political unrest, multispecies displacement and extinction, are hugely complex. We are in precarious and uncertain times, racing against the clock to keep global warming to within 1.5 Celsius of pre-industrial levels (IPCC 2018). Effective ameliorative responses

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require systemic changes to government policy, industry and education (Fazey et al. 2021) and fundamental shifts to the dominant mindsets and beliefs (Nolet 2009; O'Brien and Sygna 2013) that underpin unsustainable societal practices. Meadows (1999) suggests a powerful and deep leverage point that can create the transition to sustainability could be education.

As institutions of critical thought, universities are sites for interrogating systemic issues, goals, mindsets and paradigms (Bina and Pereira 2020) and are engines for social transformation (Facer 2020), capable of influencing the worldviews of the 'actors' who shape systemic directions (Meadows 1999). Due to this transformative educative capacity, which helps shape society, they are positioned with a responsibility to contribute thinking that promotes a more just and sustainable world (Barrineau, Schnaas, and Hakansson 2021). However, we are cautioned against seeing education as a panacea for our present 'ills' because it is the most highly educated nations that are largely responsible for the deepest ecological scars and unsustainable practices (Nolet 2009; Orr 2004; Sterling 2003).

When considering 'leveraging' education for a sustainable planet, the questions we must address, therefore, are:

- What kind of education?
- What needs to change in the way we currently educate?
- What should education include and emphasise to ensure we are able to achieve a sustainable future?'

Education for sustainability (EfS) is an approach that can assist educators to address these questions. Its purpose is to generate multilevelled change – to ways of thinking, being and acting. It is futures orientated, premised on systems and transdisciplinary thinking, and reflects a holistic understanding of sustainability, encompassing social, cultural, political, economic and environmental considerations (Kuzich 2019). The approach necessitates transformational conceptions of education, as well as the design and enactment of curriculum and pedagogy. Whilst supported as an educational goal for the last few decades, this approach is not well reflected in the curricula and pedagogy of universities. This chapter focuses on how university education can provide leadership for the urgent goals of EfS and identifies elements essential to effective curriculum design and pedagogical practices.

The role of the university in creating a sustainable future

As a societal goal to ameliorate the deleterious effects of human behaviour on the planet, sustainability is supported by all sectors of education. Universities, considered to be significant influencers and agents of change, are considered to be at the forefront (Leal Filho et al. 2019). The United Nations Decade of Education for Sustainable Development (UNDESD 2005–2014) was declared to empower learners to become an agent of change for sustainable action (Wals 2014). Following the UNDESD, universities were repeatedly called upon to be an integral force for such change by preparing future leaders and professionals (Mulà et al. 2017) with the Global Action Program (GAP; 2015–2019) (UNESCO 2018). More recently the United Nations Sustainable Development Goals (SDGs) identified that by 2030 all learners needed the knowledge and skills to promote sustainable development and lifestyles through human rights, gender equality, cultures of non-violence, global citizenship and cultural contributions to sustainable development (SDG 4.7) (United Nations, n.d.). Despite numerous agreements and declarations, progress has been slow.

More than a third of the global population, and three quarters of the population in high income countries attend tertiary education (McCowan 2021) where the majority of students are in the age range of 18-20. Given this is a critical period for identity development (Žalėnienė and Pereira 2021), universities are in a unique position to influence thinking, given their remit for research, innovation and the creation of new knowledge, which has the potential to disrupt orthodoxies and the status quo; the kind of thinking that has brought us to the current crisis. Students are driving this demand for sustainability to be included in curricula. In 2020, a global survey (N = 7000) showed that 90% of students were concerned about climate change, and 92% said sustainable development should be taught and promoted by colleges and universities (SOS 2021).

The function and purpose of universities are being reimagined. Traditionally, universities have had three missions: teaching (first mission), knowledge creation through research (second mission) and focus on engagement with the community as the third mission (Chankseliani and McCowan 2021). This 'triple helix' of university-industry-government has reinforced a market orientation in all aspects of academic work (Etzkowitz 2016) and an almost exclusive privileging of the economic perspective (Trencher et al. 2014). The consequences of this thinking are a self-reinforcing cycle of 'techno fix' or 'business as usual'. Universities, suggests Mccowan (2021), need to move from being 'part of the problem' to 'part of the solution' (Rinaldi et al. 2018).

Barber, Donnelly and Rizvi (2013, as quoted in Scott 2019, 108) draw attention to the incongruity of the current university model advising these 20th-century models of higher education are broken. They argue that we need more than ever before a generation of better educated graduates able to find solutions to complex, interconnected problems such as global tensions, poverty, growing inequity and economic and political unrest which causes mass migration of people across international boundaries. This requires transdisciplinary, transversal skills that draw on multiple knowledges and perspectives often built on the ancient wisdoms that recognise a multispecies ethic of care. It is this kind of thinking that rejects Anthropocentricism, a view of humankind as central and dominant in the world, in favour of an ecological mindset.

Anxieties about the worsening of planetary conditions in the last two decades, growing inequalities and more ubiquitous but localised examples of the climate crisis have caused universities to re-consider their 'social contract' with their communities (Trencher et al. 2014; UNESCO 2021). A shared vision of education has been accelerated by the impacts of the COVID-19 pandemic, which has been a wake-up call for humanity, as well as a catalyst for reconsidering the role of higher education (Mccowan 2021). Climate change and pandemics are examples of 'wicked problems' universities are now realising they must educate for. This necessitates a fourth mission for universities – the consideration of "transversal and complex issues, such as sustainability, whose challenges encompass social, economic, political, cultural and environmental" factors (Rinaldi et al. 2018, 69). By engaging in this mission, universities can become catalysts of change as they develop graduates into strategic leaders who drive the global sustainability agenda.

Response of universities to the sustainability agenda

Increased demand for sustainable practices in higher education (Lozano et al. 2013) has caused increased activity in the tertiary sector worldwide (Mulà et al. 2017), with institutions beginning to implement sustainability at various levels, including mission and vision statements (Bieler and McKenzie 2017), curriculum design, campus operations and multi-stakeholder research collaborations to solve sustainability-related problems (Dentoni and Bitzer 2015). However, Shawe et. al. (2019) caution that these changes are partial and fragmentary. The reasons for this are outlined by Balser (see Chapter 9.1 in this volume). Dr Balser suggests that leadership in higher education must pay attention to both operational activities that result in a 'greening of the campus' and academic aspects of sustainability. The way in which higher education responds to sustainability concerns is characterised in Table 9.2.1, adapted from the work of (Sterling 2004). Sterling identified four different ways educational institutions might deal with sustainability, which are: 1 – denial (ignoring issues as 'hype'); 2 – bolt on (adding a 'green/environmental' aspect to existing campus operations, program of activity or curriculum; 3 – built in (integration into many aspects of university life and practices; and 4 – rebuild/redesign (complete overhaul in purpose, policy and practice).

Unsurprisingly, no university has been identified as having reached stage 4, and there is little evidence EfS is embedded in universities' curricula and pedagogy (Lang, Thomas, and Wilson 2006; Leal Filho et al. 2019). In most cases universities have implemented a 'bolt-on' approach through *vertical integration* where content is added to courses or specialist stand-alone modules in sustainability which are then considered to cover sustainability issues for the entire study program (Sidiropoulos 2019). The preferred approach for systemic curriculum change combines *horizontal integration,* where issues are integrated across an entire program, with *vertical integration* (Sidiropoulos 2019). This type of integration is complex, resulting in few successful examples reported in the literature (Aktas et al. 2015). Therefore, despite some small gains, there has been little systemic curriculum change (Ryan and Tilbury 2013).

Where integration of sustainability in university curricula has occurred, it tends to be restricted to courses such as environmental science, engineering and climatology (Colucci-Gray et al. 2006; Conlon 2008; Glavič 2006; Reitan 2005). This demonstrates the continued association amongst academics of sustainability with purely environmental concerns (Žalėnienė and Pereira 2021). Recognising this curriculum imbalance, Hensley (2020) argues the humanities are essential to the enrichment of discourses around sustainability;

Table 9.2.1 Response of higher education to sustainability concerns

Response	*Result for sustainability in the entire organisation*	*Result for education*
Denial	Rejection or minimal response (token)	No change (or token)
Bolt on	Accommodation; cosmetic changes	Education *about* sustainability; no structural changes
Built in	Reformation; largely piecemeal revision of curriculum and pedagogical practices	Education *for* sustainability; some structural changes
Rebuild or re-design	Transformation; the modus operandi of education is organised according to the principles of creating a sustainable future	Education *as* sustainability; complete restructuring of education

they offer fresh perspectives by valuing human perception, experience and the facilitation of the integration of the head, heart and hands. To teach in such a holistic, integrated way requires academics to develop a view of sustainability that considers not only the environmental concerns but also the societal, economic, cultural and political and, in addition, understand and apply the principles of sustainability to their discipline content and pedagogy. However, sustainability pedagogy shows evidence of being poorly practised in universities with academics unable to see the link between ESD and pedagogical innovation (Cebrián 2017). Malone and Truong (2017) acknowledge that for many academics there is still a knowledge gap that must be addressed.

Educating for sustainability

Whilst the two most common conceptualisations of sustainability education, education for sustainable development (ESD) and EfS share many similarities, there are also distinct, fundamental philosophical differences. For the purposes of this chapter EfS is used, as it is the favoured approach in the Australian context and avoids the negative connotations associated with 'development' (Kuzich 2019).

EfS reflects a broad conceptualisation of sustainability and latterly has widened its scope, from a simplistic representation encompassing only environmental, economic and social concerns, to a holistic one that embraces and acknowledges the corollary influences of culture and politics (Kuzich 2019). It has a futures orientation and is premised on systems and transdisciplinary thinking.

As an educational approach EfS is intended to be a transformative force that empowers individuals to develop systemic and interconnected solutions to 'wicked problems' (Head 2018) facing humanity, such as climate change, mass extinctions, political conflict and social unrest causing a mass migration of refugees, food insecurity, widespread poverty and growing inequities.

The purpose of EfS is to generate change at many levels: our ways of thinking, being and acting. It is an action oriented, transformative approach as it focuses on not only changing individual but also social practices to more sustainable ones, as well as addressing the underlying structures that perpetuate these unsustainable practices (Kemmis and Mutton 2012). In order to effect this, we cannot simply employ passive, 'transmission of knowledge' models of learning – as espoused by 'education about sustainability' (refer to Table 9.2.1). EfS is premised on an emancipatory and constructivist model of education (Jenkins 2015) – one that invites and challenges the learner to bring their passions, concerns and hopes for the future of the world into the classroom.

EfS as an educational paradigm shift

The concept of sustainability cannot merely be tacked on to existing ways of teaching and learning within higher education. Thinking and acting sustainably requires a *macroshift* (Lazslo 2001) away from our current paradigmatic ways of thinking. This involves both the teacher and the learner first developing a meta-level awareness and understanding of the effect of existing dominant paradigms on our ways of thinking and being and how these are maintained. Sustainability education therefore is not only a process of learning new ways but is also a process of unlearning and replacing dominant ways of seeing and acting in the world that have contributed to unsustainable practices (UNESCO 2021).

A dominant paradigm that still holds sway on our education system at all levels is the mechanistic worldview that reflects an epistemological disposition of reductionism (Kuzich 2019). Contrasting this Newtonian metaphor of mechanistic, reductionist and linear thinking, the ecological worldview is rooted in the ontological metaphor of *ecology* (Sterling 2007). Capra (1996) clarifies the differences stating, "The basic tension is one between the parts and the whole. The emphasis on the parts has been called mechanistic, reductionist or atomistic; the emphasis on the whole, organismic, or ecological" (p. 17). The ecological worldview is epitomised by systems thinking – a view that reconciles the wholes and the parts, where the whole is considered an interdependent system irreducible to its constituent parts. Table 9.2.2 identifies some of the key characteristics of the current mechanistic worldview and the proposed shifts necessary to establish an ecological worldview supportive of sustainability thinking in education (adapted from Kuzich 2019, 57). Notably,

Table 9.2.2 Differences between mechanistic and ecological worldviews in relation to education

Mechanistic worldview	*Ecological worldview*
Level 1: Educational paradigm – core values	
Preparation of individuals to contribute to the economy	Preparation of individuals to participate in all dimensions of society and contribute to sustainability transition
Effective learning	Transformative learning
Competition	Cooperation and collaboration
Level 2: Organisation and management of the learning environment	
A prescriptive and detailed curriculum	A curriculum which is open, negotiated and representative of diverse views and knowledge bases
Fixed knowledge and 'truth'	Provisional knowledge recognising uncertainty and approximation
Uni-disciplinary – siloed learning	Trans- and multidisciplinarity
Top-down control	Democratic and participative ideals
Planning	Design
Problem solving	Problem reframing and situation improvement
Level 3: Learning and pedagogy	
View of teaching and learning as transmission and passive instruction	View of teaching and learning as transformation and active learning
Product oriented	Process, development and action oriented
Emphasis on teaching	Integrative view – teachers also learners, learners also teachers
Primarily for functional skills	Education is for functional as well as critical and creative inquiry and skills
View of learner as a cognitive being	As a whole person with full range of needs and capacities
Educators as technicians	Educators as reflective practitioners and change agents
Meaning is given	Meaning is primary and is constructed and negotiated

changes are required at three levels: at the level of core values or paradigm, organisation and management of the learning environment and learning and pedagogy.

EfS fundamentally asks us to problematise the ways in which curriculum and pedagogy for sustainability are currently organised and enacted in universities. The worldview of the academic as curriculum designer and teacher is of great significance to the learning outcomes of students. At the core of curriculum design is a representation of a particular mindset and worldview expressed through the selection and omission of subject content, learning materials and learning experiences. Curriculum and pedagogy are never neutral in that they are forged through a series of societal and personal filters and can act as mirrors-reflections of what currently 'is', but what we need them to be for EfS are sliding doors- visions of what 'can be' (Botelho and Rudman 2009).

Designing the curriculum for sustainability in higher education

Despite the importance placed on educating for sustainability for the past three decades, as yet, there is no commonly agreed framework for the teaching of sustainability (Cebrián, Junyent and Mulà 2020). In practice, educating for sustainability represents a challenge to universities, as it requires not only an ability to transcend disciplinary silos but also a holistic conceptualisation of sustainability that goes beyond a narrow view which largely privileges the environmental or economic dimensions (Sinakou et al. 2018). A significant reason for the lag in the development of a curriculum for sustainability in higher education, suggest Christie et al (2013), is the absence of clear guidelines that explicate the theoretical perspectives and pedagogical approaches for how EfS should be taught.

Fraser and Bosanquet (2007), identified four curricular understandings held by university academics: "A: the structure and content of a unit (subject); B: the structure and content of a program of study; C: the students' experience of learning; D: a dynamic and interactive process of teaching and learning" (p. 272). In the context of this chapter, curriculum as both a product (A and B), with a focus on discipline content knowledge is dealt with first, followed by a discussion of pedagogical process (C and D).

In addition to the four curricular understandings, incorporating sustainability into their teaching requires academics to demonstrate four interconnected elements: expertise in their field that translates into specific discipline knowledge (disciplinary content knowledge); knowledge of how to teach that particular content of that discipline (pedagogical knowledge for the discipline); a systemic and holistic knowledge of the tenets and principles of sustainability as they relate to their discipline area and how these transcend and connect to other disciplines (sustainability content knowledge); and lastly, a sustainability mindset to enable a transformative pedagogy to develop student agency and propensity for positive action in order to change the way the world currently operates (pedagogical knowledge for sustainability) (refer to Figure 9.2.1).

DASPACK – Disciplinary and sustainability pedagogical and content knowledges

The different knowledges represented in Figure 9.2.1 build on the work of Shulman (1986) who used the term pedagogical content knowledge (PCK) to refer to the intersection of subject or discipline knowledge (the what) and the pedagogical knowledge required to teach (the how). These two knowledge systems form the foundation of curriculum and pedagogical choices made by educators. Integral to this framework, according to Zhou (2015, 188) is the idea that:

> to develop the ability to teach a subject matter, one must not only grasp the content of the subject, learn essential principles that guide learning in the subject area, but also learn to structure and enhance learning opportunities for students. In other words, capable teachers must know why certain concepts are important and be able to flexibly incorporate new resources . . . into their knowledge of the subject pedagogy in ways that enhance learning.

This proposed model representative of the curricular and pedagogical knowledges required by educators, irrespective of what level of education, is a combination of Disciplinary And Sustainability Pedagogical And Content Knowledges, collectively referred to as DASPACK. Thus, Figure 9.2.1 demonstrates the inextricable necessity of educator competence with both teaching disciplinary knowledge and skills but also those associated with sustainability.

Elements of a sustainability curriculum

There is no definitive curriculum content for sustainability. Didham and Ofei-Manu (2018, 89) argue that it is "constructed" by reframing existing, perhaps seemingly commonplace and unproblematic, issues, events and practices that are routinely used in their own discipline area through a "sustainability lens". Thus, a sustainability-infused curriculum offers

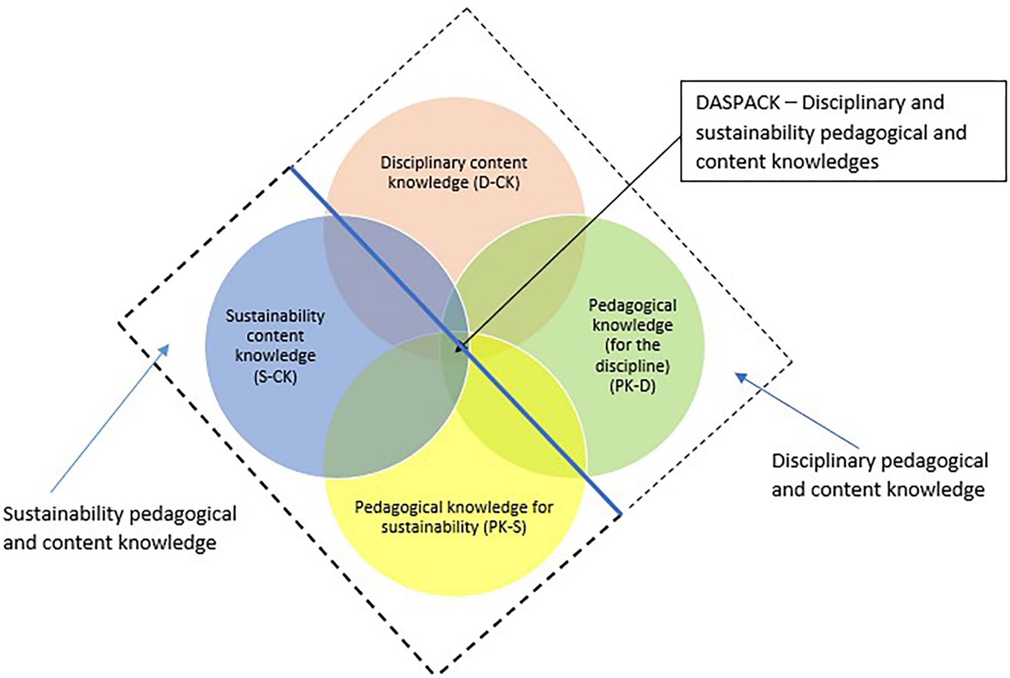

Figure 9.2.1 DASPACK – Disciplinary and sustainability pedagogical and content knowledges.

a new way of viewing the world that dismantles the current ways, creating new mindsets (ways of knowing, making sense and thinking), behaviours (ways of acting) and relations (ways of feeling and relating) through a reflexive process of creating, combining and re-combining.

Developing a robust, transformative approach to sustainability requires a constructive alignment between the curriculum elements (What is to be taught?), the curriculum goal (What is the aim of instruction?) and the curriculum outcomes (What will we be looking for as evidence of learning?) as represented in Table 9.2.3. In the spirit of Biggs's (1996) original intentions for constructive alignment, the focus moves from the teaching input, to student learning.

There is a growing consensus in the literature that to achieve transformative action for sustainability, the curriculum needs to encompass the cognitive, socioemotional (affective) and behavioural domains (Dlouhá et al. 2019), or the head, heart and hands (Sipos, Battisti and Grimm 2008; Singleton 2015). Knowledge alone, the cognitive domain, is inadequate to precipitate the long-term changes required to ameliorate unsustainable actions and process. UNESCO, in their report *Reimagining Our Futures Together: A New Social Contract for Education* reinforce the importance of universities embracing the affective components as part of the student educational experience as a way to precipitate the transition to sustainability. The report suggests that by doing so student agency is developed and this "is the key to transformation". Additionally, engaging both faculty and students with inner worlds, encapsulating "entities of values, thoughts, emotions, identifies, beliefs and worldviews", potentially leads to deep levels of change (2021, 21).

A curriculum framework that assists academics to teach with and through sustainability, therefore, requires attention be paid to four interconnecting areas: the cognitive, behavioural, affective and relational. Barnett and Coates's (2005) curriculum frame of *knowing*, *acting* and *being* maps onto these four areas (see Table 9.2.3). This framing speaks of a holistic education where students bring themselves and their passions into the learning process, where their identities are developed through a relevant and personally meaningful curriculum that has the capacity to incorporate real-world problems and where student ideas and aspirations are incorporated in a process of co-creation of the curriculum (Bovill and Woolmer 2018).

Teaching with sustainability in mind requires the problematising of each of these areas in order to challenge and interrogate our existing ways of knowing, ways of making sense, ways of thinking, ways of being, ways of feeling and ways of relating. It is in these reflexive spaces that we need to consider other knowledge systems, such as Indigenous/First Nations, that reframe the privileged place of Western scientific and neoliberal thought (Mazzocchi 2020), as well as post-human and transhuman perspectives (see Blaikie, Daigle and Vasseur 2020, for

Table 9.2.3 Sustainable curriculum elements

		Knowing		*Acting*	*Being*	
Curriculum element		Cognitive		Behavioural	Affective	Relational
Curriculum goal	To know	To understand	To think	To do	To feel	To relate
Curriculum outcomes	Ways of knowing	Ways of making sense	Ways of thinking	Ways of acting	Ways of feeling	Ways of relating

explanations of the work of Haraway, Barad and Braidotti and for a comprehensive sweep of the relational turn in sustainability refer to West et al. 2020).

Another central aspect feature of sustainability in education is the need to move beyond subject discipline boundaries that artificially delineate conceptions of knowing, curriculum and knowledge creation. Blaikie, Daigle and Vasseur (2020) posit a post disciplinary stance that embraces complexity and systems thinking in curriculum design as a form of redress for an "educational system that fences off bodies of knowledge in such a way that it becomes impossible to deal with fundamental and global challenges of our lives as individuals and as citizens in any organic manner" (Hessel and Morin, as cited in Pernecky 2020, n.p.). They assert further that the goal of any curriculum should be to develop and nurture an agentic actor able to "manoeuvre uncertain, changing and complex realities" (n.p.) and, I would add, with the capacity to transform the world.

University educators require guidance with the creation of a conceptual curriculum framework for sustainability to ensure the lofty aims of the sustainability literature with the practicalities of teaching in higher education are reconciled. The literature is replete with suggestions of what needs to be learned for EfS, but there is an absence of a coherent and agreed upon framework for teaching sustainability content knowledge (S-CK).

For higher education, Steele and Rickards (2021) suggest the 17 UN SDGs (United Nations 2015) as a potential starting point for teaching. However, despite a number of universities starting to incorporate the SDGs into their operations and planning, they have been the subject of much critique and debate. They are recognised as a flawed framework (Steele and Rickards 2021) that fail to address, for example, power imbalances and structural inequalities (Consortium on Gender, Security and Human Rights 2017) and reinforce the pro-growth neoliberal model of development that has caused the global issues, including climate change, the SDGs are purporting to address (McLoskey 2021). In addition, a further critique is there is little evidence from the literature that university academics have adequate sustainability knowledge to enable them to discern the core principles of sustainability from the SDGs (Dlouhá et al. 2019; Stein 2019; Mori Junior, Fien and Horne 2019), which may lead to their uncritical adoption, perpetuating *unsustainability*.

In order to make contextually relevant but nuanced and sophisticated curricular and pedagogical decisions, a more fruitful starting point for educators is to ensure they have a grounding in the underpinning principles and 'big ideas' of sustainability. By doing so, this enables them to better prepares the learner to deeply understand the relationships and interactions of knowledge, skills, values and attitudes and become more acutely aware of their own actions and decisions. From a synthesis of the sustainability literature Waas et al. (2011, 1645) identified four agreed principles that frame EfS:

1. Normativity principle – sustainability is a social construction. Values that vary across culture, geographical location and time frame our attitudes and views to guide our actions.
2. Equity principle – justice or fairness. Subdivisible into inter- and intragenerational equity; geographical equity; procedural equity; and interspecies equity.
3. Integration principle – whole systems thinking. The social, economic, cultural, institutional and environmental objectives are considered interdependent in that failure to achieve one undermines the success of the other.
4. Dynamism principle – sustainability is an ongoing evolutionary process. Inherent in this is the application of the precautionary principle that necessitates a willingness to act despite incomplete information in order to mitigate risk.

In conjunction with these underpinning principles, Nolet's (2015) eight 'big ideas' of sustainability form an effective curriculum framework that provides a sustainability lens to the discipline content knowledge as well as the teaching and learning processes. These understandings are an integral part of EfS curriculum design in that they shape the worldview of the educator which in turn has the potential to inform that of the learner.

In summary, Nolet's eight 'big ideas', with relevant keywords and associated concepts are as follows:

1. Equity and justice – equity (inter- and intragenerational, interspecies, etc.); justice (social, economic, environmental, food); precautionary principle; futures thinking
2. Peace and collaboration – negative peace (e.g. absence of violence); positive peace (social justice, fair distribution of power and resources, opportunity, equal protection for all species/environments)
3. Universal responsibility – reciprocal responsibility; positive, solution-focused active and collaboration engagement
4. Health and resiliency – promotion of individual and societal health; acknowledgement of impacts of unhealthy environmental conditions and climate change; resiliency.
5. Respect for limits – finite growth and capacity; planetary boundaries
6. Connecting with nature – learning from nature; affinity with nature; ecocentric rather than anthropocentric; biophilia: respect, curiosity and awe
7. Local to global – glocal; global ethic; diversity
8. Interconnectedness – systems thinking; holistic view of sustainability issues and solutions

The distillation of central elements of sustainability provides some guidance to educators and other practitioners in determining what knowledge, skills, attitudes and values are to be included and valorised in an EFS oriented curriculum design. If we consider the curriculum framework as composed of layers, the first layer is composed of principles, the second, 'big ideas' and the third more detailed layer would be divided into 'educator competencies' – what the educator needs to know (S-CK) and be able to do (S- PCK) and then 'student competencies' – what the student should know and be able to do as a result of the teaching and learning experiences (see Table 9.2.4). If we were to conceptualise this as an iceberg model, Layers 1 and 2 would be sitting under the water, representing the mindsets

Table 9.2.4 Knowledge framework for an EfS curriculum

	Educator	*Student*
Layer 4	Concepts of sustainability to teach about, with and through	Concepts of sustainability to learn, experience and enact in the real world
Layer 3	Competences of educators	Competencies of students learned through practice
Layer 2	Sustainability 'big ideas' inform curriculum design	Sustainability 'big ideas' inform learning and response to real-world problems
Layer 1	Sustainability principles inform curriculum design	Sustainability principles inform learning and response to real-world problems

and worldviews of both the teacher and learner, and Layer 3 would be above the water line as the visible manifestation of these underpinning knowledges and understandings.

Competencies for EfS

Teaching through a competency approach sits very well with the idea of EfS, as it marries the cognitive (knowledge and skills) and the affective (values and attitudes). UNESCO (2015, 1) highlights this coupling as necessary to generate the transformation needed to change individual and collective behaviours, stating ESD/EfS has:

> the potential to empower learners to transform themselves and the society they live in by developing knowledge, skills, attitudes, competences and values required for addressing global citizenship and local contextual challenges of the present and the future, such as critical and systemic thinking, analytical problem-solving, creativity, working collaboratively and making decisions in the face of uncertainty, and understanding of the interconnectedness of global challenges and responsibilities emanating from such awareness.

The power of competencies, suggests Dlouhá et al. (2019) is that they are "essential for building capacities which enable individuals to critically review prevailing values, policies and practices, and empowering them to make decisions to act for change . . . they have an emancipatory and transformative impact" (p. 2). Importantly, they stress competencies must be learned through practice, rather than taught in a theoretical way alone, therefore requiring a shift away from a mere transmission of knowledge to new ways of teaching and learning.

To breach the chasm between simply 'knowing and thinking' to 'acting' in sustainable ways, the concept of *action competence* has become an important facet of EfS. Action competence is described as a combination of factors such as capability, willingness and courage to act, knowledge of root causes and systemic understanding of potential consequences of actions, the capacity to envision and develop new solutions, how change is created and the capacity to realise the practical manifestation of that change (Almers 2013). Wilhelm, Förster and Zimmermann (2019, 3–4) identified that competencies demonstrated an action orientation as they enabled students to become "systemic 'problem solvers, change agents and transition managers' ", "deal with wicked and complex problems and ambivalent situations relation to sustainable development in uncertain and often rapidly changing environments" and developed the capacity to lead such change.

In terms of designing and teaching learning programs in higher education, these competences provide an explicit and commonly shared framework for educators; a reference point for evaluating student learning and teaching effectiveness; and clear scoping of the skill profile of students expected to be future 'problem solvers' and 'change agents' (Wiek, Withycombe and Redman 2011). Wiek, Withycombe and Redman (2011, 207–11) constructed a set of five EfS competencies and associated conceptual understandings (refer to Table 9.2.5) relevant to establishing a teaching and learning environment in higher education. They later added another: the integrated problem-solving competency as a meta-competency that enables the meaningful integration of the five key competencies in solving sustainability problems (Wiek et al. 2016). With the addition of an intrapersonal competence, suggested by Brundiers et al. (2021, 25), that focusses on "affective- motivational capacities through self-inquiry", "experience-based learning", "self-awareness of one's own values (e.g., equity, consumption, human-nature connections" and "self-regulation", this set of competencies forms an effective curriculum content structure for EfS. The elaboration of the concepts alongside each competency provides useful guidance for ways disciplinary knowledges can be reframed toward sustainability thinking.

Supportive pedagogical practices

EfS is a transformative educational approach. If sustainability in education is to result in the disruption of the invisible normative structures and ways of thinking that have led us into the current state of affairs through empowering learners to take informed decisions and responsible actions, the pedagogy must complement such a stance (Kuzich 2011). Singer-Brodowski (2017) found the missing piece of the puzzle to explain the lack of advancement of sustainability in higher education was the educator's pedagogical knowledge of sustainability. The conclusion drawn by Sandri (2020), however, is that sustainability pedagogy is as much a learning process for the educator as for the student, necessitating a reshaping of their academic identities.

Pedagogy refers to more than simply 'what' educators do and the kinds of techniques or strategies they employ; it also refers to the 'why' and 'how' (Alexander 2008). Pedagogy reflects the values of the educator; hence it is not neutral. The pedagogical choices, made by the teaching academic committed to the principles of sustainability, make a statement of their vision, values and belief of "what education is for and how society might be" (Kuzich 2011, 4). These choices are a confluence of personal socially and culturally situated ways of thinking and also professional views drawn from the dominant paradigm of their discipline. For some disciplines, for example, humanities and social sciences, the suggested EfS pedagogies may already be closely aligned to their existing disciplinary pedagogical orientation, but for others, where more traditional approaches dominate, this may be a greater challenge (Christie et al. 2013).

For EfS, the impact of the what an educator expresses through their pedagogical content knowledge for sustainability (PCK-S), as evidenced in the teaching and learning experience

Table 9.2.5 EfS competencies and concepts

Competency definition	*Concepts*
Systems thinking – the ability to collectively analyse complex systems across different domains (society, environment, economy, etc.) and across different scales (local to global)	• Variables/indicators, subsystems, structures, functions • Feedback loops, complex cause-effect chains, cascading effects, inertia, tipping points, legacy, resilience, adaptation, structuration, etc. • Across/multiple scales: local to global • Across/multiple/coupled domains: society, environment, economy, technology, etc. • People and social systems: values, preferences, needs, perceptions, (collective) actions, decisions, power, tactics, politics, laws, institutions, etc.

(*Continued*)

Table 9.2.5 (Continued)

Competency definition	*Concepts*
Anticipatory (or future thinking) – the ability to collectively analyse, evaluate and envision the future related to sustainability issues and sustainability problem-solving frameworks	• Time including temporal phases (past, present, future), terms (short, long), states, continuity (dynamics, paths), nonlinearity • Uncertainty and epistemic status including possibility, probability, desirability of future developments (predictions, scenarios, visions) • Inertia, path dependency, non-interventions • Consistency and plausibility of future developments • Risk, intergenerational equity, precaution
Normative (or value thinking) – the ability to collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets	• (Un-)sustainability of current or future states; sustainable development • Sustainability principles, goals, targets, thresholds (tipping points) • Justice, fairness, responsibility, safety, happiness, etc. • Risk, harm, damage • Reinforcing gains ("win–win") and trade-offs • Ethical and moral claims
Strategic thinking – the ability to collectively design and implement interventions, transitions, and transformative governance strategies toward sustainability	• Intentionality • Transitions and transformation • Strategies, action programs (systemic) intervention, transformative governance • Success factors, viability, feasibility, effectiveness, efficiency • Adaptation and mitigation • Obstacles (resistance, reluctance, path dependency, habits) and synergies • Instrumentalization and alliances • Social learning and social movements
Interpersonal – the ability to motivate, enable, and facilitate collaborative and participatory sustainability research and problem solving	• Functions, types and dynamics of collaboration (within and beyond academia; interdisciplinarity, transdisciplinarity) • Strengths, weaknesses, success and failure in teams • Concepts of leadership • Limits of cooperation and empathy • Concepts of solidarity and ethnocentrism

Source: Adapted from Wiek, Withycombe and Redman (2011, 207–11)

of students, can have far-reaching consequences for the knowledge and actions of graduates. By virtue of their choices, the educator has an investment in either reproducing the existing social and cultural norms, such as in the dominant mechanistic/reductionist views (see Table 9.2.2), or challenging the status quo to shift thinking and action.

Whilst the literature identifies a suite of teaching strategies that are supportive of EfS, such as problem solving, inquiry-based learning and collaborative group work, these do not inherently promote sustainable ways of thinking, being and acting. It is pedagogical intent, an alignment of the educator's vision and action that has sustainability as an organising ethos, that ensures pedagogical techniques or strategies do indeed engender the kinds of change that supports sustainable practices (Kuzich 2011).

There is a general agreement in the literature that the kinds of pedagogical practices supportive of a sustainability mindset are those that seek to transform the learner at the deepest levels of learning. Corres et al. (2020, 20–21) draw on Gregory Bateson's model of three learning levels, stating that the shallowest pedagogies are those that enable "doing things better" within existing structures and paradigms, and the second level results in "doing better things", referring to changes in thinking because of an examination of existing mindsets and values. The third and deepest level aims at creating an epistemic change in our consciousness through a great self-awareness enabling us to "see things differently". Universities, paradoxically, have tended to place a greater emphasis on the first level, prioritising the cognitive domain with a focus on the transmission and acquisition of disciplinary knowledge to gain individual certification (Papenfuss et al. 2019). Forms of pedagogy that address the cognitive, social and affective dimensions of learning in order to enable growth and change in the individual and society are only just beginning to emerge in higher education. Two key pedagogies dominant in studies of sustainability education reflective of Bateson's third level are *transformative* and *emancipatory* education (Sterling 2003; Kuzich 2019; Singleton 2015; Papenfuss et al. 2019). It is these models that are fertile ground for EfS.

Educators who come across these ideas in the literature may be at a loss as to how to, firstly, identify their current pedagogical practices and, secondly, to change these to what is espoused by emancipatory and transformative education. A helpful framework in this regard, offered by Papenfuss et al. (2019), reframes the dominant views which appear dismissive of more traditional teaching approaches. Instead, they suggest that sustainability education is an interaction of two pedagogical dimensions: the transmissive/transformative and the instrumental/emancipatory. By placing these in four quadrants (Q1: Instrumental/Transmissive; Q2: Emancipatory/Transmissive; Q3: Instrumental/Transformative: and Q4: Transformative/Emancipatory), they provide both an effective reflective tool and a "rebel's compass that points toward the development of pedagogies for sustainability education" (p. 7). They posit that Q1, Instrumental/Transmissive pedagogies, characterised by didactic instruction of prescribed content, knowledge and skills with pre-determined outcomes, may be useful in providing the foundational background knowledge for later higher-order learning but has limited impact for advancing sustainability. This suggests that the least amount of time and/or energy should be devoted to this kind of teaching and learning. The quadrant model, where Q1 is least supportive of sustainability, to Q4 that is most supportive, provides a framework against which a teaching academic can gradually calibrate their teaching approaches. They propose the kinds of pedagogical approaches most consistent with the aims of EfS need to move to learning experiences that support collaboration, develop student agency and promote self-actualisation are individualised and subjective, enabling multiple ways of making meaning and being. The model reinforces the view that EfS requires a shift from teaching to learning where the learning environment is purposely designed to be interactive and learner centred.

The aim of transformative pedagogy for EfS is to empower learners to reflect on and challenge not only their own ways of seeing and thinking about the world but to develop the capacity to effect collective change. This action orientation is critical to facilitate the development of the aforementioned competencies, as they are not acquired through direct teaching, but are developed by learners as a result of their experience and reflection (UNESCO 2021).

Transformative learning encompasses an array of constructivist, participatory pedagogies that include real-world experiential learning (Lozano et al. 2017). Corres et al. (2020) identify other salient characteristics consistent with this approach such as self-directed learning; inter- and transdisciplinary learning; student-centred, holistic, active pedagogy; and critical thinking and suggest that that using a place-based design promotes "deep relational and emotional changes in consciousness about and connections between the self and the surrounding world" (p. 21). The emotional component of learning (the 'heart') is being increasingly recognised as the catalyst that enables the learner to transcend from simply 'knowing' to 'acting'. A summary of teaching approaches, suggested by UNESCO (2018, 50), that support this view include:

- Problem/project-based learning – Such as service-learning projects that are collaborative and relate to, or solve real world problems
- Envisioning futures – Vision building exercises involving futures thinking, scenario analysis, science-fiction thinking and utopian/dystopian story telling
- Systems thinking – Analysis of complex systems such as case studies, community projects; modelling and systems games
- Critical and creative thinking – Use of dialogic strategies such as fishbowl, thinking hats, and reflective journals to promote critical and creative thinking.

Emancipatory pedagogy builds on transformative pedagogies by shifting the focus from the individual learner to a collective understanding and challenge to power structures. Derived from Paulo Freire's ideas of critical pedagogy, emancipatory pedagogy, states Papenfuss et al. (2019), is based on the idea of collective consciousness raising through critical reflection, praxis and dialogue known as *conscientisation*. They explain that this approach rests on three key premises: rejection of "banking" or instrumental and transmissive modes of education; the need to couple reflection with action in order to reorganise power structures; and the need to create a levelling of power between teacher and learner. The pedagogical manifestations of this approach are where learners are provided opportunities to talk and collaborate in order to co-create objectives and plans of action and where learning objectives are not necessarily established beforehand. The kinds of teaching approaches recommended for transformative learning previously are also highly relevant for emancipatory learning. Papenfuss et al. (2019) puts forward the ancient pedagogy of storytelling which they claim is being re-appreciated as an essential tool for sustainability education. They argue that the fact that humans are considered to be essentially wired for stories makes it a powerful pedagogy that allows to "connect and envision desirable pathways toward sustainable futures" (2019, 60).

The pedagogical strategies that underpin EfS may already be somewhat familiar to many university academics. Critical thinking, for example, is *de rigueur*. Others, like envisioning futures, are less easily incorporated into academic practice and may require time and resources to become familiar with. There are numerous other teaching strategies that could support EfS. What is critical in deciding the pedagogical strategy is the intended purpose of it and how well it enables the achievement of EfS competencies. In essence, creating collaborative, authentic learning experiences that connect to the real world and lives of students, at both a local and global level, shifting the goal of education from knowledge transfer to personal transformation, is indicative of pedagogical approaches supportive of sustainability.

Conclusion

Developing university students' skills and capacities to think and act in sustainable ways involves a transdisciplinary, transformational and emancipatory turn for curriculum and pedagogy. The aim is to design learning settings premised on the cognitive, social and emotional engagement of students that build bridges across multidisciplinary knowledges and between sustainability competencies and pedagogies in the pursuit of resolving issues of practical relevance. This can be challenging for university educators, as sustainability is still a relatively unfamiliar concept for many. Yet EfS demands a reflexivity of educators, a willingness to learn and transform their roles and a corresponding change in their mindsets and worldviews. The position is that sustainability needs to become a lens through which educators see, engage with and act in the world and through which the influence this exerts on the design, and outcomes, of teaching and learning experiences for students is critiqued. Incorporating sustainability in university curriculum and pedagogy involves a thoughtful intertwining of the content and pedagogical knowledge of the discipline area with content and pedagogical knowledge aligned with the principles and aims of sustainability – known as DASPACK. By doing so, universities can provide leadership by reconceptualisating the kind of education they currently provide into one that ensures students are assisted in dealing with "unpredictable and incalculable futures" (Barrineau, Schnaas and Hakansson 2021, 268) and are instrumental in building social, cultural, environmental, economic and political sustainability.

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9.3

REVIEWING UNIVERSITY SUPPORT FOR SUSTAINABILITY EDUCATION

An Australian case study

Annette Gough

Key concepts for sustainability education

- Some universities have been concerned about sustainability for some time.
- Universities have a key role in society achieving sustainability through the provision of education and training and through being a role model on sustainability actions.
- Supporting learning and teaching sustainability initiatives should be a major focus for action, as this is where students learn how to be act sustainably.
- Infrastructure initiatives take most of the funding allocated to sustainability in universities.
- Building staff ownership of sustainability initiatives and sustaining the initiatives in universities is a challenge.

Introduction: universities for sustainability

That universities have a role in educating the community about sustainability has been included in recommendations from United Nations' conferences on the environment since the 1972 Conference on the Human Environment where the recommendations included that "Graduate courses in natural resources administration should be made available in at least one major university in every continent" (United Nations 1972, 12).

Universities were given an expanded role in the recommendations from the 1977 UNESCO-UNEP International Conference on Environmental Education, including

> to encourage acceptance of the fact that, besides subject-oriented environmental education, interdisciplinary treatment of the basic problems of the interrelationships between people and their environment is necessary for students in all fields, not only natural and technical sciences but also social sciences and arts, because the

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relationships between nature, technology and society mark and determine the development of a society.

(UNESCO 1978, 33)

There is also a significant role for universities in developing and sustaining a 'learning society' – a society in which "people in all walks of life recognise the need to continue in education and training throughout their working lives and see learning as enhancing the quality of life throughout all its stages" (NCIHE 1997, p. 9). At a more pragmatic level, the Association of University Leaders for a Sustainable Future (2002, 3) points out that "Universities educate most of the people who develop and manage society's institutions. For this reason, universities bear profound responsibilities to increase the awareness, knowledge, technologies, and tools to create an environmentally sustainable future".

The Talloires Declaration was formulated in 1990 by what became the Association of Universities Leaders for a Sustainable Future at a meeting in Talloires, France. It was the first official statement of a commitment to environmental sustainability in higher education made by university administrators, and it provides a ten-point action plan for incorporating sustainability and environmental literacy in teaching, research, operations and community responsibilities in universities. Originally signed by 31 university representatives, there are now 520 signatories from 60 countries as of September 2021 (http://ulsf.org/96–2/). Australia now has 24 signatories, and this chapter presents a case study of the sustainability education activities at an Australian university that signed the declaration in 1995.[1]

The Talloires ten-point action plan requires signatories to

1. Increase Awareness of Environmentally Sustainable Development
2. Create an Institutional Culture of Sustainability
3. Educate for Environmentally Responsible Citizenship
4. Foster Environmental Literacy for All
5. Practice Institutional Ecology
6. Involve All Stakeholders
7. Collaborate for Interdisciplinary Approaches
8. Enhance Capacity of Primary and Secondary Schools
9. Broaden Service and Outreach Nationally and Internationally
10. Maintain the Movement

This case study focuses on what RMIT University had done (at the time of the investigation, which was pre-pandemic and before the recent extensive changes in the university's senior executive) in terms of the effectiveness and sustainability of the funded sustainability-related initiatives and what else could be done to strength this university's, and others, commitment to sustainability.

Sustainability commitments at RMIT University

RMIT University has a long history of recognising the importance of sustainability. During the 2000s overt actions included creating a Global Sustainability Institute and the position of an innovation professor in sustainability (both of which no longer exist). These activities were informed by a triple bottom line approach plus one (comprising environmental, social and cultural economic and governance dimensions) in both scholarship and operations (Holdsworth and Caswell 2004).

Since 2012, the university has had a sustainability policy, which is intended "to express RMIT's commitment to advancing its sustainability ambitions as an organisation that models institution-wide excellence by embedding sustainability principles and practices throughout learning and teaching, research and operational activities" (RMIT 2012/2020). The definition of sustainability contained in this policy states:

> As a signatory to both the United Nations Global Compact and the Universities Commitment to the Sustainable Development Goals (SDSN Australia/Pacific 2017), RMIT defines sustainability as:
>
> a. development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Building an inclusive, sustainable and resilient future for people and the planet
> b. harmonising three core pillars: economic health, social inclusion and environmental protection, which are interconnected, and crucial for the wellbeing of individuals, societies and ecosystems. (RMIT 2012/2020)

Sustainability has been incorporated into the university's Graduate Attributes (the broad skills that RMIT University expects that graduates will have acquired and be able to demonstrate to an appropriate level whatever their program of study) since 2012 as "Environmentally Responsible": "Graduates of RMIT University will have engaged in processes to develop their abilities to recognise environmental and social impacts and to provide leadership on sustainable approaches to complex problems" (RMIT 2021a).

Examples of how this graduate attribute can be evidenced include:

- Recognise the interrelationship between environmental, social and economic sustainability.
- Appraise and critique context-appropriate sustainability measures.
- Take responsibility for critical decision-making in ensuring sustainable outcomes.
- Appropriately apply their environmental and sustainability literacy in a highly diverse range of contexts. (RMIT 2021a)

RMIT has also committed to the objectives of the United Nations Sustainable Development Goals (SDGs), and has reported examples of how its sustainability agenda addresses the main targets in its sustainability annual reports since 2016 (sustainability annual reports have been produced since 2015, and SDGs impact reports have been produced for 2019 and 2020).

There is a Sustainability Committee, which is chaired by the university's chief operating officer, and it reports to the vice-chancellor's executive, according to the most recent sustainability annual report (RMIT 2020a). The committee's goal is "to ensure sustainability principles and practices are embedded within the University's core teaching and learning, research, governance and operational activities" (RMIT 2021b).

The current RMIT strategic plan, *Ready for Life and Work: RMIT's Strategic Plan to 2020*,[2] has "Improve environmental sustainability" as the fourth priority under "Goal 4 Managing resources for long-term value" (RMIT University 2015, 7). The only other context for mentioning sustainability in the strategic plan is "We will manage our investments and resources to achieve our goals in learning and impact and to enhance our sustainability and independence as an institution" (19), which is part of Goal 4. This goal and priority have economic sustainability as implicit and environmental sustainability as explicit, but there is silence around social sustainability in name, although there are social sustainability aspects to other goals and priorities. For example, "valuing and growing our diversity" is a priority within Goal 1, and "supporting access, progression and pathways" is a priority within Goal 2 (6). However, according to the *2020 Annual Report*, in 2019 the vice-chancellor's executive (VCE) committed to incorporating "the SDGs into the core business of the University and the next RMIT five-year strategy (2021–2025)" (2021c, 51).

The RMIT *2018 Annual Operating Plan* made specific and detailed reference to sustainability in tertiary education:

> ***Sustainability in Tertiary Education***
>
> RMIT is committed to ensuring that principles of sustainability are embedded in all that we do. We have facilitated many projects and activities in Learning and Teaching which stimulate our community to consider how they can contribute to a more just, sustainable and considered way of living. In 2018, we will build on these activities and:
>
> - broaden our approach to Sustainability in Tertiary Education (SiTE) by incorporating the social dimensions of sustainability and citizenship
> - renew programs and curriculum to facilitate sustainability within RMIT's physical and virtual infrastructure
> - establish special interest groups and communities of practice within each school and college
> - develop a coordinated and scholarly curriculum approach by placing SiTE Fellows across the University, and a SiTE Program Manager in the Education portfolio
> - create staff development opportunities and credentials to improve sustainable ways of working
> - develop new infrastructure for seeding grants and scholarly innovations that promote sustainability. (RMIT 2018, 25)

Curiously, given the prominence of sustainability in other parts of RMIT's priorities, the only references to sustainability in the 2020 annual operating plan (RMIT 2020b) are two related to financial sustainability.

The 2018 *Annual Report* devoted a page to sustainability. Here there were reports on recognition of RMIT's infrastructure efforts, carbon neutrality goals, four digital micro-credentials that had been developed on sustainability topics in collaboration with industry for students and as part of a staff professional development program, the appointment of a senior officer, sustainable development and the introduction of Green Impact at RMIT – a behaviour change and engagement program designed to help staff and students understand sustainability and social responsibility and show them what they can do to embed these practices at work (RMIT 2019a, 37). There was no mention of supporting sustainability education.

In 2020 RMIT published its first *SDGs Impact Annual Report 2019* (RMIT 2020c, 10), which included reporting on "Education for SDGs" and noted that several courses "have already incorporated the SDGs as an opportunity to expand the concept of sustainability in the curriculum, as well as to ensure that students acquire the knowledge and skills needed to address the SDGs through their careers". The *SDGs Impact Annual Report 2020* (RMIT 2021d) did not report on this topic.

The *2020 Annual Report,* noted that

> In 2020, RMIT was ranked number one in the world for its efforts to reduce inequalities within and among countries (SDG 10) in the Times Higher Education (THE) University Impact Rankings. The University also ranked 10th overall, rocketing up from 82nd place in 2019. The Impact Rankings were designed to showcase progress against the 17 United Nations Sustainable Development Goals by measuring a university's social, environmental and economic impact.
>
> *(RMIT 2021c, 51)*

This report also noted that the Green Impact at RMIT program for staff had continued and that the Sustainability Committee was "Participating in sectorial dialogues to advance the SDGs in the education sector" and "Supporting academic and professional staff to design and implement SDGs initiatives" (RMIT 2021c, 51). No details are provided of what these activities entailed exactly.

Learning and teaching for sustainability initiatives: a case study

Between 2014 and 2016 RMIT funded three types of initiatives as part of its commitment to sustainability education. These were the Learning and Teaching for Sustainability (LTfS) teaching fellowships and innovation projects and the Sustainable Urban Precincts Program (SUPP). The LTfS awards were available to one fellowship and one innovation project per college in 2015 and 2016.

The LTfS teaching fellowships were for staff who were developing curriculum and assessment resources to enhance the student learning experience, graduate employment outcomes and positive outcomes for sustainability. The primary focus was intended to be a collaborative project, preferably multidisciplinary and industry profession focussed, that advanced LTfS in the curriculum across and beyond RMIT. The fellowship recipients tended to come from schools in the College of Design and Social Context (DSC) (seven recipients) with one recipient from the College of Business and none from the College of Science, Engineering and Health (SEH). The fellowship program cost around $230,000 over three years.

The primary focus of the LTfS teaching projects was to encourage strategic, high-quality curriculum design and development for multidisciplinary e-learning activities and e-assessment. It was preferred that these activities were created in collaborative and innovative ways, with a professional or industry focus, hence enhancing students' learning outcomes and graduate employability. The aim was that they will not only advance LTfS in the curriculum across RMIT within multiple disciplines but also within the global sustainability, professional and tertiary sectors. Recipients came equally from DSC and SEH (three each), and there was one from the Office of the Dean Learning and Teaching. None came from the College of Business. The teaching projects cost around $240,000 over three years.

The SUPP used an energy performance contract (EPC) model to guarantee savings and achieve the university's emissions reduction target. The goal was that the university's assets will be managed using a best practice approach resulting in higher performance, future capacity, increased reliability and resource efficiency. Five learning and teaching projects were supported as part of this program. Most recipients came from SEH. The *2018 Annual Report* noted that "the completion of the Sustainable Urban Precincts Program (SUPP) in 2017 enabled us to achieve our carbon emissions reduction target – 25 per cent by 2020 – four years early" (RMIT 2019a, 37). SUPP cost around $1.4 million over 3 years.

While there is an apparent disparity in funds allocated across these three funding schemes, they were all very different with different requirements and funding sources. In addition, while each of the colleges was offered the same funding opportunities, the College of Business did not put in submissions to some of the funding schemes. The funded projects have also tended to favour environmental sustainability – "greening the university" – rather than a broader understanding of social, economic and environmental sustainability.

Impact of the learning and teaching initiatives

Recipients of funding through the three initiatives were invited to participate in an evaluation of the LTfS initiatives. Two of the eight fellowship recipients responded, four of the seven project recipients responded and none of the SUPP recipients responded.

Both fellowship respondents had a broad view of sustainability as involving at least environmental and economic components, and both mentioned social sustainability.

The Open Boundaries project of one of the fellowship recipients managed to interweave these three components and address many of the SDGs through her two projects, which were developed through her course in furniture design (in the associate degree program). The first project involved working with the Salvation Army's Collingwood housing project where students had to design furniture for a scenario of a mother and two children needing to furnish a house on a $600 grant. The second project was for RMIT students to make instruction booklet for Indigenous groups outside Katherine (in the Northern Territory) to make stools with paintings to be sold through a local gallery. These two projects did not continue after one year, as the recipient has a different research project focus each year for the students, but there is always a sustainability component to her furniture design course and she has the support of her colleagues in the associate degree program, who also address sustainability in their courses. However, the outcomes of the projects do have the potential to be sustainable in the target communities with the stool-building guidelines and low-cost furniture designs.

The other fellowship recipient embedded sustainability in her business course, as she explained:

> Sustainability is the embedding of the considerations and applications of responsible environmental and social decision making, action and implementation in multiple contexts, for example in the Business Advisory Services course as environmental management and reporting by small business.

As a result, students have undertaken applied projects in the areas of waste management, environmental reporting and waste processing consulting in collaboration with the School of Engineering and the RMIT Sustainability Committee. There had also been discussions regarding developing more projects to be undertaken with the Greenhouse and Sustainability Program in the SEH at RMIT and to develop it further. The aim was to engage small businesses through the students' consulting projects for sustainability decision making and action.

Both fellowship respondents stated that more needs to be done to engage with industry in implementing sustainability solutions. Furniture and product design students have commented on how industry is not necessarily interested in broader sustainability issues, that their prime concerns are economic and that this needs to change. There were plans for the business activities to continue to expand with an aim to engage small businesses through the students' consulting projects for sustainability decision making and action and to work on waste management problems with local government and industry groups.

Both fellowship recipients commented on time as a barrier/limiting factor. For example, "Such initiatives require a major time investment and effort. Nevertheless it is worth it and the reward is obvious in the applied learning skills attained by the students".

The respondents who received teaching project funding had varying working definitions of sustainability. While one saw it broadly as "Critical engagement with the environmental social and economic implications and impacts of policy and practice, according to the values of intra- and inter-generational equity, and the survival of the planet", others focused solely on embedding RMIT's Environmentally Responsible Graduate Attribute (RMIT 2021a) in their courses.

The aim of one of the projects was to assess whether the sustainability capabilities developed in undergraduate programs are acknowledged and used by professional graduates from the Schools of Property; Construction and Project Management; and Global, Urban and Social Studies. The findings were that most respondents would take leadership roles or take on full responsibility for implementing 'top-down' sustainability measures. A large portion would also take on these roles and responsibilities to take initiative on unrecognised impacts. The majority felt they sustainability attributes were expected and supported in their workplace. Almost all felt their knowledge and experience to answer the survey came from RMIT studies (RMIT 2021a).

The funding recipient had her initial project from the 2014 funded form in both funding sources and involving colleagues. In 2015, drawing on the 2014 findings and working with other RMIT colleagues, she received a seeding grant from the Australian Government's Office for Learning and Teaching. She has also received funding from Australia-Germany joint research co-operation scheme for a 2018–2019 project on Sustainability Graduate Attributes Assessment and generated a number of publications. While the focus of this work has its origins in RMIT's Environmentally Responsible Graduate Attribute, students are being encouraged to see sustainability much more broadly:

> 'Managing for Sustainability' requires students to explore the diverse definitions of sustainability using the dimensions of natural environment, society and culture and the economy. It requires students to develop their own definition of sustainability, which requires them to reflect on their personal and subsequent professional practice of sustainability, including recognition of the different philosophical/disciplinary orientations and the emerging consequences in practice.
>
> *(Holdsworth and Thomas 2015, 152)*

Another recipient incorporated her broad view of sustainability in her social work project. Here, scenarios were developed that embedded sustainability considerations in social work practice. Students, staff and human service practitioners responded to and discussed the implications of the scenarios for their own professional practice. Sadly, as with several other initiatives, changes in course coordination and teaching responsibilities meant the course for which the scenarios were intended has not been able to use them. Instead, she adapted them for use in other courses, and she has generated peer-reviewed papers and journal articles. She also saw the scenarios contributing to academic development regarding sustainability principles and their connection with social work across the staff group as well as on students, educators and practitioners who had exposure to the scenarios who are now actively thinking about future-oriented practice.

Other staff received funding for two related projects over two years that focused on applying the key principles of sustainability, specifically in their online laboratory management course in the bachelor of biomedical science (laboratory medicine). The course addressed waste, energy and water as key issues in laboratory and hospital settings. They saw the course as being relevant to other groups across the university, such as first-year science students to provide them with basic sustainability understandings in laboratory contexts, health sciences (nursing, medical radiographers, osteopathy, chiropractic, Chinese medicine) and across medical sciences. A key focus of the course was to inspire the students to be agents of change for more sustainable practices in laboratories.

A different project developed two learning tools for two topics in the Advanced Power Systems and Power System Analysis and Control courses in electrical engineering to improve students' understanding of fundamental concepts. The tools were used in 2017, and student performance improved markedly. The recipient wrote a journal article based on the learning tool architecture and their experience with the learning tools created in this project.

While these responses are generally positive about the impact of the teaching project initiatives on progressing sustainability at RMIT and giving the involved students a broad understanding of sustainability, given the large number of courses and programs offered at RMIT, the overall impact on the general student population's experiences is small.

Respondents were enthusiastic about their own projects, but they also commented on the barriers, hindrances and limiting factors they experienced. The two main themes were having enough time to do what they had planned and lack of support (from colleagues and at the school or college level) for their initiatives and for sustainability in general. Comments included:

> It was difficult to find time to generate interest in other programs within the school and across the university, which was (and remains) something that I had hoped for that project.
>
> It was a great thing to attempt, but it needs ongoing investment of a kind that the institution may not currently prioritise (interdisciplinary, integrated, inquiry based collaboration).
>
> Graduate Attributes need to be mirrored at College and School levels – currently there is a disconnect between RMIT vision and actions because of this.
>
> The web server to host the learning tools was the major barrier, since the RMIT web server doesn't host these items and also doesn't want to pay for a private server to host these tools for foreseeable future. Subsequently, learning tools were developed in google sites which has some limitations in comparison to web sites hosted in standard web servers.

These issues and strategies for addressing them are discussed further in the section on "Building ownership of and supporting sustainability initiatives in universities".

As noted previously, the RMIT *2018 Annual Operating Plan* indicated that there would be an expansion of support for the inclusion of sustainability in programs and curriculum, for the incorporation of social dimensions of sustainability and citizenship across programs, creation of Sustainability in Tertiary Education (SiTE) positions in Colleges and the Education portfolio and a new infrastructure for seeding grants, among other actions related to sustainability (RMIT 2018, 25). None of these activities were reported as having been implemented in the *Sustainability Annual Report 2018* (RMIT 2019b) or the *RMIT Annual Report 2018* (RMIT 2019a), or in any more recent reports.

Infrastructure initiatives

The majority of university expenditure on sustainability-related matters is on infrastructure. As noted in the recent annual reports and sustainability reports, there is an emphasis on reducing emissions and achieving carbon neutrality, reducing energy and water consumption, installing solar panels and building a wind farm and infrastructure upgrades. These projects are expensive, although some will create savings into the future.

Most of these expenditures have little to do with the learning and teaching activities in the university, although some may be referred to in engineering and other programs. However, they can serve a broader purpose – as a role model for the community. As the Association of University Leaders for a Sustainable Future (2002, 4) notes, "The university is a microcosm of the larger community, and the manner in which it carries out its daily activities is an important demonstration of ways to achieve environmentally responsible living".

Building ownership of and supporting sustainability initiatives in universities

The important role of universities in achieving a sustainably literate citizenry has long been emphasised, but this role is beyond preparing 'work-ready graduates' and mastery of relevant content knowledge: it means preparing students with critical thinking, problem solving, creativity and innovation skills for active participation in achieving sustainable development. As Walter Leal Filho and Paul Pace (2016, 3) note, "although preparing students for employment is a very important aspect of HE institutions, ESD programmes should focus on a wider target: preparing students for a future that is still unknown".

There is potential for achieving this goal in the "Tertiary education" section of RMIT's Sustainability Policy (RMIT 2012/2020) which states:

(10) Engage students at all levels in learning about relevant sustainability concepts (knowledge, skills and values), identifying issues of importance and taking actions in order to empower them as future leaders in industry and society.
(11) Embed sustainability capabilities/competencies within disciplinary and professional contexts and encourage interdisciplinary collaboration.
(12) Support academic and teaching staff to develop high levels of discipline relevant sustainability literacy so that they are able (competent and confident) to facilitate sustainability learning.
(13) Support our students to drive innovation and sustainable enterprise.

This policy has potential to be realised in a range of teaching and learning activities beyond current and past initiatives. The LTfS initiatives of 2014–2016 (discussed earlier) provided opportunities for individual academics to develop specific initiatives to enhance their particular areas of teaching. However, the impact of these initiatives was limited in scale, and in some cases the activity developed was only offered once, if at all.

Building ownership of and supporting sustainability initiatives require central leadership to advocate for and support the inclusion of sustainability in courses and programs across the university as part of building capacity and ownership of sustainability as a key university priority. This involves more than writing it in a policy and having a committee. The Sustainable Development Solutions Network – Australia/Pacific (SDSN) guide (2017) provides five steps to the SDG-engaged university:

Step 1: Map what you are already doing.
Step 2: Build capacity and ownership of the SDGs.
Step 3: Identify priorities, opportunities and gaps.
Step 4: Integrate, implement and embed.
Step 5: Monitor, evaluate and communicate.

With the introduction of the SDG impact annual reports (RMIT 2020c, 2021d) there is now some mapping of what is happening across the university, though much remains to be done to map the curricula offered across the university. However, building capacity and ownership of sustainability by academic staff is an ongoing challenge, as are the subsequent steps toward the SDG-engaged university.

The only designated sustainability position at RMIT is the senior manager of sustainability, a position located in the Property Services Group, who is responsible for the refurbishing, planning, design and construction of facilities for academic and administrative purposes, not course and program content. The appointment of a designated SiTE program manager in the Education portfolio could provide guidelines and assistance for curriculum development that embeds sustainability concepts and competencies within the various courses and programs. Professional development programs for academic staff could be offered to develop their confidence and competence in delivering sustainability-related knowledge, skills and values.

The LTfS grant recipients were enthusiastic individuals, but most commented on the barriers and apathy they experienced from colleagues and school and college leadership to expand their work, and in some cases to continue it. These recipients could have been named as the SiTE Fellows which were proposed, in the *2018 Annual Operating Plan*, to be placed across the university to develop a coordinated and scholarly curriculum approach to sustainability, but this activity did not proceed.

While some academic staff know about sustainability, they often see it in terms of environmental sustainability, and they do not see it as relevant to them or their teaching and research. There is little understanding of the breadth of sustainability concepts or what they could do to work towards the achievement of these through their teaching and research.

The LTfS grant recipients noted a mismatch between the university's policy and vision and the practices at school and college levels, which manifested as a lack of support for going beyond what had been funded (or even to complete what had been funded by the LTfS initiative). The recipients could see great potential for implementing their project in other courses and in other schools, but this possibility generally met with resistance because it was not in school plans or there were not funds or time for further work. Sadly, this is a common experience with curriculum innovations, but it could be avoided if there were designated sustainability curriculum support staff at central, college and school levels to advocate for sustainability and seek accountability from schools and colleges. Resistance by academic staff to engaging with sustainability has been noted by others in this volume, including Balser (in this section, see Chapter 9.1 in this volume) and, in Section 5, both Gomera, Antúnez and Villamandos (see Chapter 5.5 in this volume) and Segalas and Tejedor (see Chapter 4.3 in this volume).

Although the sustainability policy and the Sustainability Committee have moved from a focus on greening the university to a broader concept of sustainability (as reflected in the SDGs), not everyone understands or shares this vision, and there are some conflicting messages within RMIT's own rhetoric. For example, the detailed Graduate Attribute "Graduates of RMIT University will have engaged in processes to develop their abilities to recognise environmental and social impacts and to provide leadership on sustainable approaches to complex problems" is summarised as "Environmentally responsible", whereas the attribute is actually about much more than just environmental sustainability. Many staff perhaps do not even look beyond the summary dot point and consider the broader implications of the expanded attribute or how it may be evidenced.

Achieving national and international recognition for efforts in sustainability is another strategy designed to build ownership of sustainability within the university. As the *Sustainable Development Goals Impact Report 2020* (RMIT 2021d, 2) noted

> In the 2021 Times Higher Education Impact Rankings, RMIT was ranked number three in the world for overall global performance against the SDGs, out of more than 1,100 universities from more than 90 countries. Standout results across the SDGs included the University being placed second in the world for SDG 10: Reduced Inequalities, and third for SDG 17: Partnerships for the Goals. RMIT ranked fifth in the world for SDG 8: Decent Work and Economic Growth for the second consecutive year, 13th for SDG 11: Sustainable Cities and Communities and 23rd for SDG 6: Clean Water and Sanitation. RMIT rose 18 places to be ranked 40th for SDG 9: Industry, Innovation and Infrastructure and was ranked 84th for SDG 12: Responsible Consumption and Production.

The university was not ranked on SDG 4: Quality Education.

RMIT has received several Green Gown awards at the Australasia and international level (https://www.rmit.edu.au/about/our-values/sustainability/about-us). Most recently, RMIT won two Green Gowns Awards Australasia in 2021 (https://ggaa.acts.asn.au/2021awards/). These awards were for "Climate Action" and "Leading a Circular Economy", both areas of activity for Property Services. Sustainability education initiatives are only recognised at the individual level in these awards, and an RMIT academic has not received one of these.

Conclusion and moving forward

Based on the previous discussion, there would seem to be a number of areas for future actions towards sustainability education across the university.

Following the SDSN (2017) five steps to the SDG-engaged university, the first step should be to map where sustainability is already being covered in various courses across the university. This mapping should not just be looking for greening of the curriculum, as in the "environmentally aware" graduate attribute (RMIT 2012/2020), but for broader social engagement in terms of the total environment (see Chapter 7): "Environmental education should consider the environment in its totality – natural and built, technological and social (economic, political, technological, cultural-historical, moral, aesthetic)" (UNESCO 1978, 27).

Taking this broader view of sustainability education, beyond its connections with the environment and consistent with the SDGs, there is another Graduate Attribute that could be considered part of RMIT's commitment to sustainability, i.e. the one on "Culturally and Socially Aware" which states, "Graduates of RMIT University will have developed cultural, social and ethical awareness and skills, consistent with a positive role as responsible and engaged members of local, national, international and professional communities" (RMIT 2021a). Examples of how this graduate attribute can be evidenced include:

- Show understanding of the social and cultural heritage of Aboriginal and Torres Strait Islander peoples in Australia through active engagement with individuals and communities.
- Recognise and respect the role of cultural difference and diversity in work and social contexts.
- Practise non-discriminatory attitudes in relation to all kinds of difference and diversity, not simply culturally but also those based on gender, religion, sexual orientation, identity and ability.
- Acknowledge and critically reflect upon personal attitudes, decisions and conduct.
- Articulate and apply personal ethical actions in professional and vocational situations.
- Assess and evaluate issues of social justice as they apply in particular discipline, vocational and professional contexts.
- Analyse and examine issues of social justice and equality with respect to Aboriginal and Torres Strait Islander peoples and individuals.
- Appraise and critique the potentially powerful social and economic effects of enterprise and business activities on particular groups and individuals. (RMIT 2021a)

Much of this elaboration is describing what is just good sustainability education.

Taking on board the comments from the LTfS grant recipients, and acknowledging neoliberal university accountability requirements, if the university is serious about achieving its sustainability education goals, then sustainability needs to be built into school and college strategic planning targets related to teaching and learning.

Then, if these targets are to be achieved, there needs to be mandated, not voluntary, professional development programs for all academic staff to build capacity and ownership for incorporating sustainability into their teaching, to ensure that they understand and own responsibility for implementing sustainability concepts and understand how these concepts could be incorporated into their various courses. The professional development should also assist academic staff to identify priorities, opportunities and gaps that could be addressed in their courses. Staff should also be given the opportunity to identify areas of shared interest across the university and opportunities for internal collaboration and external partnerships that could enhance their teaching of sustainability concepts.

Following this professional development, staff need to have the opportunity to be assisted mentors with integrating, implementing and embedding the sustainability concepts into their courses. Once this has happened, the initiatives need to be monitored and evaluated and their successes communicated to other staff and showcased more broadly.

Academic staff who are revising their courses or introducing new ones to take on board the sustainability concepts should have access to grants and time allowances to enable them to fully engage in the development, implementation and dissemination of their work. As part of this, staff who are up to the dissemination stage could be named as "Sustainability Ambassadors" and provided with time and funds (if needed) to promote and disseminate their initiatives more broadly across the university.

Notes

1 It is interesting to note that the RMIT Sustainability Annual Report 2020 does not mention that it is a signatory to the Talloires Declaration. The key global and local organisations mentioned are United Nations Global Compact Network Australia, Australian Technology Network (ATN), Australasian Campuses Towards Sustainability (ACTS), Green Building Council of Australia (GBCA), Sustainable Development Solutions Network (SDSN), and Tertiary Education Facilities Management Association (TEFMA) (RMIT 2020, 21).

2 This strategic plan was meant to be replaced in 2020 but due to the pandemic and then the resignation of the vice chancellor, the university seems to be awaiting the arrival of the new vice chancellor in early 2022 before releasing the new strategic plan.

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9.4

ANCHORING SUSTAINABILITY IN THE AUSTRALIAN EDUCATION CURRICULUM

Rachel Sheffield and Sonja Kuzich

Key concepts for sustainability education

- Internationally many school systems are seeking to embed sustainable education into curriculum. UNESCO has been promoting this through the Global Citizenship Education Development (GCED).
- The Australian Curriculum currently has a piecemeal approach to sustainability with concepts largely taught in science and humanities and social science (HASS).
- *Sustainability* is one of the Cross Curriculum Priorities alongside Aboriginal and Torres Strait Islander histories and cultures and Asia and Australia's engagement with Asia; however, the outcomes are vague and challenging to measure. Anchoring it in the curriculum as a General Capability provides a measurable developmental progression for teachers.
- A more holistic pedagogy to teach sustainability could come through the integration of subjects such as science, technology, engineering and mathematics (STEM).
- Teaching sustainability in the Australian Curriculum requires not just a holistic curriculum with assessment criteria but also infrastructural physical and policy supports, coupled with appropriately funded staffing.
- Student voice and co-creation are critical to developing effective curriculum for sustainability.

Introduction

Internationally all school systems are seeking to embed sustainable education into curriculum. UNESCO has been promoting this through the Global Citizenship Education Development initiative (GCED) (UNESCO 2014). Australia, at the forefront of this way of thinking, incorporated 'sustainability' into their new national curriculum (version 1) (ACARA 2009). Each country addresses this differently, and this chapter explores how Australia, as a case study, approaches sustainable education as an outcome of this international impetus. In doing so, we articulate how the sustainable mindsets of Australian students are nurtured during their schooling as a preparatory phase for tertiary education.

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The challenge for teachers, working with an overcrowded and content-heavy curriculum, is to find ways to incorporate *sustainability* in a deep and meaningful way. Sustainability, although articulated as a cross curriculum priority, has held a precarious position in teachers' pedagogical practice. Students are leaving school with patchy incomplete ideas around sustainability and climate change, lacking the ability to take definitive action. To be an effective force for change, sustainability needs to move from a peripheral, fragmented representation in the curriculum, where it may be considered just another 'important' topic to be included, to a more integrated and holistic approach. We suggest anchoring sustainability through an integrated transdisciplinary curriculum approach that leverages the benefits of the General Capabilities (GC) and the STEM thrust in schools will support teacher pedagogy and improve the breadth of student learning in sustainability.

The challenge for sustainability in the Australian Curriculum

This chapter reviews the Australian Curriculum and considers key recommendations required to ensure sustainability has a strong presence in student learning. It considers suggestions including re-orientating or re-contextualising STEM with an urgent sustainability focus; the implementation of necessary policies, procedures and platforms; and the development of an accountability framework to measure the achievement of classrooms, teachers and schools. The goal is to create a learning environment which will:

> Empower young people as change agents for sustainable development by creating opportunities for learning and civic engagement and providing them with the competencies and tools to participate in ESD as co-creators of individual and societal transformation.
>
> *(UNESCO 2021)*

These are turbulent, precarious times with multiple and intersecting social, cultural, environmental, economic and political issues, both local and global, affecting our collective futures. Ensuring all students graduate from school with a strong understanding of, and competency with, sustainability thinking is an imperative for the future of our planet.

In the development of the Australian Curriculum, the goals of the *Melbourne Declaration of Educational Goals for Young Australians* (MCEETYA 2008) were a strong influence. The two central goals spoke of the role of Australian schooling to promote equity and excellence and the development of successful learners that are confident, creative, active and informed. The Australian Curriculum and Reporting Agency (ACARA 2009) noted the "Complex environmental, social and economic pressures such as climate change, that extend beyond national borders pose unprecedented challenges" heralded a "need to nurture an appreciation and respect for social, cultural and religious diversity, and a sense of global citizenship" (ACARA 2009, 5).

The impetus for the development of a national Australian Curriculum was to enable learners to respond to these kinds of changes by developing their capacity "to engage with scientific concepts and principles, and approach problem solving in new and creative ways" (MCEETYA 2008, 5).

In support of this ideal, the Australian Government created three cross curriculum perspectives that spanned all the learning areas and every year level – Aboriginal and Torres Strait Islander Histories and Cultures, Asia and Australia's Engagement with Asia and Sustainability. Sustainability was to be "a commitment to sustainable patterns of living . . .

reflected, where appropriate, in national curriculum documents" (ACARA 2009, 13). The intent of this sustainability Cross Curriculum Priority (CCP) was to:

> allow young Australians to develop the knowledge, skills, values and worldviews necessary for them to act in ways that contribute to more sustainable patterns of living. It will enable individuals and communities to reflect on ways of interpreting and engaging with the world CPP.
>
> *(ACARA. n.d, para 2)*

The Australian Curriculum therefore ostensibly supports students to act in favour of greater sustainability providing opportunities for developing their capacity to reflect on the world and ways to contribute to a more sustainable future. Yet, despite this imprimatur, there is a concern about the limited impact on student learning and their ability to actively respond and act to address sustainability issues.

An additional concern is that teachers may also have limited knowledge of sustainability, which inhibits the development of systematic and conceptually coherent teaching programs (Berger, Gerum, and Moon 2015; Hill, Emery, and Dyment 2012).

A growing global anxiety, triggered by successive natural disasters caused by climate change, and the effect on societal health and wellbeing of the current COVID-19 pandemic, has brought a new sense of urgency in rethinking the way we educate for sustainability. The current piecemeal, fragmented approach to sustainability education suggests there is a need for a more robust conceptual and practical anchoring in the curriculum. Education for sustainability (EfS) is an educational response for these times and guides the required changes to school policies, practices, infrastructure, pedagogy and the formal curriculum to provide hope for the future (Kuzich, Taylor, and Taylor 2015).

History of the Australian Curriculum

In 2009 the Australian National Curriculum Board met and approved the version 1.0 of the curriculum. A blueprint was created taking a look at the Melbourne Declaration on Educational Goals for Young Australians (2008), research in the area, identified learning needs in 21st century and the current national and international curriculum. After input was considered from thousands of stakeholders and multiple iterations of the curriculum were reviewed and refined (ACARA 2013), in 2014 the Australian Curriculum was approved by the ACARA Board and all education ministers and was published at www.australiancurriculum.edu.au (ACARA 2022) initially in mathematics, English and science and then adding in other learning areas and the General Capabilities. Due to differences and divisions between the states and territories, there is a National Curriculum and State Curricula, dependent on the subject and the perceived needs of the state/territory.

Structure of the current Australian Curriculum

In Australian Curriculum version 8.4 there are learning areas in Foundation to Year 10, GCs and Cross-Curriculum Priorities. Figure 9.4.1 describes how these systems are interrelated, with the learning Areas supported by the continuum of the GCs and the overarching

Figure 9.4.1 Interrelated systems in the Australian Curriculum

Cross Curriculum Priorities. The discipline knowledge is described in eight learning areas. These are:

- English,
- Mathematics,
- Science,
- Health and Physical Education,
- Humanities and Social Sciences,
- The Arts,
- Technologies and
- Languages.

English, Mathematics, Science and Health and Physical Education are single study areas, whereas Humanities and Social Sciences, The Arts, Technologies and Languages are made up of multiple subjects.

In the learning areas there are three dimensions which include disciplinary knowledge, skills and understanding. In each learning area, the content descriptions specify what students will learn in the areas of content knowledge and skills. The achievement standards "describe the depth of understanding and the sophistication of knowledge and skill expected of students at the end of each year level or band of years" (ACARA 2021, p. 24). In the learning areas, the content descriptors are based on the developmental progress around a big idea. For example, in the Science curriculum the big idea of energy runs through Foundation to Year 10, and the energy focus gets more developmentally abstract as it progresses. Figure 9.4.2 demonstrates how big idea – the big idea of energy gets more complex and the building of concepts from concrete to the more abstract concepts.

Knowledge concepts that can describe aspects of sustainability are found in Science and HASS. These include a content descriptor around global systems ("global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere" [ACSSU189]) and are taught in Year 10 (ACARA 2022). 'Sustainability' concepts are taught throughout the science curriculum in the areas of physical science related to energy, biological science related to ecosystems and adaptations of plants and animals Earth and Beyond explores renewable and non-renewable it examines renewable and non-renewable resources and how the Earth is formed and shaped. These science concepts are frequently not taught in an integrated way and lack real-world examples to help students with understanding. There are also similar concepts in HASS or social sciences, such as geography and economics.

In primary school one teacher usually teaches all the subjects, which enables a more integrated approach towards learning. In Year 3–6 geography, including in Year 3, describes "The main climate types of the world and the similarities and differences between the climates of different places" (ACHASSK068) and "The use and management of natural resources and waste, and the different views on how to do this sustainably" (ACHASSK090) and "The impact of bushfires or floods on environments and communities, and how people can respond" (ACHASSK114) (ACARA 2022). There are a number of outcomes in science across all the strands, particularly in 'earth and space science'. There are also connections in economics, including Year 6, with the content descriptor "Types of resources (natural,

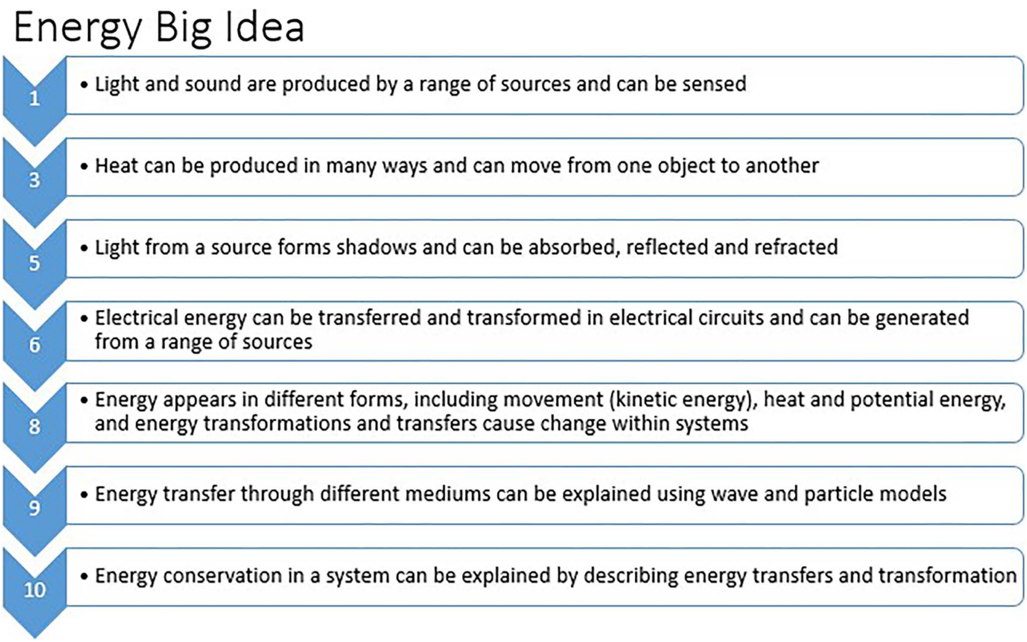

Figure 9.4.2 Progression Example of a Key 'Big' Concept unpacked for Students' Understanding

human, capital) and the ways societies use them to satisfy the needs and wants of present and future generations" (ACHASSK120) (ACARA 2022).

With the patchy knowledge and skills around 'sustainability' contained in the learning areas, then can the overarching systems in the Australian Curriculum provide the necessary framework to support schoolteachers to teach sustainability in a holistic and cohesive way? In the Australian Curriculum there are the General Capabilities and the Cross Curriculum Priorities, which are discussed later. Whilst the Cross Curriculum Priorities contain the area of 'Sustainability', the Priorities are vague and lack a progression to help guide teachers to create materials to progress students to a deep and meaningful understanding. The General Capabilities discussed next are more detailed and use developmental curriculum to describe the learning outcomes, and may provide a more detailed framework that could better support sustainability.

General Capabilities as a possible place for sustainability

In the Australian Curriculum, GCs encompass knowledge, skills, behaviours and dispositions that, together with curriculum content in each learning area and the Cross Curriculum Priorities, enable students to live and work successfully in the 21st century. They fit across all the learning areas, and all seven areas have been developed into elements and across a developmental continuum. These are:

- Literacy,
- Numeracy,
- Information and Communication Technology Capability,
- Critical and Creative Thinking,
- Personal and Social Capability,
- Ethical Understanding and
- Intercultural Understanding.

For example, the Learning Continuum of Personal and Social Capability (Version 8.4) has four elements with the other elements having three or four sub-elements. The sub-elements are arranged in a developmental continuum from Level 1 to Level 6 in Year 10 (Table 9.4.1).

Table 9.4.1 Elements and sub-elements from the personal and social capability

fi	*Self-awareness*	*Self-management*	*Social awareness*	*Social management*
Sub-elements	• Recognise emotions • Recognise personal qualities and achievements • Understand themselves as learners • Develop reflective practice	• Express emotions appropriately • Develop self-discipline and set goals • Work independently and show initiative • Become confident, resilient and adaptable	• Appreciate diverse perspectives • Contribute to civil society • Understand relationships	• Communicate effectively • Work collaboratively • Make decisions • Negotiate and resolve conflict • Develop leadership skills

Each sub-element has developmental levels that progress from Level 1 to Level 6. Table 9.4.2 shows the progression of the element self-management and the sub-element 'work independently and show initiative'.

The framework and developmental levels enable teachers to measure students' progress through their schooling from Kindergarten to Year 10. The General Capabilities include the progression from Year 2 at Level 2 through to Level 6 which are the expectations to Year 10. For example, when examining a child in Year 4, they are considered to be working independently if they achieve Level 3 which means they are able to 'consider, select and adopt a range of strategies for working independently and taking initiative' (Table 9.4.2). In the classroom, the teacher would then need to consider what this would look like and how to provide opportunities for students to demonstrate they are able to select a 'strategy' that enables them to work independently. The CGs have been designed to be assessed and have the structure and rigour in place to guide teachers, unlike the Cross Curriculum Priorities, which lack detail and the progression. It may be that if sustainability' could be explored and expanded as a GC, it would provide teachers with more support through the curriculum to help them to teach this area.

Sustainability as a curricular Cross Curriculum Priority

The *Cross Curriculum Priorities* and the organising ideas within each were designed to enrich the content descriptions and the associated elaborations, providing depth and richness to student learning. They are not present in a systematic way across the curriculum, nor are they organised as a progression or continuum.

The Australian Curriculum has three Cross Curriculum Priorities:

- Aboriginal and Torres Strait Islander Histories and Cultures,
- Asia and Australia's Engagement with Asia and
- Sustainability

Table 9.4.2 Element (self-management) and sub-element 'work independently and show initiative' progression (Level 1–6)

Level 1	*Level 2*	*Level 3*	*Level 4*	*Level 5*	*Level 6*
Attempt tasks independently and identify when and from whom help can be sought	Work independently on routine tasks and experiment with strategies to complete other tasks where appropriate	Consider, select and adopt a range of strategies for working independently and taking initiative	Assess the value of working independently, and taking initiative to do so where appropriate	Critique their effectiveness in working independently by identifying enablers and barriers to achieving goals	Establish personal priorities, manage resources effectively and demonstrate initiative to achieve personal goals and learning outcomes

In the Australian Curriculum the intent of the sustainability Cross-Curriculum Priority is fundamental to:

- understanding the ways social, economic and environmental systems interact to support and maintain human life
- appreciating and respecting the diversity of views and values that influence sustainable development
- participating critically and acting creatively in determining more sustainable ways of living' (ACARA 2021, para 1).

These ideas underpin the three key concepts of *Systems, World Views* and *Futures* which are represented in the nine organising statements that are designed to be infused across all the learning areas (Table 9.4.3).

This system has been developed to be general and open to ensure teachers can use them across a wide range of learning areas. The disadvantage is that the statements are vague and there is no way for teachers to capture the specific learning. The learning in the area of the CCPs are not reported to parents nor are they recorded, and therefore understandably it is not an area of focus for teachers in classrooms. The CCPs do, however, align with the sustainability mindset (Kassel, Rimanoczy, and Mitchell 2017).

Table 9.4.3 Organising ideas of the sustainability Cross Curriculum Priority

Organising Ideas	
System	
OI.1	The biosphere is a dynamic system providing conditions that sustain life on Earth.
OI.2	All life forms, including human life, are connected through ecosystems on which they depend for their wellbeing and survival.
OI.3	Sustainable patterns of living rely on the interdependence of healthy social, economic and ecological systems.
World View	
OI.4	World views that recognise the dependence of living things on healthy ecosystems, and value diversity and social justice, are essential for achieving sustainability.
OI.5	World views are formed by experiences at personal, local, national and global levels, and are linked to individual and community actions for sustainability.
Futures	
OI.6	The sustainability of ecological, social and economic systems is achieved through informed individual and community action that values local and global equity and fairness across generations into the future.
OI.7	Actions for a more sustainable future reflect values of care, respect and responsibility, and require us to explore and understand environments.
OI.8	Designing action for sustainability requires an evaluation of past practices, the assessment of scientific and technological developments, and balanced judgements based on projected future economic, social and environmental impacts.
OI.9	Sustainable futures result from actions designed to preserve and/or restore the quality and uniqueness of environments.

Source: (ACARA 2021)

Integrated approach to incorporate sustainability in the curriculum

In the primary area the learning is often more integrated as teachers can teach across multiple learning areas including HASS and science. This provides opportunities to consider some of the content knowledge in the curriculum such as energy flow and adaptations and biodiversity in organisms. Experienced primary teachers are able to focus on themes or problems within their classroom and create a holistic approach to learning. Whilst this is now umbrellaed in the term STEM, it was previously researched under the term 'integration', which was a more expansive and comprehensive description of all the learning that was necessary for the students to solve a problem or explore a topic. STEM can be implemented differently in different contexts and constrained by the school systems (Vasquez 2015). Vasquez's STEM continuum (Figure 9.4.3) provides a language for researchers and practitioners to discuss the STEM integration taking place in their school. STEM can be separated into its discipline subjects at its most narrow context or it can be considered as a wider transdisciplinary approach where the problem transcends the subjects and students apply the necessary skills and knowledge to solve the problem.

In secondary classrooms, however, teachers teach one subject only, and therefore a more integrated approach in this siloed situation is less feasible. Secondary educators teach in a single content area, and sometimes more specifically the biology teacher will teach the biology unit or human biology unit and then a chemistry teacher will teach the chemistry unit in the science course in the same lower secondary classes (Year 7–10). This ensures the teachers teach and specialise in their content area, but it can reduce the connectedness of the learning.

STEM has become a very popular area that readily attracts funding to schools and demonstrates the value of a more integrated approach to teaching and learning. As STEM is already a well-rehearsed pedagogy that champions a transdisciplinary approach in school contexts, it has the potential to be reframed to incorporate the ideas of sustainability and climate change. Students have declared that these two issues are of great importance to them and would be a way of further engaging those that are drawn to the scientific-mathematic learning, as well as re-engaging others who prefer real-world

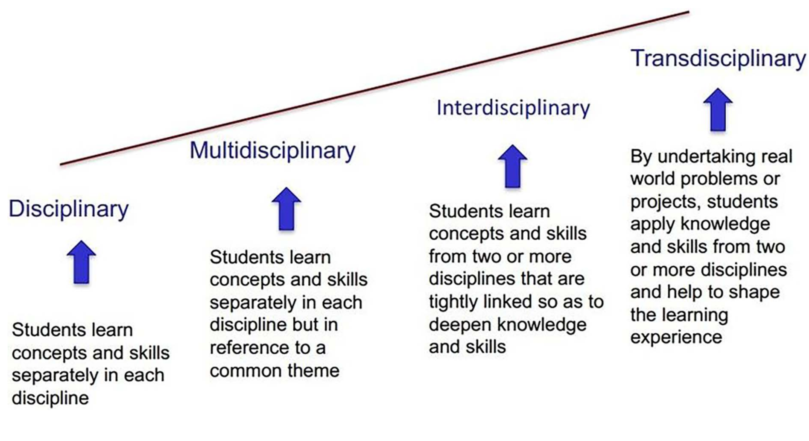

Figure 9.4.3 STEM Continuum (Vasquez, 2015)

problem solving (Pearson et al. 2021; Sheffield and de Kok 2020). It would be a transdisciplinary approach where the context is the sustainability 'problem' or issue that would provide the focus and students would then develop a range of skills and knowledge (Radloff and Guzey 2016). This would enable young people to "acquire the knowledge and skills needed to promote sustainable thinking throughout their lives and in their future careers" (Pearson et al. 2021, 5).

So, whilst there is an apparent abundance of content knowledge embedded throughout the curriculum to help students learn about sustainability, the fact remains that students leave formal schooling with a lack of comprehensive understanding of sustainability and the ideas considered to be important to their future.

Recommendations for the future

Education for sustainability (EfS) requires alterations to policies, practices, infrastructure, pedagogy and the curriculum of formal education (Kuzich, Taylor, and Taylor 2015). In a submission to Parliament in response to an inquiry around climate change and sustainability in Western Australian schools, five overarching general recommendations (item 2–6 next) were put forward (Pearson 2021). The subsequent discussion draws upon specific features of recommendations 2, 3 and 4, as they are particularly relevant to matters of curriculum that need to be considered in the implementation of sustainability education in schools. To contextualise the discussion that arises from these three recommendations, we first discuss the importance of developing sustainability mindsets.

1. Sustainability mindset
2. Governance
3. School policy
4. Curriculum
5. Training, support, networks and partnerships
6. Infrastructure

Each of the recommendations is dealt with in the order identified. Within each section, suggestions are made for ways that sustainability can be more firmly 'anchored' in the curriculum to better support teacher and student understanding and capacity for sustainable action.

Sustainability mindset

There is a fundamental requirement for worldviews to shift from anthropocentrism towards eco-centrism, thus creating strong sustainability mindsets (Rühs and Jones 2016). Such deeper worldview changes are considered precursors to shifting teacher pedagogy that will encourage a greater utilisation of critical and systems thinking (Meadows, Sweeney, and Martin-Mehers 2016) and action-oriented teaching aligned with the sustainability CCPs and the GCs.

A sustainable mindset is premised on an eco-centric way of thinking. Eco-centrism shifts thinking from a utilitarian approach to the world, where humans have supreme importance, to a socio-ecological view that frames the human/nature relationship in terms of care and stewardship (Imran, Alam, and Beaumont 2011). Kassel, Rimanoczy and Mitchell's (2016) definition draws upon this view:

> a way of thinking and being that results from a broad understanding of the ecosystem's manifestations, from social sensitivity, as well as an introspective focus on one's personal values and higher self, and finds its expression in actions for the greater good of the whole.
>
> *(p. 5)*

There is plenty of research about the characteristics of a sustainable mindset. Laufenberg-Beerman et al. (2021) suggest that a sustainable mindset uses system thinking to bring together knowledge, and those that hold that knowledge, to articulate values and consider actions. Having a sustainable mindset means that importance is placed on collaboration with all stakeholders and that values are developed and communicated. In addition, it entails taking a holistic view that include 'seeing' and acting across a global, national and then local perspective. The aim is to engage all stakeholders, seek compromise, develop and transform approaches to meet the needs of all participants using empathy and develop innovative and future-suited solutions. Table 9.4.4 provides a framework developed from UNESCO (2012) and the work of Kassel, Rimanoczy, and Mitchell (2016) to show the key aspects of a sustainable mindset. Kassel, Rimanoczy, and Mitchell's (2016) sustainability framework considers three areas: knowledge, value and actions which can be described as competencies. These are considered across four frames including first as the complexity of the global issues, which requires system thinking and approach; the second which is an ecological worldview; the third is emotional intelligence and includes compassion and self-awareness; and the final area is spirituality, which includes openness and the embracing of all that there is. UNESCO (2012) included similar frames and includes collaboration. Table 9.4.4 incorporates the UNESCO collaboration into the Kassel, Rimanoczy, and Mitchell (2016) sustainability framework to produce an elaborated version that considers knowledge, collaboration, values and actions. Using the UNESCO, Kassel, Rimanoczy and Mitchell sustainability framework enables teachers to focus on developing students' mindsets which includes a more holistic focus including knowledge, skills, and values and in certain circumstances predicts actions. For teachers, the sustainable mindset does not limit or direct their development of sustainability in their classroom. It is open enough to enable them able to explore a raft of ideas across multiple learning areas.

Governance Policy framework for sustainability

Sustainability education in schools requires a strong underpinning policy framework. The policy framework in Australia that acted as a support for the inclusion of sustainability in education has been successively weakened. A number of influential national documents and initiatives assisted Australia to map its journey towards embracing sustainability, not only in education but also across wider government. For example, the 2005 report, *Educating*

Table 9.4.4 The UNESCO, Kassel, Rimanoczy and Mitchell sustainability framework

	UNESCO (2011)				
		Knowledge and skills Knowing	*Collaboration*	*Values/being*	*Competency/ actions*
Kassel, Rimanoczy, & Mitchell	Systems perspective or thinking	System theory	Bringing experts together	Interconnectedness	Engage with all stakeholders and the community
	Ecological worldview	Eco-literacy	Listening to others' knowledge and sharing	Bio spherics orientation	Consider protective and restorative actions
	Emotional intelligence	Self and others becoming more self-aware	Supporting others	Compassion and multiple perspectives	Practical global sensitivity Demonstrate proactivity and negotiate
	Spiritual perspective intelligence	Purpose and mission	Empathising together	Oneness with all that is	Contemplative practices being mindful and reflective regarding their impact

for a Sustainable Future: A National Environmental Education Statement for Australian Schools (DEH 2005), promoted the kind of education that dealt with 21st-century issues, embodying "sustainability in the broadest sense, with an emphasis on transformational change in values and behaviour from the individual to a global scale" (p. 6). This led to a pledge to embed EfS in formal schooling in the 2007 report *Caring for Our Future: The Australian Government Strategy for the UN's Education for Sustainable Development*.

Following this, *Living Sustainably: The Australian Government's National Action Plan for Education for Sustainability* (DEWHA 2009) catapulted sustainability front and centre. To support curriculum developers to interpret the intent of sustainability in these various policies and plans, the federal government developed the *Sustainability Curriculum Framework: A Guide for Curriculum Developers and Policy Makers* (DEA 2010). These documents, along with the imprimatur provided by the Melbourne Declaration of Educational Goals for Young Australians (Melbourne Declaration) in 2008, were the impetus for the inclusion of the sustainability CCPs in our first national Australian Curriculum in 2012. Such policy initiatives enabled an Australia-wide voluntary network of schools committed to engaging with sustainability and the Australian Sustainable Schools Initiative (AuSSi) schools network to flourish. The change of federal government in 2013 resulted in the shelving of these policy initiatives and the cessation of funding to the AuSSi network (Kuzich 2019). Since that date there has been no policy directive related to sustainability and education produced nationally.

Despite being a signatory to international multilateral agreements, such as the Paris Agreement in 2016, that affirmed the importance of climate change education and the United Nations 2030 Agenda for Sustainable Development Goals (SDGs) (UNESCO 2015), Australia has taken no action to develop a coordinated educational policy approach. As well as a lack of action, there is evidence of a policy 'wind back'. References to climate change and of the importance of integrating sustainability across the curriculum were notably absent from the most recent national guiding framework for the goals of Australian education, the Alice Springs (Mparntwe) Education Declaration, yet they were present in the previous 2008 Melbourne Declaration (Gough 2021).

It can be argued that the absence of a strong policy direction and mandate, to help shape and support the thinking and action and provision of possible associated funding, weakens the ability of those who would wish to pursue sustainability in education. In addressing these issues, the AAEE recommended, in their submission to the parliamentary inquiry, the need for two key aspects of governance:

1) Legislative framework and action plan to:
   - outline the vision for all sustainability education, with a particular emphasis on climate change, and the practical support to be provided for the design, implementation, monitoring and evaluation of policies, strategies, curricula and programs; and
   - encompass a whole of government approach laying out expectations of all government agencies, including the Department of Education, articulating responsibilities and deliverables.
2) Designated government directorate to:
   - oversee the allocation of funding to schools, development of curriculum, on-line resources, training, support and partnerships for all schools. Part of their responsibility would be to monitor and gather data on the implementation of UN SDG Target 4.7 to "ensure [that] all learners acquire knowledge and skills needed to promote sustainable development". (UNESCO, 2015)
   - utilise the knowledge and expertise of multiple stakeholders, such as environmental scientists, technical advisors to support school sustainability officers, sustainability and climate change researchers, curriculum experts, educators, but with a particular emphasis on giving a voice to young people.

Voices of children and young people

Whilst there are clear reasons mechanisms of governance such as legislative mandates, government policies and high-level action plans may be of great value in providing an impetus and guiding framework for sustainability; however, they often lose traction in the implementation stage. One reason for this rhetoric-implementation gap is the lack of engagement with and provision of a voice for children and young people. Pockets of youth across the world are evidencing their willingness to engage in policy and decision-making processes, particularly in relation to climate change education, at intergovernmental and local levels.

EfS seeks to redress this disenfranchisement of our young and provide multiple opportunities for them to develop the critical thinking, problem solving and deliberation skills to devise solutions to local and global issues.

In the largest study on the impact of climate change on children and young people to date, (Hickman et al. 2021) found their high levels of climate anxiety and distress was correlated to the perception of government inaction and feelings of betrayal and abandonment by governments and adults. They identified that children were now resorting to legal action to redress their sense of powerlessness. Trott (2021, 302) suggests the trouble is that whilst we treat them as 'adults in waiting' they are left "without a voice in consequential decisions and actions that affect their lives". She concludes that deference to primarily top-down solutions for the issues within their educational experience, determined at the levels of governance set by adults, negates the opportunities for students' active participation and agency.

Developing the necessary skills to engage with, and contribute to, the development of policies, laws and plans can be supported through a greater emphasis on the GCs. In particular, GCs such as Critical & Creative Thinking, Ethical Understanding and Personal and Social Capability reflect essential skills for the current generation. These capabilities flourish in an education that promotes participatory methods for empowerment, building of agency and development of leadership skills so they feel heard and their "voice shapes outcomes" (Trott 2021).

School policy

At the school level, implementing sustainability and integrating it into teaching and learning across the whole school is a long-term project. For many schools, EfS demands a significant shift in ethos and a reconceptualisation of the ways education is currently performed (Evans, Whitehouse, and Gooch 2012). Teachers, faced with numerous and competing demands, are forced to rationalise their time and energy. They are much more likely to invest time and energy if sustainability is a) clearly articulated by educational leaders at the school as a priority and b) funded and resourced.

Having a clearly agreed and jointly developed school sustainability policy would give teachers confidence that sustainability is not another educational 'fad'. Teachers have become wary of new initiatives, particularly ones that appear to be contradictory in purpose. For example, Kuzich's (2019) research identified a paradoxical situation is created for teachers when, on the one hand, they are judged on student results in narrow tests of literacy and numeracy, and on the other, following EfS requires a fulsome, rich and expansive view of curriculum.

There are a number of factors that need to be considered to maximise the impact and effectiveness of school sustainability policies. Two primary purposes of school-based policies are to guide educational practice and resource distribution. Taking the first point, Moore, Almeida and Barnes (2018) observe if " policies are 'overloaded' with infrastructure (such as an emphasis on energy efficacy, identifying water leaks and installation of solar panels) rather than education" they inhibit the incorporation of sustainability into the curriculum. Whilst the physical infrastructure is an important visible and tangible component of EfS in schools (Kuzich 2019), the more effective way to ensure it has educational relevance is for a clear articulation in educational policy. In the absence of any other active overarching sustainability policy framework, a school sustainability policy is a contextual interpretation of the Australian Curriculum. Each school, suggests Moore, Almeida, and Barnes (2018) needs to remake, renegotiate and reshape according to their individual school needs. However, teachers need to be given time to meet, talk, research, plan and implement these, and of course, require the corresponding funds to do so. They also need professional learning to develop their knowledge and understanding of EfS and the pedagogical practices that best support it. Arguably a school-based sustainability policy that focusses on these aforementioned aspects and prioritises educational practice is paramount.

EfS can also be effectively reinforced as an important educational endeavour by ensuring it is a) evident in school strategic and organisational plans, business plans, and annual reports to parents and the community; b) reflected in the discourse of staff meetings and newsletters; and c) represented as an indicator of school excellence and quality where real-world learning outcomes are celebrated. This is, of course, in addition to teachers' own curriculum planning documents.

The second factor of importance is the way in which school-based policies articulate the kinds of tangible physical, human and financial support being made available. Much of the work in the name of EfS in Australian schools is run by one or two passionate individuals in the school community: parents, staff or volunteers. As a policy maker this sends the signal that these projects and initiatives are not valued enough to merit school resources. A definitive policy action that demonstrates belief and commitment is the funding of at least one dedicated EfS position. This person would oversee the development of sustainability policies and initiatives, as well as be a resource for the teachers, students and the broader school community.

Developing school and community ownership of sustainability policies is critical as it is well understood that 'trickle-down' policy initiatives are inadequate for impacting practice (Moore, Almeida, and Barnes 2018). A whole-school approach has long been advocated as an effective model of infusing sustainability into the curriculum. One mechanism that supports the 'ripple out' of knowledge, skills and practices for sustainability is to create a School Sustainability Committee. Broadening the membership to involve school leaders, teachers, students, parents and other community representatives ensures that diverse views inform policies and has a greater likelihood of becoming embedded in school culture and ethos.

Curriculum Making sustainability explicit in the curriculum

Many teachers have had difficulty operationalising sustainability within their teaching. A number of reasons relating to how sustainability is identified in the Australian Curriculum can account for this. One reason is what Kuzich (2019) refers to as "fragmentation". This occurs when there is no clear connection between the *content descriptor*, the mandated and assessed curriculum component and the associated optional *elaboration* intended to provide suggestions for the pedagogical application of that concept. In many instances there was little clarity about what sustainability concept was to be taught. A further problem was the ad hoc nature of tagging sustainability concepts, marked with a three-pointed leaf icon, across the curriculum year levels and learning areas. There was a lack of an explicit representation of a coherent, developmental sequence of content knowledge, skills, attributes related to sustainability across the year levels.

A recommendation in the submission proposal put forward by the Australia Association of Environmental Education (AAEE) to the Western Australian parliament in 2021

(Pearson 2021) was that the GCs may be a more suitable mechanism as a guide for teaching sustainability and climate change concepts. The GCs, as noted earlier in the chapter, articulate the progression that students should take as they journey from Foundation to Year 10. They are aligned with the EfS principles as they are action oriented and focused on application to problem solving in the real world. The fact that they are intended to be taught in a cross disciplinary way, that is, they are relevant across all learning areas and demonstrate that learning is multidimensional, makes them eminently suitable.

The AAEE recommendation advises that there is still some additional work to be done by the Australian Curriculum and Assessment Authority (ACARA) to make this option feasible. The elements and sub-elements of each of the seven GCs could be coded to show sustainability values, concepts, skills and actions across each of the learning areas. This would make sustainability explicitly evident for teachers and provide a clearer guidance when developing classroom plans for curriculum and pedagogical. In this way teachers would not only focus on curriculum content knowledge, as the sustainability CCPs direct them to but also enable a greater integration of knowledge, skills within and across learning areas. A further consideration would be to ensure that this progressive framework is coupled with specific outcomes for students. This would enable a judgement to be made about student learning for sustainability via a grade or a mark, so parents also develop an appreciation of their child as a local and global citizen. By providing teaching and assessment examples that enable rich authentic learning opportunities the construct of sustainability would be broadened not only for students but for teachers also.

A further recommendation of from the AAEE submission was to remove the sustainability CCPs entirely from the curriculum and instead replace them with a combination of sustainability content descriptors aligned with the GC.

Refocusing STEM

The popular push in schools towards STEM may offer an opportunity to redefine how sustainability is taught. There are tremendous synergies between EfS and STEM that can be utilised to not only engage students in their learning but also to ensure they acquire the knowledge and skills to promote sustainability in their personal lives and future careers.

Reframing STEM initiatives to explicitly incorporate sustainability knowledge and values and climate change issues may be an effective way to develop student agency and learning. There is some international evidence to suggest that when the learning shows a direct link between advances in science and technology and ways to address climate change and environmental issues, young people are more readily engaged (Gough 2021). Our children and young people continually demonstrate their desire and need to be active participants in creating solutions. They can see the relevance and value of science when it is used to create positive social, cultural and environmental impacts (Rousell and Cutter-Mackenzie-Knowles 2020).

It is important to note whilst outside the remit of this chapter, there are other factors, which are also critical to creating an environment to encourage sustainability in Western Australian schools. These include the training, support and partnerships (as identified in Recommendation 5 in Pearson et al. 2021) to help enact identified changes and this comes with the necessary funding options. Infrastructure (as identified in Recommendation 6 in Pearson et al. 2021) is another important aspect of this process. It is not enough that schools teach sustainability; it is also important that schools also practice sustainability though the necessary processes and infrastructure. This can include audits of power, water and consumption, which can include consideration of schools recycling and other additional practices. If these are to be considered, schools would need to have a system that measures achievements from baseline standards and reports on these achievements so that the community, parents and students are made aware of the sustainability efforts of their local schools.

Conclusion

For sustainability to authentically integrate into teaching and learning, the key concepts, skills, values and attitudes require clear articulation and signposting in the curriculum. Anchoring these ideas through the integration of the sustainability CCP and the GCs to provide an explicit and systematic progression of sustainability concepts in the Australian Curriculum is a priority. Developing a sustainability mindset happens when students see the connections between ideas whilst working in an integrated, transdisciplinary way, such as in STEM projects. It also happens when we ensure our children and young people have a participatory role in co-creating, not only their learning but also solutions to real-world problems, such as climate change. Schools can set the agenda for learning through supportive policy frameworks that allocate human, physical and financial resources – an indication of how EfS is valued. Nurturing students' willingness and energy to learn for a sustainable future in these ways ensures that they leave formal schooling with a deeper understanding of the complex systems at play and their role in creating a better future for all.

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9.5
SUSTAINABILITY EDUCATION IN INDIA
A discourse in education development

Shaji Joseph, Kanchan Patil, Apoorva Vikrant Kulkarni and Michele John

Key concepts for sustainability education

- Education is the best means to achieve both awareness and dissemination of sustainability knowledge and thinking to a population of 1.4 billion in India.
- India was one of the earliest signatories to the Sustainable Development Goals (SDGs) and has initiated a number of programs to include sustainability in national educational plans. However, more effort is needed to increase curricula focus on education for sustainable development in India, as most efforts are still voluntary in nature.
- The establishment of national and regional organizations to conduct research on sustainability education, the initiatives of various educational boards, and the creation of the University Grants Commission to introduce short-duration courses on sustainable development have been notable items of progress in Indian sustainability education development.
- The role of voluntary organizations and non-governmental organizations (NGOs) in promoting sustainable development education has also been important.
- Instead of stand-alone courses on sustainability, there is a need to incorporate sustainability into all courses and programs. Above all, there is a need to train teachers in sustainability education.
- Sustainability education and values education are inextricably linked, with the latter providing fundamental moral and political ideals that help to underwrite the sustainability norms and dispositions required in sustainability education.

Introduction

> "A man is but a product of his thoughts. What he thinks he becomes."
>
> *(Mahatma Gandhi)*

India has one of the earliest civilizations in the world and is a country with diverse cultures and backgrounds. The periodic occurrence of droughts and floods has resulted in large-scale

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famines. With over 60% of the population depending on agriculture for their survival, a symbiotic existence between man and nature was inevitable. Human beings responded to this need differently. While some tried appeasing nature and venerated it as God(s), others tried to create a peaceful coexistence between these God(s) and nature. Indian social life too has a similar coexistence among various sections, creating a patron-client relationship where the patron necessarily took care of the client. The Constitution of India has reiterated this spirit when it said,

'We, the people of India, having solemnly resolved to constitute India into a sovereign socialist secular democratic republic and to secure to all its citizens, justice, social, economic and political; liberty of thought, expression, belief, faith, and worship; equality of status and of opportunity; and to promote among them all fraternity assuring the dignity of the individual and the unity and integrity of the nation.'

This coexistence of man and nature has been at the heart of its leaders when India became a signatory to the UN Earth Summit in 1972 and the Sustainable Development Goals (SDGs) in 2015. However, without a common consensus among its citizen, the SDGs cannot be achieved. Hence education takes a preeminent role in our effort toward disseminating sustainability values to its citizens. Both schools and universities need to incorporate sustainability lessons into the curriculum to make this possible (Joseph and Shetty 2022).

The concept of sustainability was first discussed at the United Nation's Earth Summit in 1972 in Stockholm. However, it was only in the 1980s that the term sustainability was coined by the Brundtland commission and the term 'sustainability' became a buzzword. Nation-states, business organizations, NGOs, and even educational institutions have incorporated sustainability values in their vision and mission documents. There is an increasing awareness regarding sustainability among Indian people. Schools and colleges organize events with sustainability themes, and organizations have started publicizing annual sustainability reports. Nature clubs and nature walks have become a trend among universities and schools. Newspapers have at least one dedicated column on sustainability every day. Children's magazines and periodicals regularly feature articles and comics to create awareness among children (*Poompatta, Balarama,* and *Chandomama*, to name a few children's magazines that have sustainability content regularly).

In 2020 the Indian prime minister reiterated the nation's commitment to creating a sustainable world and promoted the launching of a '*global education program that prepares the next generation to protect and conserve Nature*' (Miller 2020) The *National Education Policy 2020* recognized the need for reconfiguring the education system to further learning in all the critical SDG targets (http://www.education.gov.in). A cursory look at sustainable education in India does reveal a very positive outlook toward incorporating sustainability into its education system (Priyadarshini and Abhilash 2020).

With the introduction of the SDGs in 2015, there is a marked difference in awareness-creating programs in India. Education for sustainable development (ESD) has found its way into building university and school curricula. However, it is observed that there is more focus on environmental sustainability than social and economic sustainability. Through education for sustainable development, each person should acquire the knowledge, abilities, attitudes, and values necessary to create a sustainable future. The degree of basic education in a country determines its ability to formulate and achieve sustainability goals. Education is key to boosting living standards generally, increasing the status of women, increasing environmental protection, decreasing population growth rates, and improving agricultural production. Educational reforms are a must in achieving these goals. Including important sustainable development concerns and sustainable consumerism (sustainable consumption and production) in teaching and learning is necessary. Additionally, it calls for active learning and teaching strategies that inspire and equip students to alter their behaviour and take positive steps toward sustainable development (UNESCO 2022).

Furthermore, it is also postulated that sustainability should become part of the values education curriculum for all education institutions. This chapter explores the current status of sustainability education in Indian primary, secondary, and tertiary institutions.

Education for sustainable development

India holds a preeminent position, having 4 out of the 34 global biodiversity hotspots and 15 out of the 200 global ecological regions falling in its geographical area. With just 2.4% of the global land area (Times of India 2019), India is home to more than 8% of the world's recorded species (FAO India 2022). India is also the second most populous country in the world. The socio-economic inequality created by the Indian caste-based hierarchical arrangement of society and the impoverishment of its population in the wake of an exploitative colonial past still afflicts the nation. A combination of poverty, inequality, illiteracy, and scarcity of resources has forced the population to struggle more for survival than think about sustainable development. This is where education becomes central to the sustainability transition. ESD aims to use education as a tool to empower people and claim respect, equality, peace, and social justice (UNESCO 2022). It builds knowledge and skills to create a sustainable world. It helps people foster the value of leaving no one behind. It reminds us continuously of the Great Indian value of Vasudaivakutumbakam (The world is one family) which includes every living thing including plants and animals (Begum 2021).

ESD teaches us about responsible consumption, sustainable economic growth, and advocates global citizenship (Estellés and Fischman 2021). To achieve these goals ESD also calls upon sustainable innovation (Alam 2021). SDG-4 (Quality education) encourages us to acquire the information, abilities, attitudes, and values necessary to promote human rights, development, and global well-being. Education, therefore, must include all three aspects of the triple bottom line including people, planet, and profit. While early school education helps in building awareness (Paaske et al. 2021), higher education makes significant contributions to economic growth and the creation of sustainable lifestyles. In order to increase the employability of young people, university and professional education should take the lead in preparing professionals in cutting-edge fields like artificial intelligence (AI), 3-D printing, big data analysis, machine learning, genomic studies, biotechnology, nanotechnology, and neuroscience. These fields should also be integrated into undergraduate education (Harit and Thara 2021). In view of the need for promoting ESD, the government of India, through the National Institution for Transforming India (NITI Ayog), launched *Project SATH-E*, (Sustainable Action for Transforming Human Capital-Education) in 2017 and identified Jharkhand, Odisha, and Madhya Pradesh (MP) as model states (Batra, Nangia, and Reimers 2020; Panda and Ojha 2021). This scheme achieved many things including

a) A program to improve learning or remedial instruction using workbooks for almost 2.3 billion students.
b) Academic monitoring of schools and pupils has been updated.

c) Increased teacher training.
d) In two years of the "Dakshta Unnayan" learning improvement program," 30% of the children in MP advanced from lower-level basic literacy and numeracy learning cohorts to the highest learning level for grades.
e) With the "Ujjwal-Utthan" learning enhancement program, learning outcomes in Odisha saw an average improvement of 10–15%.
f) Through the "Gyan Setu" learning enhancement program, Jharkhand saw a 12% improvement in learning abilities.
g) As the COVID-19 pandemic spread, *SATH-E* changed into "*Digi-SATH*" to continue offering support through digital channels.
h) Programs like MP's "*Hamara Ghar Hamara Vidyalaya*" (our family our school) and "*Digi-LEP*" (or "Digital Learning Enhancement Programme"), Odisha's "*Shiksha Sanjog*" and "*Shiksha Sampark*", and Jharkhand's "*Hamara Doordarshan Hamara Vidyalaya*" (Our TV Our School) has been offering online education and teacher training as part of the *Digi-SATH* initiative. (Niti Ayog 2021).

Education, equality, and sustainability

Until the 1990s colonial values dominated education in India which had a Brahmanical (Upper caste) bias and was discriminatory in nature (Nayak and Surendran 2022; Lahiri-Roy, Reshmi, and Belford 2021). The decades after 1990 led to a series of discussions and debates that reshaped education. The Mandal commission recommended caste-based reservations and made education a universal right in India. However, this period is also marked by the increasing influence of private players in the education system (Tilak 2018). Fewer and fewer students are enrolling in government-run institutions. This private, profit-led education system continued with the previous Brahmanical bias by excluding those who are economically impoverished (Bingman 2020). Hence it is argued that education failed to bring equity and social sustainability as was desired by the leaders (Mohanty and Dash 2018). The inferior quality of the government education system, which catered to the large majority of the socially and economically impoverished students, could be attributed as the reason for the creation of the educated unemployed instead of the uneducated unemployed who dominated the earlier period (Patra et al. 2022). This inequality is evident in the way the state responded to the COVID-19 lockdown and education in India. While schools were closed for months, the privileged groups had access to education online and on television (Mathrani et al. 2020). As India is approaching a population of 1.4 billion it is imperative to link sustainability throughout its entire education system.

Early contributions to sustainability education in India

In terms of sustainability education the contributions of some of the early thinkers are noteworthy. The writings of B.R. Ambedkar (2018), Mahatma Gandhi (Kumari 2016), Rabindranath Tagore (Tagore 2009), Mahatma Jyotiba Phule (Rege 2010), Pandita Ramabai (Kosambi 1998) and M.N. Srinivas (1977) reflect values of social development. They not only provided a conceptual framework for sustainable development but also practically demonstrated it through their own actions and activities (Table 9.5.1).

Table 9.5.1 provides a list of Indian educational reformers and their contribution to the development of inclusive education in India.

Table 9.5.1 Early Indian contributions to ESD

Indian leaders	*Sustainability education*
Dr B.R. Ambedkar	Integrated sustainable development principles into the November 26, 1950–adopted Indian Constitution.
Mahatma Gandhi	His education philosophy known as NayiTalim adopted a holistic approach to education to gain knowledge for life.
Rabindranath Tagore	Shantiniketan and Vishwa Bharathi experimented with the philosophy of a symbiotic relationship between humans and the environment.
Swami Aurobindo	Integral education promoted by him aims for a deeper harmony in society.
Jyotiba Phule and Savitribai Phule	Contributed towards women's education.
Tarabai Shinde and Pandita Ramabai	Humanistic education and women's education.
M.N. Srinivas	Sanscritization: Education was proposed as a means for social mobility.

Mahatma Gandhi and Nayi Talim: Social inclusion was best epitomized by Gandhi's vision for development based on village panchayats. However, there are some indications of the concept of a rural university in the University Education Institution of 1948–1949, India's first independent education commission. The humanist, educational, and socioeconomic aspirations of this commission, which was led by the philosopher S. Radhakrishnan, were completely disregarded. Focusing on the lifetime nature of education, its social nature, and its form as a holistic process were the three pillars of Gandhi's pedagogy. (Agnihotri 2017). Nayi Talim adopted a holistic approach to education. The student-teacher relationship was to be that of fellow workers, and together they explore the world. Education should help the student to gain knowledge for life. India, which has a hierarchical arrangement of society based on the profession they engage in, needed a drastic change in mindset, and Gandhi wanted to provide this for the social and economic development of all (Kool and Agarwal 2022; Sharma and Mir 2019).

Another notable theoretical contribution was provided by Rabindranath Tagore. His 'Shantiniketan' and 'Vishwa Bharathi' served as the testing grounds for his symbiotic relationship theory between people and the environment (Walker 2022). Santiniketan was created on the principles of humanism, internationalism, and a sustainable environment (Chandra 2018). Tagore developed a curriculum that was a unique blend of art, human values, and cultural interchange (Jelnikar 2022).

In Pondicheri, Mirra Alfassa (fondly called the mother) and Sri Aurobindo founded a commune. He promoted an approach to education called integral education, which aimed for "deeper harmony and peace that can only be manifested by moving beyond the use of the human mind whose action is essentially separative in nature and cannot become the true basis for harmony within the individual or the society" (Mohanty 2019). The three fundamental concepts articulated by Sri Aurobindo – "nothing can be taught," "the mind has to be consulted in its progress," and "to work from the close to the distance, from that which is to that which shall be" – may be used to develop integral education curriculum (Gupta 2014).

There were also educationists such as Jyotiba Phule and Savitribai Phule who pioneered women's education in India (Biswas 2020). There were also great women reformers such as Tarabai Shinde (Rajan 2020) and Pandita Ramabai (Mudgal 2013) who championed humanistic education and values equity of and brotherhood. M.N. Srinivas, a very prominent Indian sociologist, advocated education as a means for social mobility, especially for those who are socially and culturally discriminated against and kept backward by the social system. He promoted a concept called 'Sanskritization' and claimed that people in the lower strata could claim upper status by imitating the practices of the upper caste groups (Srinivas 1977; Patel, Sharma, and Singh 2020). One of the things that distinguished them from the lower castes was their education. Hence education was seen as a means of social transformation.

Another very important person that contributed to social development in India was Dr. B. R. Ambedkar. He himself came from one of the lowest strata of society and through education achieved one of the highest positions in India, becoming the father of the Indian constitution (Meka 2022; Sarkar 2013). He is considered an educationist of the marginalized. Education propels a person on the path of struggle. Ambedkar said,

> "It is education which is the right weapon to cut the social slavery and it is the education which will enlighten the downtrodden masses to come up and gain social status, economic betterment and political freedom."
>
> *(Sharma 2015)*

In 1926 he started an organization called 'Bahishkrit Hitkarni Sabha' to extend education to the marginalized in an effort to improve their economic situation. His slogan, "Educate-Agitate-Organize" became an awakening for the lower caste communities in India.

All these educational thinkers provided a basis for looking at education as the means for the social and economic transformation and development of the nation. Many looked at education as a means to socially upgrade themselves. Despite very serious efforts towards implementing affirmative action programs, the education system in India did not become equal as inequality was deep-rooted. The increasing concern for modernity and development, however, led education to focus on job-oriented courses and the true value of education took backstage.

Government initiative towards sustainability education in India

In 1972 the then prime minister of India, Mrs. Indira Gandhi, addressed the first Earth Summit in Stockholm and emphasized the need for an effective education system as the prerequisite for creating environmental sustainability (DTE staff 2022). She lauded the role of the United Nations Educational, Scientific and Cultural Organization (UNESCO) in creating awareness programs and various campaigns directed at children. India incorporated sustainable education at a very early stage in the school curriculum that relates to life needs and the aspirations of the people and the nation (Movchan and Komisarenko 2020). Inspiring and involving the next generation in skill development and action-based learning is an important aim of sustainable education. It aids in the development of sustainably minded individuals. It is hoped that the younger generations will ultimately help drive India toward a better and more sustainable future.

India recognized the fact that education is a key to development and made primary and secondary education free and accessible to all during the *1st Five-Year Plan* from 1951 to 1956 (India had incorporated a five-year plan modeled after the then USSR). To ensure the maximum number of students attend school, there was also a plethora of 'freebies' provided to the students including mid-day meals, free uniforms, and books. The government-run schools and private-aided institutions offered free education (Tilak 2002). The socialist outlook of the early governments was key to making education a means for the socioeconomic transformation of the nation. Education was looked upon as a means for social change, and students were considered the agents of change (Vertesi 1999; Nazimuddin 2015). This was done by incorporating chapters on sociocultural and environment-related topics in the textbooks. The government also introduced the District Primary Education Program (DPEP) model of education to make learning more experiential. This was an initiative under the Social Safety Net Credit Adjustment Loan under the Structural Adjustment Program of the World Bank to India in 1991. The major funding for this program comes from UNICEF, the Official Development Assistance (ODA) (UK), Swedish International Development Cooperation Agency (SIDA), and the Netherlands. This is an educational program that encourages community participation in all aspects of education (Glinksya and Jalan 2013).

Environmental education and education for sustainable development in India

In 1977, the Tbilisi Declaration gave a major boost to environmental education, which is an integral component of sustainable development, by promoting the need for creating awareness, knowledge, attitude, skill, and participation in the conservation and promotion of the environment (Quadri and Sambo 2011). According to Bhat et al. (2017), environmental studies in India revolved around three topics: 1) concern with environmental disturbances and how the impact can be minimized; 2) soil, water, and, air pollution science; and 3) environmental engineering which studied the activities that can minimize pollution production. In 2005 the Ahmedabad-based Center for Environment Education in collaboration with the Commonwealth of Learning (COL), Canada, launched an initiative called 'Green Teacher'. This was an initiative to train teachers in environmental education. This could be considered an outcome of the National Policy of Education 1986 and the Supreme Court ruling in 2003 to make environmental education compulsory (Ravindranath 2007).

India has been a strong contributor to UNESCO and has been collaborating with its promotion of sustainability education (Mohanty and Dash 2018). The new *Education Policy in India* (NEP 2020) has made a remarkable plan for both interdisciplinary as well as multidisciplinary education. Leaders have observed that investing in higher education institutions is the same as investing directly in sustainability actions, and hence NEP 2020 is a document aimed at creating a sustainable future (Teki et al., 2020) This has paved the way for education for sustainable development. Some of the broad objectives of sustainability education are identified as 1) awareness creation, 2) knowledge generation, 3) building interest, 4) commitment to voluntary service, 5) building skills and capacity, and 6) ensuring everyone's participation in the path to sustainability.

The United Nations identified 17 areas where nation-states should work towards achieving sustainability. However, SDG 4.7 specifically mentions ESD. SDG 17 also urges a global partnership for achieving sustainable development goals. UNESCO (2021) provides a conceptual model for enhancing global partnership and sustainability. The model consists of the 4Ps (policy, people, planet, and prosperity), where a multistakeholder partnership framework in ESD would serve as the focal point for all activities including raising awareness, disseminating data, assessing progress, tracking SDG accomplishments, objectives, and strategies, integrating all SDGs, working with all drivers (4Ps), resolving any conflicts or impasses that arise between the drivers, and attempting to achieve or improve sustainability across all domains (Eichhorn, Hans, and Schön-Chanishvili 2021).

Continuous weather fluctuations has lead to droughts and abject poverty in India. This necessitated the creation of a food sufficiency program in India in the1960s, which is popularly known as the 'green revolution'. Many committees were formed to reduce poverty and inequality. The government's commitment to imparting sustainability education through school syllabi was observed from the very beginning of the sustainability movement. Keeping sustainability a focus in Indian government policy also resulted in various research projects in agriculture to improve agri-production in the country (Table 9.5.2). In 1955 the Damle Commission, and in 1959 the Randhawa Commission, and in 1960 a commission under the leadership of Ralf W. Cummings were set up to study the need for establishing agricultural universities in India (Singh and Prasad 2017). As early as the 1970s the India Business Academy had already focused its research on important social sustainability topics (Sharma 1974). Today there are over 70 agricultural universities spread across the nation. These universities have largely focused on environmental research for food sufficiency.

Some researchers directly link the lack of sustainability in India to the existing socioeconomic conditions. They conducted experiential learning research with school children from

Table 9.5.2 India's journey in sustainable development.

1930	Environmental education was introduced into the curriculum.
1964	The Kothari Commission, which is considered a landmark in Indian educational reform, made recommendations on bringing environmental education into the curriculum.
1970	The International Union for the Conservation of Nature formalized environmental education.
1976	The 42nd amendment to the constitution of India made education a joint responsibility of the state and the center (Bhat et al. 2017).
1980	With the formation of the Ministry of Environment and Forest, environmental education was formally introduced into school curricula.
1984	The Center for Environmental Education (CEE) established under the Ministry of Environment and Forest drafted an environmental education curriculum for schools and colleges.
1991	Supreme Court order as a result of a public interest litigation (PIL) filed by MC Mehta mandated colleges to offer compulsory environmental education.
2003	Environmental education was made compulsory in formal education in India through a Supreme Court ruling.
2004–2005	The government formally introduced environmental education in its schools and colleges.
2009	The government of India enacted the right to free and compulsory education. It also established a voluntary association for all the different education boards known as the Council of Boards of School Education In India (Singh and Nagpal 2010).
2009	Council of Boards of School Education In India and NITI Ayog help schools to build and incorporate sustainability curricula across the different education boards to ensure every student is reached. (Gilderdale 2007).
2017	NITI Ayog launched Project SATH-E, (Sustainable Action for Transforming Human Capital-Education).
2020	New Education Policy in India (NEP-2020).

Puducherry and found that students who were taught sustainability had a statistically significant difference in environmental knowledge, behavior, attitudes, and skills. (Alexandar and Poyyamoli 2014). This was a project under the UNESCO Environmental Education for Sustainable Development (EESD) program. Sustainability was studied from the perspectives of tourism, manufacturing, hospitality, and education, and it was found that there is a need to make people aware of the concept of sustainability which includes knowledge of Indian culture and values being taught to its students (Jitendra and Baum 2000). Sengupta (1972) talks of policy initiatives toward making sustainability education in Indian universities. In the context of the UNEP (Holdgate et al. 1983) the government of India initiated sustainability programs and established skill development centers in Indian universities. The curriculum builders identified five sustainability areas, namely, 1) human sustainability, 2) social sustainability, 3) environmental sustainability, 4) economic sustainability, and 5) personal sustainability. To instill sustainability through project-based learning they identified 4Cs and 3Rs (reading, writing, arithmetic, communication, creativity, critical thinking, and collaboration (Ahuja et al. 1970 and Bariotaki, Kalaitzakis, and Smonou 2012).

Constitutional provision for social sustainable development in India

Societal development is essential for the economic and political development of mankind. Social sustainability is ensured through good governance, a strong judiciary, and accountable and transparent government bodies (Santiso 2001). India has a constitutional provision for sustainable development, where Articles 29–31 of the constitution emphasize cultural and educational rights (Ali 2013). The Constitution of India focuses on social, economic, and environmental drivers and introduced a section called the 'Directive Principles of State Policy', asking each state to make policies taking into consideration the sociocultural, economic, and political situation of the region. This provision was introduced to strive to promote the welfare of the people by setting up a social order where social, economic, and political justice is extended to all (Pattnaik 2018).

India has used a centralized planning system to allocate its resources for nearly 60 years. The prime minister's planning commission created five-year plans for India's economic development. The planned growth of the nation was seen to be fundamentally dependent on education. Free and compulsory education for all was guaranteed by Article 45 of the Indian Constitution (adopted in the year 1949), along with improvements to teacher status, pay, and training, language development, equalization of educational opportunities, talent identification, work experience, national service, encouragement of science education and research, and education for agriculture and industry (Roy et al. 1992).

Since 2015, India's sustainability initiatives have been led by the National Institution for Transforming India (NITI Ayog 2022). The formulation of social policy and the Government of India's steadfast implementation of it in accordance with constitutional requirements is expected to shape social sustainability in India, particularly in education, employment and gender empowerment and equality over the coming decades.

Sustainability education in primary and secondary education

Given the current socio-economic and ecological systems in India where inequality and poverty are widespread, where drinking water is becoming a scarce commodity, where pollution in the cities has reached a point where life has become intolerable for many, and where climate change is becoming a constant phenomenon, sustainability education holds a very important place. The incorporation of sustainability education in the school curriculum can be viewed from two dimensions: 1) Environmental education was introduced in 1991 after the Supreme Court of India mandated it. It was, however, left to the states to create a syllabus toward this goal. By 2004 the National Council of Educational Research and Training (NCERT), the body in India that is responsible for developing school curricula, formally incorporated environmental education in the school curriculum (Table 9.5.3). Gopal and Anand 2006). 2) Social sustainability was incorporated into the syllabus of other subjects like languages and social science subjects. The DPEP provided experiential learning opportunities to children, making them more aware of the socio-economic aspects of Indian society. However, this was limited to the select areas where it was introduced.

Education is seen as a powerful tool for creating awareness about sustainability as a way of life, as reflected in the presence of global goals and targets for education (Priyadarshini and Abhilash 2020). In most developed nations, sustainability science (SS) is a highly sought-after program (Kates et al. 2001; Bettencourt and Kaur 2011), but it has yet to gain prominence in the Indian education system.

In supplementing the school curricula, many NGOs emerged alongside the state to extend sustainability education. They worked with schools to provide social awareness to children. NGOs such as *Kalpataryu* (Delhi), *Tarumitra* (Patna-Bihar), *Kerala Shastra Sahitya Parishad* -KSSP (Kerala), *Jeevit Nadi* (Pune), Jyoti (Jamshedpur), and the Center for Environment Education (Ahmedabad) have been very active in providing both environmental and social awareness among school children. These city-specific institutions had a large number of schools associated with them. Many of them are supported by their respective state governments and UNESCO. They have developed their curriculum to teach students about the environment, taking students for nature walks and tree plantation programs (nature-based education) where students can get their hands dirty and feel at one with nature.

Table 9.5.3 Some landmarks in the Indian Education system

Year	*Government policies*
1935	Central Advisory Board of Education (CABE)
1948	University Education Commission
1950	The government of India set up a planning commission by resolution (Kudaisya 2009)
1950	Provision for compulsory education was embodied in the Constitution
1952	The Secondary Education Commission was set up
1968	National Policy on Education popularly known as the Kothari Commission report submitted
1968	The introduction of the 10+2+3 pattern by most states
1986	National Education Policy equal educational opportunities
1992	Modified National Education Policy for globalization
	District Primary Education Program (DPEP)
2000	Sarva Shiksha Abhiyan (Education for All Program)
2005	Right to Education Bill
2009	The Right of Children to Free and Compulsory Education (RTE) Act
2009–2010	Rashtriya Madhyamic Shiksha Abhiyan (national middle-level education program)
2012–2022	Rashtriya Uchcha Shiksha Abhiyan (RUSA) (National Higher Education Programme)

The Kothari commission that was set up in 1964 was one of the earliest commissions that reviewed the education system in India and suggested that sustainability education should be part of basic education and should relate to the life needs and aspirations of the people. It decided to provide basic conceptual knowledge of the physical and social environment in primary schools. The treatment of this at primary, secondary, and high school took different trajectories. In 2004 NCERT organized the first consultation on curricula for sustainability education in schools in New Delhi (Sonowal 2009). While these consultations focused on the environment-related curriculum, they did not include other aspects of sustainability.

To bring in education for sustainable development, the establishment of the following institutions was important: 1) The Centre for Environment Education (CEE), an NGO supported by Ministry of Environment and Forest (MoEF) 1984, 2) Paryavaran Mitra (PM) 1996, 3) 'Friend of the Environment Program' 2001, and 4) the MoEF's 'National Green Corp Program' (NGC) 2001 (Roberts 2009). The NGC established over 120,000 eco-clubs across the nation for school children. Paryavaran Mitra proposes nine strategies underpinning its programmatic approach: 1) linkage with the curriculum; 2) alignment with national policies; 3) a focus on community action; 4) local contextualization;(5) alignment with international initiatives; 6) motivation through recognition and reward; 7) creating lead schools; 8) optimizing synergies with government and non-government bodies; and 9) seeking partnership and building dynamic networks. They also created a comprehensive handbook that is published in 15 different languages (Bangay 2016).

A common curriculum is used by the Central Board for Secondary Education (CBSE) in all Indian states, and it covers subjects like the biosphere, the greenhouse effect, the ozone layer depletion, the use of fertilizers and pesticides, wildlife protection, soil chemistry, management of domestic and industrial waste, noise, air and water pollution, soil pollution control measures, management of non-degradable substances, edible and ornamental plants, nuclear power, and radiation dangers (Aurobindo et al. 2006).

Green schools in India

The idea of green schools can be traced back to an ancient Indian education system, popularly known as the *gurukuls*, where students lived with the gurus (teachers) in a natural environment and learned from nature directly. However, environmental education in India is currently managed through both government and NGOs (Sonowal 2009). Articles 48 and 51 of the Indian Constitution call upon everyone to protect the environment and also make it a fundamental duty of every citizen to protect and improve the natural environment such as lakes, rivers, and wildlife (Vardhan 2014).

The Constitution also considers the provision of better primary health conditions and improved standards of living for its people as fundamental duties of the state. Article 21 of the constitution makes 'right to life' a fundamental right of every citizen of the country. The right to a healthy environment is an important attribute of the right to live with human dignity (Sharma and Kanaujia 2020). In 1984 the Ministry of Environment, Forest and Climate Change (MoEFCC 1984) established a Center for Environmental Education (C.P.R.EEC) to systematically help state governments centred in developing curricula related to environmental sustainability. In 1988 this center developed the National Curriculum for Elementary and Secondary Education -a framework to help states to develop environment-related curricula in schools (Taylor 1991). According to the NCERT, a green school is based on the concept of environmental sustainability. It stresses that the school should facilitate and nurture students' capabilities through its innovative curriculum and teaching-learning process (Sharma 2006). After the Supreme Court order mandating environmental education, the NCERT developed a national curriculum to impart environmental education referred to popularly as 'Habitat and Learning' in 2006 (Bhatia 2020).

National Education Policy 2020 and sustainable development in India

The National Education Policy 2020 is a comprehensive policy document on the direction of education in India into the future. Universities and education boards have already started implementing the programs under this policy. This document gives emphasis to improving the quality of teacher education and improving equitable and inclusive education using the existing social structure. The introduction in the document observes that investing in education can help in achieving the SDG targets. Hence it is possible to look at this document as an initiative by the Indian national government towards sustainability. The document also talks of improving the quality of life through education (Muralidharan et al. 2022; Aithal and Aithal 2020).

Non-governmental initiatives to bring sustainability education into schools

It is also worthwhile mentioning some of the interventions to bring sustainability outside the formal curriculum and aided by non-governmental agencies. **Jamshedpur Youth for Tomorrows India (JYOTI)** is one such program that started in the Loyola school at Jamshedpur. Jamshedpur is the home to Tata Steel and Tata Motors and is one of India's most developed industrial cities. This is a student movement that started over four decades ago and has been continuously motivating students to engage in sustainability programs. They celebrate environment days with rallies across the city. Today JYOTI is present in 50 schools. This works closely with the school administration and organizes many campaigns where students use this platform for developing leadership. Environmental campaigns are one of the main activities of the organization. It also helps underprivileged students. Today it is mostly run by the students.

Kerala Shastra Sahitya Parishad (KSSP) started as a science writers' forum in the state of Kerala in 1962. By 1968 KSSP had started publishing popular science communications in Malayalam to reach rural schools making it possible for mass dissemination of scientific knowledge across the state. Gradually a people's Science Movement began to form in the state. KSSP engaged in a variety of programs including education, development, environmental protection, access to energy, and mass literacy campaigns. Today it has over 60,000 members spread across about 2000 schools This is in addition to the many Indian students who use KSSP resources annually. KSSP has received several awards, including UNEP's Global 500, the Vriksha Mitra, and the King Sejong (UNESCO) award. One of the initiatives includes KSSP, which involved over 10,000 teachers, offering teacher training programs, help in the assessment of school curricula and textbooks, promoting innovative teaching, and publishing science books and magazines for children. They were instrumental in making Kerala State a 100% literate state.

One of its mission was to raise awareness of environmental problems among the entire Kerala public. They use campaigns, education, and promotion of good environmental practices.

KSSP has also been campaigning for strong democracy, conducting field experiments, and empowerment activities. They also promoted the Kerala model of development which is based on sustainability. Its R&D center called the Integrated Rural Technology Center (IRTC) has developed a participatory resource mapping methodology in training. This has been instrumental in achieving a high Human Development Index (HDI) despite Kerala having a low income. The state of Kerala now tops the HDI among all the states in India (Malik and Kundu 2021).

Half a million homes have installed KSSP's high-efficiency wood-burning stoves, saving an estimated 0.6–0.8 million tons of firewood per annum. KSSP also has a program to replace a substantial portion of 20 million 60-watt light bulbs with compact fluorescent lamps and is helping local governments to install small-scale hydro stations.

Sustainability in higher education institutions in India

Sustainability has been inbuilt into the Indian school curriculum. However, university education has not been proactive in implementing sustainability. In spite of many directives from the government, judiciary, and competent authorities the implementation of tertiary sustainability education has been lackluster. It was only after 2015 when India became a signatory to the SDGs has there been an urgency felt by the universities to implement programs for education for sustainable development. Kates et al. (2001) Universities should combine a global perspective with a locally based strategy to integrate sustainable development goals. A large number of environmental science programs have emerged in the past few decades; however, these were not able to combine well with social science disciplines, and hence interdisciplinarity has been lacking. Chakraborty et al. (2021) argued that there is a compelling case to take sustainable development into University research and operations.

Since sustainability is a universal need, universities play a critical role in bringing in policies and practices to take sustainability to the Indian population. Universities should incorporate sustainability into both the curricula as well as the operations of the university itself. Currently, most universities are at the compliance stage.

Ravindranath (2007) and Kanaujia and Gorana (2019) further argue for equipping teachers to take up the sustainability demands through focused teacher training in sustainability in India.

ESD has been a neglected field in Indian universities for a long time. Since 1972 agricultural universities have offered environmental science courses (Patel et al. 2020). Most state and central universities did not offer courses in sustainability until the late 1990s. Some colleges offered environmental science as part of their science courses. There were very few universities that offered a full degree in environmental science. The earlier approach to environmental science in Indian universities was a piecemeal approach where a few related courses were offered as part of scientific disciplines or as foundation courses. Only after the SDGs were adopted in 2015 was a more holistic perspective taken by Indian universities (Priyadarshini and Abhilash 2020).

The University of Pune, which is now known as Savitribai Phule Pune University (SPPU), was one of the pioneers in offering a postgraduate degree in environmental science. In 1978 they started a diploma program which by 1986 was elevated to a one-year BSc program. Later it was converted into a full MSc in environmental science. Among private universities, Symbiosis International University started an MBA degree in energy and environment in 2009. The first fully fledged university that solely focused on environmental sustainability degrees was The Energy and Resources Institute (TERI) University established in 1998. The focus was on scientific and policy research to confront the 21st-century concerns of energy, the environment, and sustainable development (Banga Chhokar 2010). Today the University Grants Commission (UGC) has mandated that every undergraduate program in India should implement a six-module program on environmental education (Chakraborty et al. 2021), which comprises ecosystems, biodiversity and its conversation, environmental pollution, social issues, environment and human population, and environment with additional fieldwork activities. With the introduction of Indian voluntary ESG reporting, there is now a concerted effort to bring sustainability and human values into the university curriculum. UGC and the National Assessment Accreditation Council (NAAC) incorporated these values into their university assessment criteria (Nanware et al. 2020).

There are currently close to 200 environmental studies departments in Indian universities and colleges. They provide degrees, diplomas, and certificate programs that address different facets of environmental engineering and sciences. Additionally, there are programs leading to diplomas, bachelor's degrees, master's degrees, doctoral degrees, and programs in environmental studies and sciences. In addition to this, the departments of civil engineering and chemical engineering provide ME, MTech, and PhD programs in environmental engineering. There are also postgraduate degree programs in environmental management and courses leading to MSc degrees in environmental toxicology, chemistry, biology, or geology. The word sustainability was not common nomenclature until 2015. Only with the introduction of the SDGs did Indian universities start using the word sustainability, and even then the emphasis was mostly on environmental sustainability. However, there were also a few institutes such as the Indian Institute of Sustainability in Gujarat and the Indian Institute of Sustainable Development in Delhi that had already been using the term sustainability in the naming of their institutes. The Council of Scientific and Industrial Research (CSIR), Indian Council of Agricultural Research (ICAR), and Indian Council of Social Science Research (ICSSR) have also been undertaking research and publication on sustainability, but their impact has been limited.

Universities and institutes that offer sustainable development programs

India has over 1070 universities and 45,000 colleges with a student enrolment of over 37.4 million (Nanda 2019). To make sustainability a part of education in these colleges, the UGC in 2019 mandated a six-month module program on environment studies compulsory for all undergraduate programs. Even though in 1991 the Supreme Court made a judgment to introduce environmental studies in colleges and in 2003 the UGC issued notices to colleges in this regard, it has only been since 2019 that this has been attended to by most colleges.

Only when the NAAC 2019 accreditation program included sustainability as a part of the accreditation process, did most colleges introduced the six-month module program on environmental studies. Colleges have in turn introduced this in the form of value-added courses or foundation courses. Value-added courses are part of the curriculum designed to provide students with the necessary skills to increase their employability and skills to succeed in life. Both these programs are aimed at making students aware of social, cultural, economic, and environmental realities, at the local, national and universal levels (GOI 2020).

Although there was no universal adoption of these values by Indian universities and colleges, no universities had started any courses on sustainable development until the UN launched the SDGs in 2015.

Sustainable development often became incorporated within social science departments. The Indian Institute of Management, which is an institute of repute and has over 20 branches across India, inaugurated its postgraduate program in sustainability management in 2015. In 2020 IIT Guwahati started the first program on sustainable development within their humanities department. In the 2022 QS-ranking IIT Bombay, IIT Delhi, and JNU have featured among the top 400 global institutions for their sustainability initiatives.

The Postgraduate Program on Sustainable Management (PGPSM) started by the Indian Institute of Management (IIM) aimed to produce management professionals with a comprehensive view of economic, social, and environmental issues. The program includes courses such as systems thinking, social entrepreneurship, externalities, life cycle management, stakeholder management, and public policy. The objectives of this program are 1) to actively participate in the world debate on responsible business, 2) to create an informed public who are self-aware and socially and environmentally responsible, and 3) to challenge the established systems and practices and innovate new opportunities for businesses that are sustainable (https://www.iiml.ac.in/).

Some private universities such as Symbiosis International University and Terna Engineering College are more proactive and offer courses on sustainable development. These programs, although focusing on individuals, communities, and organizations, aim to provide a global outlook. Some of the focus areas in these programs include: sustainable development, economics of sustainable development, government and sustainability, new technology and innovative sustainability, approaches toward a sustainable future, introduction to climate change, environment, and sustainability, and sustainability tools- foot-printing, mapping, auditing, sustainability life-cycle management and assessment and green accounting, sustainability innovation and green marketing, organizational culture, and stakeholder engagement, organizational design and operations management, developmental economics, and compassionate capitalism (https://ternaengg.ac.in/).

In 2020 we have seen a spurt of sustainability institutes across different universities. Among them, the Indian Institute of Sustainability (IIS) (Gujarat) and the Indian Institute of Human Sentiments School of Environment and Sustainability deserve special mention. They offer courses in agriculture and forestry, heritage and smart cities, circular economy, rural studies, digital finance and sustainability, sustainability, agripreneurship, and value chain management, among other courses (https://iisg.ac.in/). They also have courses such as policy and governance, urban management, economic development, human development, planning, design, infrastructure, environment and climate, disaster and risk management, land and housing, and urban studies (https://iihs.co.in/schools/school-of-environment-and-sustainability/).

Symbiosis International (Deemed) University (SIU)

Symbiosis International (Deemed) University is a 50-year-old private university set up in 1971. The university offers mostly professional courses and has over 25,000 graduates every year. SIU endeavors to inculcate sustainability into its curriculum. Apart from integrating sustainability courses into the MBA curriculum across institutes, SIU also has two institutes dedicated to providing degrees in environment, energy, and geoinformatics. Apart from these two institutes, the university also has a dedicated center for researching sustainability known as Symbiosis Centre for Climate Change and Sustainability. Some of the courses offered include non-renewable energy resources, renewable energy sources, and technologies, environment impact assessment, climate change, carbon markets and financing, development studies, sustainable standards, sustainability reporting, corporate governance, and ethics. Its liberal arts program has incorporated courses like gender justice and feminist jurisprudence, women and work, peace and conflict studies, human rights practice, diversity studies, etc. The effort is to educate business leaders who are aware of sustainability both as a theory as well as something that can be practiced (https://www.siu.edu.in/).

Values education in India

> "The greatness of a nation and its moral progress can be judged by the way its animals are treated."
>
> *(Mahatma Gandhi)*

Twenty-first-century education should equip students with the values, knowledge, and understanding necessary to face the challenges of the sustainability transition. Education must play an important role in developing both intellectual and moral reasoning capabilities of students.

Values education, often known as moral education or ethics education, is critical to formative and transformational sustainability education. Whilst moral or ethical education can cover slightly different perspectives, they both highlight the important nexus between personal and societal values (Lovat and Toomey 2009).

Lovat and Toomey (2009) suggest that earlier education thinking, that values were exclusively the preserve of families and religious bodies, and that schools should function only in values-neutral mode, is changing. They suggest that it is now commonly accepted that values based education is an essential component of comprehensive public education responsibilities as an inculcator of personal morality and cohesive citizenry that enables students to understand their social responsibilities.

Values like global citizenship are increasingly seen as important in modern education. Global citizenship education has been included in the curricula of many European schools. The importance of values education encouraged the introduction of cross-curricular subjects like 'education for citizenship'. UNESCO undertakes a global assessment of the level of global citizenship education (GCED) engagement as part of the SDGs and collaborates with an extensive global network to disseminate GCED, including with the UNESCO Mahatma Gandhi Institute of Education for Peace and Sustainable Development (https://en.unesco.org/themes/gced). (See Chapter 3.1 in this volume)

Sustainability education and values education are inextricably linked (see Chapter 2.4 in this volume), with the latter providing fundamental moral and ethical ideals that help to underwrite the sustainability norms and the dispositions required in sustainability education. Mainstream culture should also be informed of and reflect sustainability values, so that our political and industry leaders are cognizant of the changing norms and expectations that are supportive of the sustainability transition.

Values-based education should provide students with the personal, national, and sustainability values that enable them to participate effectively as good local and global citizens. By embedding values within sustainability education, we can assist students in the development of their personal commitment to a more sustainable way of life. If sustainability education can make sustainability values the norm for expected behavior, we can accelerate the sustainability transition and more effectively underwrite its widespread development. In terms of sustainability education values-

Personal values could include respect for others and honesty.

National values could include democracy, equity, respect for other cultures, and justice.

Sustainability values could include:

- Acknowledgement of the importance of all life on Earth
- Protection and conservation of the environment
- Integrating environmental, social and economic dimensions into our production and consumption decision making
- Eliminating waste production and pollution in our production and consumption activities
- Using eco-design principles to make products and services more sustainable
- Movement away from fossil fuels to renewable energy

As Swami Vivekananda noted, "The purpose of education should be man-making, character-building, and nation-building". The world needs to create a new worldview that is rooted in the values of care, nurturing, development, and equality in order to build a sustainable future.

In this sustainability transition, there is a greater need to emphasize this care for all inhabitants of the world (human and nonhuman) in values-based education in our education institutions. The sustainability values of respect for all people, the environment, and future generations are key foundations in sustainability education. The goal of values education, also known as moral education or character building education, is to develop students with positive, ethical, pro-social, and pro-environmental inclinations and competencies across all disciplines.

The overemphasis on the cognitive aspects of traditional education models has led to the sidelining of values education globally. A strong values-based education can help in the development of responsible and sustainable lifestyles that respect the values of gender equality, equitable treatment of every citizen, and environmental protection. Such values could in India, for example, help to prevent rampant deforestation and indiscriminate disposal of plastic and other toxic materials. A proper values-based education that is integrated into the curriculum can provide the necessary sustainability values that may not necessarily be evoked or promoted in the home.

Gandhi observed that education consisted of cultivating good character, rather than filling the brain with knowledge, facts and statistics, or the passing of exams. The Indian National Policy on Education in 1986 stressed that education should create universal and timeless ideals directed towards the usefulness and integration of persons in a culturally heterogeneous society. The report argued that such values and ideals could help reduce violent extremism, superstition, and fatalism (Kaur 2020).

Gul (2017) noted that an individual's behavior is influenced by their values, and hence if one needs to influence behavior towards sustainability values there is a need to inculcate sustainability values in student thinking. The National Curriculum Framework for School Education (GOI-NCERT, 2000) regretted the "erosion of the core social, moral, and spiritual values" in Indian curriculum and the associated increase in cynicism at all levels. This framework advanced the call for curriculum to include values education, stating that "Schools can and must seek to resolve and perpetuate the universal and everlasting values oriented towards the unity and integration of the people enabling them to discover the wealth within".

The Vedic education system has much to offer values based education in India. According to this system, one of the most cherished objectives of education is emancipation. Education should support the creation of feelings of cooperation, compassion, and holistic growth (Lakshimi 2009). The Vedic education system saw "learning to be and to become" as an ongoing, lifelong process.

Continuing in this path, the Indian UGC initiated a five-day faculty development program on human values for higher education teachers in India in the year 2020. This five-day program is to be followed up with an advanced program. The expectation is that teachers would include human values in curricula while creating learning experiences for their students. The UGC has recently incorporated values-based education in curriculum, university assessment, and university accreditation (Rabha 2019). Rabha argues that values education should foster the ideas of cooperation, mutuality, harmony, spirit of common brotherhood, growth of scientific temperament, and spirit of humanness. India as a nation is committed to the values of socialism, secularism, democracy, and national integration in the preamble to its constitution. Indian education systems should therefore foster values that promote equality, social justice, national cohesion, and democratic citizenship.

The National Conference on Minimum Curriculum Standards for Primary education, held by the NCERT in July 1970, stressed the importance of instilling in students the moral and spiritual values that are a part of Indian culture, including honesty, kindness, charity, tolerance, courtesy, sympathy, and compassion. This event is considered one of the turning points in values education development in India. In November 1976, the National Seminar on Primary and Work-oriented Education, organized by NCERT, stressed the relevance and importance of Gandhian values in reforming education. The Kohtari Commission in 1966 first talked of the need to incorporate Indian cultural and social values to help guide the nation's progress, security, and welfare (Tharakan 2017). The commission used the word 'moral education'. The new Indian National Education Policy (2020) endeavors to bring Indian values into the education system (Shukla et al. 2022). Though the policy does not refer directly to values-based education, it proposes that education should promote human values of empathy, tolerance, human rights, gender equality, non-violence, global citizenship, inclusion, and social equity. If we add environmental protection and conservation values to this list, we have the outline of an important values-based education framework for the sustainability transition.

The All India Council for Technical Education (AICTE) has also created a program to impart values education within universities and has started training university professors in values-based education (https://fdp-si.aicte-india.org/5day_onlineUHV.php).

NCERT has released the National Curriculum Framework and the Framework on Values in Schools. In order to make India a secular, democratic, and progressive country that is proud of its cultural history, the National Policy of Education (NEP) (GOI, 1992) emphasized the importance of values education in eradicating discrimination, violence, and superstition and promoting social, cultural, and scientific ideals. Values education fosters broader talents, attitudes, and skills that are important not only in the classroom but also for their family, friends, co-workers, and community. The NEP-2020 is focused on promoting Indian traditional value systems which include holistic and *bharatcentric* (India centric) education (Patil and Patil 2023; Panditrao and Panditrao 2020).

Conclusion

Education plays a crucial role in creating a sustainable future. Sustainability is the responsibility of every citizen in creating a sustainable future. Although there has been a plethora of sustainability-related programs introduced by the Indian government and various national and international voluntary agencies, India has a long way to go before becoming a truly sustainable society.

Sustainability must become an inherent part of Indian culture. ESD is a crucial step toward that goal. The Indian government should initiate a consensus-building process, leading to sustainability education policy development that provides a common direction for all schools and universities.

This policy must be translated into strategies and programs that will help implement education for sustainable development in India.

There should also be periodic evaluations and accreditation audits to ensure the momentum is not lost and the curricula development is clear.

Most authors who have written on India's journey in sustainability education have been very critical of it its lax implementation. India has a sociocultural heritage that takes a holistic and symbiotic approach to life. This value system somehow is not being manifested in the Indian education curricula. Students must need to empathise with both the need and value of sustainability and the starting point for the development of this empathy should be in our classrooms.

ESD is also an important challenge for India in terms of teacher training, curricula development, and the necessary accreditation systems to maintain and extend the role and value of sustainability education. As wisely noted by Rabindranath Tagore, "Don't limit a child to your own learning, for he was born in another time".

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9.6

SUSTAINABILITY EDUCATION DEVELOPMENT IN INDONESIA

Yun Arifatul Fatimah, Michele John and Zainal Arifin Hasibuan

Key concepts for sustainability education

- Government regulations and policy support are critical in helping to develop timely and effective sustainability education programs.
- Teachers are important agents of change in the education system, and their commitment and professional development in sustainability education are essential for the sustainability transition.
- International university ranking programs like the 'Times Higher Education' (THE) and the University of Indonesia's UI Green Metric Rankings are helpful in supporting university focus and investment in sustainability education development.
- Sustainability education–focused accreditation programs are a missing link in the development of sustainability education, and their development and implementation are essential in formulating sustainability education curricula, managing sustainability education quality control, and establishing norms for sustainability education development.

Introduction

The Indonesian population is currently around 284 million (2024 Worldometer), which places it as the fourth largest population in the world with 26% of its population belonging to the Millennial generation. It is a rich economy in natural resources with an increasingly significant contribution to global trade and economic development. This burgeoning population together with increasing levels of industrialization, high levels of consumption, and significant natural resource and environmental pressures have become critical issues for sustainability education in Indonesia. Massive and ongoing deforestation in Indonesian rainforests has significantly reduced biodiversity in Indonesia. Indonesia is currently the eighth largest global greenhouse gases (GHG) emitter (World Resources Institute 2023).

Sustainable development is a policy focus for the Indonesian government. Significant focus has been given to a variety of sustainability issues including environmental protection, economic development, poverty and economic inequality reduction, climate change

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mitigation, and emissions. Given the size of the Indonesian economy and pressures from global environmental challenges in terms of climate change and biodiversity protection and conservation, innovative changes are urgently required to help support sustainable development (Ministry of National Development Planning 2019).

Sustainability education in Indonesia will require a transformation that involves mindset, cultural and behavior changes, science and technological improvement, new understandings of human welfare, social innovation, community commitment, and international cooperation to help successfully achieve the Sustainable Development Goals (SDGs) (Nomura 2009). It is anticipated that sustainability education will be an important part of this transformation.

Sustainability education promotes changes in knowledge, skills, values, and attitudes to enable and provide more sustainable and equitable development for all. Sustainability education seeks "to empower and equip current and future generations with the knowledge, understanding, and skills necessary to meet economic, social, and environmental needs by incorporating key sustainability goals (e.g. SDG climate change, SDG biodiversity conservation, SDG poverty reduction" (Nomura 2009).

Sustainability education is not just about educating students about sustainability issues, it is about educating students as agents of change who are actively involved in the development process of sustainable development (McFarlane and Ogazon 2011; Engjellushe 2013). Sustainability education provides values of respect for diversity, social impact, and environmental conservation. It encourages people to respect themselves, their community, and their environment. It demands a sense of social and environmental justice and a responsibility for sustainable behaviors (Minton et al. 2012; Hüseyin and Gul 2018; ATES and Gul 2018).

The Indonesian government has committed to providing sustainability education, through its participation in the UN's Decade of Education for Sustainable Development (2005–2014). A joint collaboration between the Minister of State for the Environment and the Minister of National Education on the Development of Environmental Education was regulated in the KEP-07/MENLH/06/2005 and 05/VI/KB/2005, an agreement on environmental protection and management which was regulated in Law No. 32 of 2009 to help achieve "good environmental citizenship". Globally, the United Nations Education and Culture Organization (UNESCO) also launched the Education for Sustainability Development (ESD) Framework in 2019 to support the focus on the SDGs (Rieckmann 2018).

The framework has five priorities including advancing education policy, transforming learning environments, developing educator capacity, mobilizing the young generation towards sustainability education, and accelerating local education systems' actions (Farokhinia et al. 2022; Giangrande et al. 2019; Kioupi and Voulvoulis 2019). To support the global ESD framework, an initiative called 'Indonesia's initiatives toward education for sustainability by 2030' was introduced by the Indonesian government in 2021 (Kioupi and Voulvoulis 2019). The Ministry of Education and Culture of Indonesia declared that the vision of Indonesia for 2035 is to "Develop the Indonesian people to become lifelong learners who excel, continue to develop, prosper, and have noble character by cultivating Indonesian cultural values and Pancasila" (Rieckmann 2018; Silalahi and Yuwono 2018). However, sustainability education cannot be done by the government alone. The involvement of higher education institutions as the driver of sustainability education and practices is important.

Universities educate young people (our youth) to work in many areas such as in government, politics, commercial, and professional roles so they can actively adopt sustainability management in their work. Indonesian youth have a history of being 'agents of change' in politics and social communities. Their spirit has been key in leading Indonesia, starting from an independent nation-state, the resignation of President Suharto, and the restoration of democracy (Silalahi and Yuwono 2018; Jusuf et al. 2020). In 2021, it is predicted that nearly 17% of the population will be between 15 and 24 years, with 16.7% of the population studying in high schools or higher education (Iyer-Raniga and Dalton 2017). Indonesian youth have tremendous potential in both supporting and actioning sustainable development.

Although significant literature on sustainability education in higher education (Jusuf et al. 2020; Sterling 2010) is noted in this Handbook, very little has focused on sustainability education in Indonesia. This chapter will now review what has been done in terms of sustainability education by Indonesian higher education institutions, the challenges for sustainability education in Indonesia, the sustainability education frameworks that exist as a guideline, and what can be done to accelerate the achievement of sustainability education focus and uptake in Indonesia

Sustainability education development in Indonesia

The Ministry of Education and Culture's 2035 Declared vision for Indonesia has become the fundamental reference for 21st-century national skill achievement in Indonesia (Parker 2018). This vision introduces sustainability education at all levels of education from elementary schools to higher education levels. The competencies required to meet the Indonesian national qualification framework (KKNI), consist of nine levels (Presidential decree 8/2012). Each level applies sustainability education across four focus points in education: academic, internship, training, and independent learning (Sibarani 2021).

Each level of education understands its role in sustainability education. Early childhood education (PAUD) to secondary schools (SMA) have introduced sustainability values using different pedagogies. For example, PAUD introduces a sustainability focus through children playing sustainability-related games at school. Elementary schools to secondary schools focus on sustainability curriculum development using local content to introduce and implement sustainability practices via roleplaying and gaming. Roleplaying applications and gaming are popular with students since they are more concerned with fun learning and student-centered learning, and local components have their own uniqueness. Secondary schools teach the importance of the triple bottom line – economic, social, and environmental assessment in all decision-making. At a university level, the emphasis is on curriculum development across the triple bottom line with specific economic, social, and environmental curricula content that is directly related to sustainability education.

It is also emphasized in the Strategic Plans 2010–2014 and 2018–2022 by the Ministry of Education and Culture that sustainability must become an important part of all levels of education. Education should increase the understanding of the importance of sustainability in the global ecosystem and provide an understanding of the importance of ecological systems and human wellbeing for all students (Sibarani 2021; Sinakou et al. 2019a; Rosser 2018).

The Indonesian sustainability education framework

The purpose of sustainability education in higher education is to promote sustainability issues through the learning process based on an Indonesian sustainability education framework, illustrated in Figure 9.6.1.

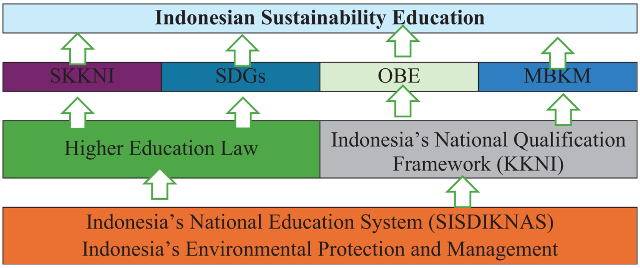

Figure 9.6.1 Indonesia sustainability education framework.

Source: Modified from Ministry of Education and Culture (2020)

Figure 9.6.1 shows that sustainability education is supported by Indonesian laws, regulations, and policies to support sustainability education development. Indonesia's National Education System – SISDIKNAS (Act of the Republic of Indonesia No 20/2003) and Environmental Protection and Management (Act of the Republic of Indonesia No 32/2009) are the fundamental framework of sustainability education. The act is a specific law that regulates the education system in Indonesia from basic elementary education to higher education (i.e. university, academics, and institutions). The act refers to Pancasila and the 1945 constitution, which has power as the foundation of Indonesia's education (Silalahi and Yuwono 2018). The act is focused on developing the nation and people of Indonesia, who are devoted to God, accepting of the many faiths and cultures in Indonesian society, the development of knowledge and skills in the Indonesian people, and support for a spiritually and physically healthy and independent society that takes responsibility for Indonesian national development according to the value of Pancasila. The act is expected to provide guarantees that everyone has the right to receive sustainability education, access to information, and rightful participation in Indonesian society in order to live good and long and, hopefully, sustainable lives.

The Indonesian Qualification Framework (IQF)– KKNI (Presidential decree 8/2012) is one of the main governmental frameworks to support sustainability education. It is a competencies-based grading system used to benchmark the skills and knowledge required in sustainability education for Indonesian workers. The Indonesian higher education curriculum adopts this KKNI framework, in which undergraduate students must achieve level 6 of the KKNI (Sibarani 2021). Level six of the IQF consists of five generic competencies (i.e. one character and four related to the field of study), as illustrated in Figure 9.6.2.

Sustainability education in this framework is implemented based on the level of qualification. Each level has four parameters, including skills, the scope of knowledge, level of knowledge, and managerial ability. For example, the description of the KKNI level six for sustainability education is:

a) mastering in-depth theoretical concepts of sustainability knowledge, culture, and practices to solve sustainability issues,
b) being able to take decisions and improvement based on comprehensive analysis for better sustainability solutions,
c) being responsible and continuously performing sustainability actions.

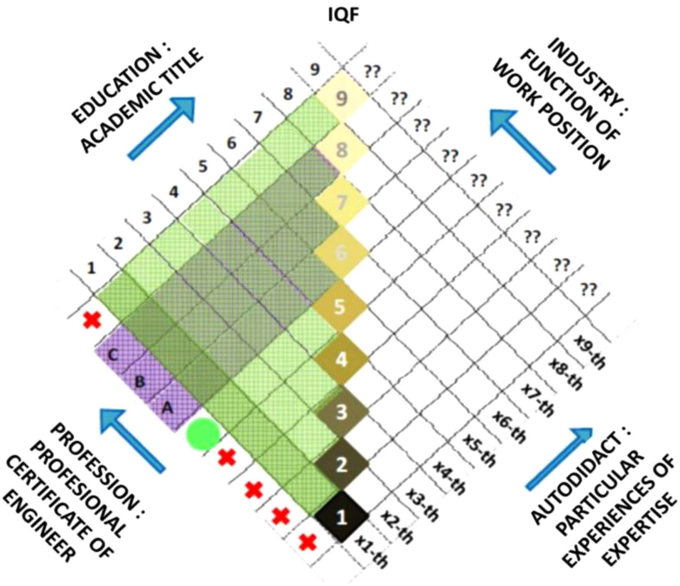

Figure 9.6.2 KKNI (IQF) framework (Ministry of Education and Culture 2012).

Another supporting sustainability education framework is found in the Law of Higher Education no 12/2012, which provides the Higher Education National Standards. In this act, the implementation of the "Higher Education Three Dharma" framework is based on national education, research, and community services standards. The act notes that social attitudes and professional performance standards are important elements in sustainability education that must also be embedded in research and community services programs.

Some regulations and policy directions are also used to supplement the aforementioned sustainability education-focused legislations. The Indonesian National Work Competency Standard (SKKNI) also provides a work-life competency framework that focuses on knowledge, skills, expertise, and attitudes related to occupancies. The SKKNI framework provides working competencies specifically for sustainability education in higher education. The SKKNI for sustainability education is set from basic competencies to high standard competencies, which include knowledge, skills, and attitudes to achieve sustainability issues, challenges, and opportunities.

The Ministry of National Development Planning of the Republic of Indonesia (PPN/Bappenas no 7/2018) also contains regulations concerning the implementation of the SDGs in education, research, and public service office. The PPN/Bappenas, as the government coordinator agency on SDGs, encourages society, organization, and local governments to take actions to support the achievement of the SDGs. The PPN/Bappenas recognizes the stakeholder contribution and participation in SDGs by providing the so-called "Indonesia's SDGs Action Awards". This award shows the appreciation of the Indonesian government to all stakeholders involved in achieving SDGs targets.

The most recent regulation for sustainability education development in Indonesia is from the Ministry of Education and Culture, called the "Merdeka Belajar Kampus Merdeka

(MBKM)", which provides freedom for the development of local content-focused education and local problem-based education. This local content is to be focused on the development of environmental and social values within curricula in Indonesia. The problem-based education is to encourage students and lecturers to go out of the campus and be part of solutions for problems faced by society, the environment, and all sectors of life (health, small medium enterprise, education, climate change, and so forth). Besides that, through the MBKM education program, government encourages higher education institutions to broaden the scope of recognizing credit earning and credit transfer toward the degree program. For example, it is a student's right to have an education experience up to three semesters outside their study program and still earn credit hours toward their degree. In another words, if the student is on leave for a project activity or for a research activity or for internship, the student can be recognized for this activity and it can converted into up to 20 credit hours towards the degree.

The Indonesian National Development Planning Agency (Bappenas) together with the Ministry of Education and Culture and the Ministry of Environment largely have the responsibility to promote and implement SDGs programs in Indonesia. Many Indonesian universities have developed specific SDGs centers or sustainability offices that are responsible for the development of SDGs programs and collaboration with the Indonesian government and other stakeholders on sustainability education development (Kioupi and Voulvoulis 2019).

University international ranking systems in sustainability performance

To assess the relative performance of sustainability achievement in higher education, there are two world ranking systems related to sustainability education and the SDGs that are popular among Indonesian universities. Firstly, the Times Higher Education Impact Rankings (THE) and UI Green Metric World University Ranking. Both the National Accreditation (i.e. BAN PT, LAM) and International Accreditation (e.g. ABET, IABEE) have considered sustainability achievement of higher education in the accreditation assessment. In particular, the Independence Accreditation Agency (LAM) that accredits at the study program level, encourages each study program to promote its uniqueness and its excellence according to its discipline. Unlike previous accreditation practices, the accreditation body uses one accreditation instrument applied to all study programs. Applying LAM, different disciplines use different accreditation instruments. Hence, it encourages each study program to find its uniqueness or its excellence by reference to the SDGs. For example, an informatics study program that is close to a mountainous area may focus on implementing their knowledge related to agriculture and try to achieve the targets of Life on Lands (Goal 15), while another informatics study program that is close to the open sea or close to shore may focus on implementing their knowledge related to fisheries and try to achieve the SDG target of Life Below Water (Goal 14).

THE ranking is a world ranking that focuses on the assessment of university research, stewardship, outreach, teaching program focus, and impact on the 17 SDGs. In 2021, 1406 universities from 106 countries/regions entered the THE rankings. There are many well-known Indonesian universities that participate in the THE rankings, including the University of Indonesia and University of Gajah Mada. In 2022, the University of Indonesia was ranked 18th out of the 1406 universities rated. There was an increase of 23% in the total number of universities that entered the THE's ranking for assessment between 2021 and 2022, highlighting the growing importance of the SDGs within world higher education, including Indonesia (Time Higher Education 2022).

The UI Green Metric is a sustainability-based sustainability world ranking initiated by the University of Indonesia in 2010 to provide an international ranking of university sustainability performance on campus, as compared with the THE rankings and their performance relative to SDG impact. The UI Green Metric includes more than 956 higher education institutions from 80 countries. The UI Green Metric focuses on the assessment of six sustainability metrics relative to campus performance setting: infrastructure, energy and climate change, waste, water, transportation, and education and research (Universitas Indonesia 2022).

The Education and Research criterion in the Green Metric has six indicators including

1. The ratio of sustainability courses to total courses offered on campus
2. The ratio of sustainability research funding toward total research funding
3. Sustainability publications
4. Sustainability events
5. Sustainability-focused student organizations
6. Sustainability websites

In Indonesia, curriculum development is overseen by a national accreditation body (e.g. BAN PT), LAM, and/or international accreditation bodies (e.g. IABEE, ABET). The general requirement for accreditation in relation to sustainability education is through the potential contribution of the study program to its uniqueness and excellence by referencing the SDGs. Not all goals can be achieved by any single study program, and each study program has to focus on its strengths, especially related to the SDGs. The higher education institution accreditation conducted by BAN PT is a comprehensive evaluation and assessment process of higher education institution commitments to the quality and capacity of higher education "Tri Dharma" focused programs (i.e. education, research, and community services). The commitment to Tri Dharma is translated into a number of criteria including 1) the statement of the vision, mission, objective, goal, and strategy; 2) good governance and collaboration; 3) students; 4) human resources; 5) funding, infrastructure, and information systems; 6) education; 7) research; 8) community service; and 9) Tri Dharma output and achievements. With these higher education accreditation programs, universities are required to analyze all indicators in each criteria, taking into account the quality dimensions of relevance, academic atmosphere, internal and organizational management, sustainability, efficiency and productivity, leadership, equity, and governance (BAN PT 2019).

International accreditations (i.e. IABEE, ABET) also play an important role in promoting sustainability education development. The Indonesian Accreditation Board for Engineering and Technology (ABET) emphasizes that graduates should be able to

> "design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability"(UNDIP 2020; Utama and Ambariyanto, 2021; ABET 2018; Garbie 2017).

The Indonesian Accreditation Board for Engineering Education (IABEE), emphasizes two criteria that support the implementation of sustainability internationally. They are:

> A study program should promote self-reliance, welfare, advancement, fairness, and justice for the national and global community in general, based on science, technology,

culture, and sustainable utilization of resources and it is important for the study program to broadly publicize the learning outcomes to society.

The IABEE stipulates that a study program should also engage in continual improvement whilst considering the sustainability of the operations (ABET 2018; Garbie 2017).

Sustainability education development in Indonesian tertiary institutions

Published literature shows that sustainability education development at both private and public universities in Indonesia is varied in its application and development. The following universities were reviewed by telephone survey and through available literature.

Universitas Indonesia

The University of Indonesia (UI) is one of the oldest university campuses in Indonesia and has a world-class reputation. In order to achieve and promote the sustainable development goals, UI provides 291 different study programs with different courses that provide a variety of education, research, and community services by collaborating with various stakeholders including industries, businesses, governments, and local and international communities. UI has developed a prestigious world ranking (i.e. Green Metric) to increase its sustainability reputation. Education, research, and community services programs related to the 17 SDGs have become UI priorities. From 1995 to 2019 more than 3800 research-related SDG focused projects have been conducted to support the achievement of national and international sustainability (Universitas Indonesia 2022).

UI has an SDG hub as the center of excellence in the achievement of the sustainable development goals. The hub serves all sustainability programs that focus on the achievement of sustainability education in UI, which covers economic, social, and environmental fields. UI believes it is a pioneer in sustainable development science (i.e. economy, law, environmental, social) both nationally and globally, through the implementation of sustainability education programs. UI has some 50 student organizations working in sustainability fields and has published more than 300 articles related to sustainability and sustainable development. In addition, more than 22% of its courses offered are related to sustainability, and more than 160 billion rupiah in research funding is dedicated to sustainability issues. In 2021, UI through Green Metric offered a specific online course on sustainability focusing on the SDGs. This course has become the first online course by a Green Metric–ranked university. This course is designed as an introduction to an undergraduate degree. The course discusses the complex interactions between the triple bottom line perspectives of economic, social, and environmental outcomes (Universitas Indonesia 2018, 2022).

UI is currently focused on three priority sustainability programs including global higher education and research, industrial collaboration, and global sustainability leadership. The implementation of the programs is expected to create a collaborative university ecosystem that contributes to national and global sustainability achievements (Universitas Indonesia 2022).

Universitas Diponegoro

Universitas Diponegoro (UNDIP) is a public university that offers more than 120 courses, from engineering fields to social science. Sustainability has become the main pillar for policy development at UNDIP. In the sustainability report of UNDIP 2021, and the report of the Green Metric assessment, the implementation of sustainability education at UNDIP was the strongest. With a vision "to become an excellent research university" and a mission to provide education to produce excellent, competitive graduates, UNDIP is committed to continuously promoting sustainability nationally and globally (Utama and Ambariyanto 2021; UNDIP 2021).

Sustainability education at UNDIP includes multidisciplinary research centers at the core of their research development. Coastal region eco-development is the main research focus of the university. Business incubators have been developed to scale up and commercialize green products developed at the university (Utama and Ambariyanto 2021).

According to Green Metric 2021, the UNDIP has made comprehensive efforts to support the implementation of sustainability education. The sustainability education and research criterion assessment was found to be the highest-ranked score compared to other Indonesian universities. UNDIP offers some 5900 sustainability related courses (80.95%) of a total of 7288 courses. They also have 19 student organizations, 5 cultural events, 56 events, 145 projects, and 3056 publications related to sustainability during the period 2018–2020. The research funds related to sustainability constitute some 90% of total research funds ($3.8m) (Universitas Indonesia 2022; UNDIP 2021).

Universitas Sebelas Maret

Universitas Sebelas Maret (UNS) is a public university that offers 67 different study programs, ranging from law to engineering. According to the Green Metric ranking in 2020, UNS was in the 'Top 10' of sustainable campuses in Indonesia. The university has a strong commitment to contributing to sustainable development through sustainability education, green technology, and a sustainable campus ecosystem. The Faculty of Engineering plays an important role in successfully implementing sustainability education and practices. In the engineering faculty, among 12 study programs (academic and vocational), 9 study programs (75%) have sustainability content (i.e. environmental and climate change). The development of a green campus has helped to introduce new students to increased environmental awareness. A significant number of seminars, conferences, and workshops related to sustainability issues have been conducted by both students and lecturers, with this level increasing by about 70% between 2018 and 2019 (Universitas Indonesia 2022; UNS 2020).

In addition, sustainability has become an important part of the UNS research focus, including collaboration with international institutions in sustainable transportation research as part of smart cities development.

Universitas Muhammadiyah Magelang

Universitas Muhammadiyah Magelang (UNIMMA) is a private Islamic university with 20 different course offerings. The university advocates incorporating religious values into education, research, and social services activities. The university also acknowledges that the implementation of sustainability into higher education and research is very important and urgently required to support the achievement of the UNIMMA vision, which is focused on Islamic values and being a competitive university. Education, research, and community services related to sustainability outcomes have become a priority in UNIMMA academic development. The university vision is translated into course program visions, such as sustainable manufacturing for the industrial engineering study program, green computing for the informatics engineering program, eco-energy efficiency in the automotive engineering study program and Islamic entrepreneurship in the economic management study program. Older curricula have in the past 5–10 years been redesigned to include the principles of sustainability and sustainability management.

The sustainable manufacturing course began in 2019 as an elective course option. The course focuses on environmental sustainability, lean manufacturing, and pollution prevention. Students in this course gain exposure to understanding sustainability theory and practice in manufacturing services, participate in laboratory activities, and engage with some stakeholders (i.e. community and industry representatives). Some of this stakeholder engagement involves visits to manufacturing plants in both urban and rural areas that provide lessons in the practical application and implementation of sustainability. Currently, more than 200 students have taken sustainable manufacturing courses at UNIMAA and more than 50 students have researched a sustainability-related final thesis over the past 3 years.

In 2020, two research centers at UNIMMA associated with sustainability, including Sustainable and Intelligent Circular Economy (SICE) and Energy for Society and Industry (CESI), have been launched to support the acceleration of sustainability-focused research development and capability development in the Engineering Faculty. Under the SICE research center, UNIMMA has produced a number of sustainability-focused research, education practices, community service activities, publications, seminars, and workshops associated with sustainability issues and green energy and technology innovation. UNIMMA recognizes the need to continue its development of sustainability education and plans to continue to expose students, lecturers, and staff to a broader range of sustainability programs and sustainability education initiatives.

University of Pembangunan Jaya

University of Pembangunan Jaya (UPJ) is a private university with ten study programs and uses sustainability education as the university's main scientific teaching and research interest. At UPJ, a sustainable development course is taken by students in their first one to two semesters. The learning objectives include that students are able to identify global sustainability issues, have knowledge of important international-national sustainability policy, and have local wisdom and application of sustainability across economic, social, and environmental parameters. From this course, it is expected that students can become agents of change for sustainability achievement nationally and globally. The learning content includes an introduction to sustainable development, consideration of environmental and population-related impacts, a review of climate change impacts, and regulation and green policy (UPJ 2022).

UPJ believes that an understanding of sustainable development is not only about understanding the theory and practices of sustainability itself but also about elaborating and applying them through communication skills, cultural sensitivity, reasoning and problem solving, learning integration, lifelong learning, and moral and social responsibility. It is expected that after finishing the course, the student will have strong cognitive, affective, and psychometric understanding of sustainability issues. In addition, students are expected to be able to understand, explain, analyze, and evaluate the fundamental principles of sustainable development; be able to adopt the principle of sustainable development in their daily life; and able to share and promote the principles of sustainable development with family, community, and colleagues. The direct interaction with sustainable development thinking helps students to improve their social sensitivity and empathy and enhance sustainability awareness. UPJ focuses on student-centered learning activities through discovery learning, small group discussion, cooperative learning, collaborative learning, contextual instruction, and project- and problem-based learning. These methods benefit students not only in improving their sustainability ability but also in strengthening their critical thinking, and systematic and integrated learning. UPJ also maintains the quality of the sustainability lesson, through a number of evaluation techniques including the use of a logbook, group discussions, presentations, and published articles that help students to become more sustainability conscious (UPJ 2022).

Sustainability education challenges in Indonesia

The aforementioned sustainability education practices at public and private universities in Indonesia show the wide variety of different approaches and responses from universities to the implementation sustainability education. However, the world continues to face a myriad of new and additional sustainability challenges (i.e. new industrial revolution 4.0, ongoing internationalization, increasing demands for quality education, and the COVID-19 pandemic) that sustainability education needs to respond to. Figure 9.6.3 highlights some of the sustainability education challenges faced in Indonesia's higher education sector.

Firstly, the industrial revolution 4.0 needs increasing levels of new technology including rapid information communication technology with significant resource consumption that may create further sustainability challenges. Reshaping higher education into Education 4.0 that meets the sustainability is challenging for many Indonesian universities. However, limited educational resources, poor infrastructure, and the lack of direct links between educational curricula with industrial trends and teaching methods may hamper the achievement of Education 4.0. Secondly, it is stated in the Indonesian Education Roadmap 2020–2035 that universities are encouraged to develop a world-class higher education system to develop their competitiveness. Education for sustainability through internationalization is challenging because it needs a transformative process and transnational and transcultural exchanges that must be experienced by all university staff who may have different character, vision, and mission. Thirdly, Education 4.0 connects education where all people, things, and machines are connected to produce personalized learning The focus is on developing more innovative and creative students, through reskilling and upskilling on digitalization and sustainability. However, in some remote areas, poor education systems and human resources create demotivation and a negative image of education. Fourthly, the COVID-19

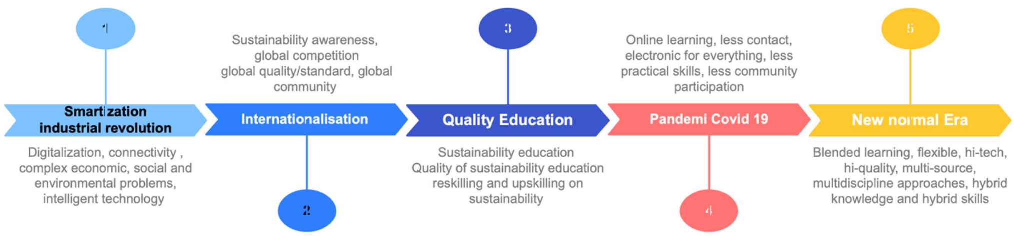

Figure 9.6.3 Sustainability education challenges in Indonesia's higher education.

pandemic crisis brought about sustainability challenges that are related to human culture and behavior, environmental disasters, technology adoption, and economic mechanisms. These situations led to serious consequences that changed the university environments including social distancing, widespread lockdown and restrictions. Blended learning, flexible learning technology (i.e. virtual lab), multisource education (i.e. MOOC, Coursera), and hybrid knowledge and skills became the new normal in education. However, not all universities are ready to move to this situation due to limited resources.

Instead of an education system just focusing on technology development, multidisciplinary and hybrid disciplinary skills competencies, a new sustainability education model in Indonesia is moving toward the development of core sustainability skills, called sustainability competencies.

These competencies include capabilities and mindsets that are directly related to sustainability, including critical thinking, collaboration skills, a focus on teamwork, and problem-solving skill development. To help develop effective sustainability competencies, higher education institutions need a holistic approach in which the knowledge, skills, values, and attitudes related to sustainability are closely interconnected. Sustainability education needs to focus on interdisciplinary studies, integrated thinking, and look towards futuristic timeframes and beyond local interest (Figueiró, Neutzling, and Lessa 2022; Lozano, Bautista-Puig, and Barreiro-Gen 2022).

In Indonesia currently, some universities apply sustainability learning and knowledge through a specific sustainability course (Gigauri, Vasilev, and Mushkudiani 2022). However, the focus on sustainability knowledge and skill development is still lacking integration and effectiveness across university-wide curricula. Other universities are focused on specific pedagogical approaches that focus on student-centered learning, incorporating different perspectives and real-life case study application. This focus hopes to transform conventional thinking and behaviors into modern sustainability thinking and behaviors (Hüseyin and Gul 2018; Alm et al. 2022; Mahmud 2020). Comprehensive sustainability competency guidelines that integrate sustainability across all disciplines are urgently required for further sustainability curriculum development in Indonesia (Hüseyin and Gul 2018; Redman and Redman 2014).

Sustainability education should also recognize and focus on the role of individuals, professionals and organizations and their sustainability responsibilities. This reorientation is critical in sustainability education and needs to be developed further in the Indonesian sustainability curricula. Sustainability education in Indonesia also needs to capture and build resilience in young students in order to more effectively develop sustainability-oriented lifestyles and workplaces, through increased critical reflection, creativity, and collaborative decision-making. However, given the relatively young age demographic in Indonesia, further focus should also be given in sustainability education to innovative social empowerment that involves students in local, national, and international sustainability problem solving and empowerment.

Indonesian sustainability education needs to focus on these challenges if it is to deliver an effective curricula for the 21st century. However, the Indonesian government's new Education Policy – Merdeka Belajar Kampus Merdeka (MBKM), or 'Freedom to Learn', offers a new and innovative educational approach to both Indonesia's higher education system and sustainability education development.

Sustainability education in Indonesia through the new MBKM policy

MBKM, or 'Freedom to Learn – Independent Campus', is a new education approach launched by the Indonesia Ministry of Education and Culture in 2020 to provide freedom to learn and freedom of thought for higher education students. The objective of the MBKM is to provide field experiences that will improve student competencies, creativity, capacity, and self-reliance through contact and involvement with their community e.g. local industry, research centers, village people and school students. In addition, it will provide opportunity to be more flexible, independent, and innovative in their education program development, which should be a good opportunity for increasing focus on sustainability education curricula and pedagogy development.

In Indonesia, currently there is no specific governmental outline on sustainability education content or pedagogy. The new MBKM policy provides universities with the opportunity to develop their own approaches to sustainability education focused on active student-centered learning. The MBKM suggests how students can learn actively from real-life environments through project-based learning, case study–based learning, research-based learning, experiential learning, action learning, and practice-based learning pedagogies, with a focus on external learning environments outside campus (i.e. internships, village projects, school teaching programs, exchange students, research, entrepreneurship projects, and humanitarian projects). Figure 9.6.4 illustrates the implementation of sustainability education through MBKM. MBKM offers students the opportunity to learn sustainability-related practical knowledge and to improve their skills.

The **internship program** offers students apprenticeships in an industry or non-profit organization, government institution, or green start-up for one semester which is valued at 20 course credits. This six-month internship is expected to improve the hard and soft skills of students and provide sufficient experience for students to be ready to enter the work environment. This internship will help provide students with exposure to real-life

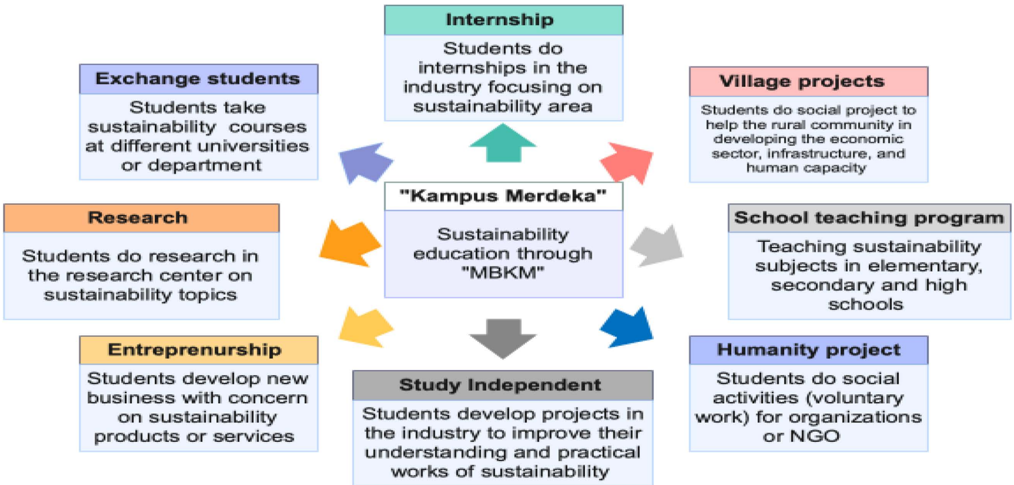

Figure 9.6.4 MBKM and sustainability education, modified from (Ministry of Education and Culture 2020).

(sustainability) issues and involve them in the development of solutions for sustainable development outcomes. The **village projects** will help students to engage local communities in the rural areas and build their capacity look at sustainability challenges in a local context. Potential sustainability projects ranging from agriculture, village-based small-medium enterprises, infrastructure, and IT development will be prioritized (i.e. SDGs 1, 2, 4, and 5).

The **student exchange** program is about taking sustainability classes outside the university for one to two semesters by special arrangement between two institutions. This program is expected to improve sustainability competencies and strengthen community empowerment in the sustainability area. Learning across campuses can also enhance cross-cultural, unity, and ethnic collaborations, which are very important for achieving a cohesive sustainable society (i.e. SDGs 4 and 17). The **entrepreneurship** focus provides students with opportunities to build their own businesses with supervision, training, guidance, and mentoring provided by the lecturer on running a sustainable business. This program is expected to increase employment and economic development (i.e. SDGs 8–10).

The **humanitarian project** offers students entrepreneurial activities in working closely with a national or international humanitarian organization involved with natural or environmental disasters. The program will focus on decreasing poverty, increasing disaster resilience, and improving the health of local communities (SDGs 1, 2, 3, and 6). **Teaching in schools** will look at teaching activities in elementary, secondary, and high schools for one semester to help implement sustainability education programs. Many schools have become part of the Indonesia Adi Wiyata program in which schools have applied sustainability issues in curricula. Adi Wiyata (Green School Program) is an essential program created by the Ministry of Environment to promote knowledge and awareness to Indonesia's students on environmental conservation (i.e. SDG 4).

The **research** program allows students to participate in a research project in a university research group for one to two semesters. The objective of the program is to prepare the students to continue their studies to a higher level. The Indonesian Ministry of Educations Research Roadmap 2021 highlights that sustainability education has become a research priority. During this MBKM research, students can explore many sustainability problems together with research experts (i.e. SDGs 7 and 10–15). The **independent study** offers flexibility to students to develop their potential hobbies and talents that might not be included in the study program. The students will have new experiences through certified trainings or certified internship programs that will develop essential competencies on creativity and innovative thinking. The students with these competencies could then potentially enter global employment opportunities (i.e. SDGs 4, 9, 11, and 17).

Learnings from sustainability education development in Indonesia

Successful sustainability education requires participatory teaching and learning methods that motivate and empower learners to change their behavior and thinking and take responsibility and action for sustainable development. Sustainability education also requires broad changes in the way education is often practiced today. Several approaches have been adopted by Indonesian universities to introduce and implement sustainability education:

first, by introducing sustainability topics (e.g. circular economy, resource and energy efficiency) to new students at beginning of the year through general lectures or seminars, second, by integrating sustainability issues into the existing subject content, and third, by integrating the sustainability issues as a special course (i.e. sustainable manufacturing, sustainable engineering).

Many courses in Indonesian universities have included sustainability content in their education, research, and community service programs. However, an essential component of successful sustainability education development is in creating a 'sustainability curriculum' that should be integrated into all disciplines and across all university programs. The curriculum has a direct impact on the knowledge, understanding, and skill of students across sustainability issues (Nejati and Nejati 2013).

Lecturers as agents of change are also important elements in sustainability education development. Improving the quality and capacity of Indonesian lecturers as professional educators who have the required understanding, knowledge to teach sustainability effectively should be the concern not only of the university but also the concern of government, non-governmental organizations (NGOs), and international agencies (Rieckmann 2018; Kioupi and Voulvoulis 2019; Hüseyin and Gul 2018; Iyer-Raniga and Dalton 2017). In Indonesia numerous training workshops have been conducted for Indonesian educators/lecturers focusing on a wide variety of sustainability issues including sustainable agriculture, sustainable energy, sustainable natural resources, and sustainable entrepreneurship (Mahmud 2020; Al-Ansi, Garad, and Al-Ansi 2021). Higher education should also be expected to design and implement innovative education programs and pedagogies that help students achieve the expected learning outcome (i.e. knowledge, attitude, and practices).

Sustainability education should also focus on the development of the skills and values required for students to be able to contribute to a sustainable world. Sustainability education is expected to respond to the challenges of the 21st century and also meet the changing demands of its broader community (Guanio-Uluru 2019; McFarlane and Ogazon 2011; Engjellushe 2013).

Sustainability education in Indonesia needs to be about a transformation process towards sustainable development for its large, relatively young demographic population (McFarlane and Ogazon 2011; Parker 2018). It needs to involve a comprehensive learning process that engages with the real world, the broader community, academic institutions, and business stakeholders. They are essential parts of the sustainability education model in Indonesia

While sustainability education is still an emerging process in Indonesia, it is expected to strengthen and add resilience to Indonesian society and its economy, as well as preserve and protect the national environment.

To accelerate the focus on sustainability education in Indonesia, the national policy framework for sustainability education needs to be extended from a national directive to a local directive. In addition, the knowledge, skill, and willingness of university members and the commitment of the lecturer to supervise the sustainability process and practice are important contributions to successfully achieving future sustainability requirements. Additional sustainability education accreditation programs are required to maintain the integrity and credibility of the sustainability education performance of the universities at a senior management level. Furthermore, universities need the political will to ensure that university leadership in sustainability education is well resourced and is seen as an education priority.

Conclusions

The essence of sustainability education in Indonesia is to promote sustainability knowledge, skills, understanding, and actions to help achieve a national and international sustainable society. Over the past 20 years Indonesian higher education has made positive inroads towards the development of sustainability education, research, and social services.

The new government education policy MBKM (2020) offers new approaches and opportunities to further develop sustainability education in Indonesia. The MBKM programs include internships, village-based projects, student exchanges, study independent, teaching at schools, and entrepreneurial activities. All are designed to prepare students for national sustainable growth. The implementation of sustainability education will be further strengthened with sustainability being further embedded into primary, secondary, and university courses; curriculum; research; and social services under the MBKM. In addition, increased focus by the Indonesian government through policy and regulation, accreditation programs, and education development incentives are expected to further strengthen the implementation of sustainability education in higher education.

University international ranking systems are valuable benchmarks in the effective evaluation of university sustainability education and campus sustainability performance; however, the development and application of sustainability education accreditation systems should take this focus to a much-needed higher level to ensure that we are able to meet the sustainability challenges of the 21st century, particularly for a young developing country like Indonesia.

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9.7

KEY LEARNINGS FROM INTEGRATING SUSTAINABILITY IN EUROPEAN HIGHER EDUCATION INSTITUTIONS

The value of networks and reflective leadership

Marie Weiss, Ingrid Mulà, Anne B. Zimmermann and Mario Diethart

Key concepts for sustainability education

- Higher education institutions need to acknowledge their role in supporting progress towards sustainable development and take responsibility for addressing sustainability challenges.
- Institutional sustainability integration processes in higher education are diverse but follow recognisable patterns.
- Integration of sustainability can range from a "bolt-on" to a "whole-institution" approach.
- Sustainability champions steer institutional sustainability integration processes.
- Networks and personal leadership are key drivers for integrating sustainability in higher education.
- Sustainability champions go through a variety of learning processes that can and should be fostered by adequate networks and institutional support.

Introduction

Integrating sustainability in higher education

The transition to sustainable development (SD) requires new ways of thinking and acting in the world, and transformative learning is a core lever for this. Universities have an important role to play, as they can act as catalysts for transformative change by educating future change agents (Brundiers et al. 2021; Orr 2004) and by being hubs for innovation and community engagement (Wals et al. 2016). As Sterling (2021, 1) points out:

> "Formal education systems have – or should have – a critical role in the global social learning process underpinning the Great Transition. . . . [But] it is not so simple. If

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education is to be an agent of change, it has itself to be the subject of change. Our educational systems are implicated in the multiple crises before us, and without meaningful rethinking, they will remain maladaptive agents of business as usual, leading us into a dystopian future nobody wants".

The Berlin Declaration (UNESCO 2021), recently released by UNESCO, explicitly embraces transformative learning as a key process to engage individuals and society in sustainable development, as such learning supports holistic personal and collective development, iterative learning cycles, and the paradigm change needed for behaviour change (Mezirow 2009). Ultimately, introducing transformative learning into higher education implies adopting a "whole-institution approach" to integrating sustainability into higher education (HE), i.e., by incorporating sustainability into teaching and learning, research, campus operations, and outreach, while engaging a variety of stakeholders (COPERNICUS Alliance 2012).

In his recent call for rapid and full integration of sustainability into HE, Sterling (2021, 3) distinguishes between four levels of integration: "(1) no response, (2) accommodation, (3) reform, and (4) transformation". These levels correspond with his earlier, more elaborate categorisation applied to education as learning and teaching in the context of the education for sustainable development (ESD) debate (Sterling and Thomas 2006), summarised in Figure 9.7.1. This differentiation between (1) "denial" and "no change", (2) "bolt-on" and "education about sustainability", (3) "build-in" and "education for sustainability", and (4) "redesign" and "education as sustainability" constitutes a very insightful framework for analysing what level of institutional sustainability integration has been reached by universities in the context of the higher education for sustainable development (HESD) debate (Barth et al. 2016). Ultimately what needs to be reached is a paradigm change, "education as sustainability", which is only possible with a whole-institution approach.

Given the urgency of the Berlin Declaration's call, it is important to ask how universities are engaging with sustainability in practice and what strategies they are using to increase integration and possibly introduce transformative learning. A large number of universities have been actively integrating SD (and more specifically ESD, see Weiss and Barth 2019), especially since the launch of Agenda 2030 and the Sustainable Development Goals (SDGs) (UNESCO 2020). But universities that have succeeded in redesigning their organisation are rather rare (Weiss, Barth, and von Wehrden 2021). Do we understand when such radical organisational change occurs, and how it can be designed and fostered? Evidence from single case studies (Trechsel et al. 2018) exists, as well as theoretical reviews on drivers and barriers (Barth 2015); recently, more generalised insights from a meta-study (Weiss 2021) have been made available. But discussions about SD also always insist on the importance of context and diversity; thus details matter as well.

This chapter shares the sustainability integration stories of five European higher education institutions, told by actors who were involved in different ways and responded to different contexts. Using Sterling and Thomas's (2006) four levels of integration as a conceptual framework for analysis, it illustrates the nuances of driving and hindering factors often missing in published case studies, theoretical work, and meta-studies. For example, how was the university community engaged in the integration process, what tools were used for communicating about HESD, and how does culture affect participatory processes?

Level	**HEI response**	**Type of ESD**	**Description**	**Pedagogical Approach**
high/ very strong	redesign	education *as* sustainability	-holistic change and paradigm shift that places sustainability principles, ethics, and values at the core of the curriculum and requires the engagement of the entire person and institution -ESD is integrated into common core requirements and/or the vision of the HEI	emancipatory & transformative (third-order learning)
middle/ strong	build-in	education *for* sustainability	-significant changes to the curriculum are made by including coherent coverage of content, values, and skills associated with sustainable development and a critical questioning of assumptions -sustainability is addressed in (interdisciplinary) programs/courses that focus on integrating sustainability issues -first linkages of ESD modules to other HEI areas such as operations/campus	
low/ weak	bolt-on	education *about* sustainability	-leaves current paradigm change unchallenged -sustainability concepts are added to specific existing disciplinary courses or programs (content based sustainability literacy) -minimal effort from the institution	instrumental & simplistic (first-order learning)
very weak	denial	no change	/	

Figure 9.7.1 Levels of institutional sustainability integration in higher education (adapted from Sterling and Thomas 2006).

Given that a variety of factors can influence the integration process and that arbitrariness of detail would lead to irrelevance, we focus on two factors in particular that have not yet sufficiently been explored in former research within this context, although they have been highlighted as significant in earlier HESD documents: leadership and networks (see Rio Treaty: COPERNICUS Alliance 2012; Dlouhá et al. 2018).

Transformative change does not just happen, it requires leadership. We explore how integration of sustainability in HE is led and by whom, drawing on Ferdig (2007), who argues that transformative change requires a new form of leadership, where holding formal leadership positions may not be the same as acting as a leader. Ferdig (2007) suggests an understanding of leadership in which everybody can choose to be a leader, means of leading with others instead of over others are needed, and holistic interconnections between people and natural systems should be acknowledged. Therefore, we use the term leadership not only to describe formal top-level leadership (e.g., presidents, deans) but also bottom-up approaches where any university community member can lead processes of embedding sustainability within the institution.

In addition, to lead transformative change, individuals need to be motivated and capable of doing so. This requires relationships different from the ones usually governing academia and dominated by the principle of competition. When leadership needs to be transformative, it must rely on collaboration, which is why we also analyse what role networks play in integrating sustainability into HE (Scott et al. 2012) and how networks support individuals' leadership development. In other words, leadership and networking go hand in hand (Zimmermann, Mulà, and Diethart 2021).

Our interviewees were given the possibility of defining networks in the ways that made most sense to them in the context of embedding sustainability into their own higher education institution (HEI). For some this meant consolidated international, regional, and national networks or Regional Centres of Expertise (RCEs) aiming to mainstream sustainability in HE with typically more formalised structures (Dlouhá et al. 2018; Mochizuki and Fadeeva 2008). Others associated the concept with informal learning networks in the sense of communities of practice (Warr Pedersen 2017).

By sharing these leaders' stories of transformation (Lotz-Sisitka 2004), we expect to add nuances to known drivers and barriers and hope to open the possibility of learning from others' experiences. We thus rely on phenomenological arguments buttressed by comparisons between understandings and experiences of HESD, leadership, and networks. We invite the reader to reflect on what might work best in their own context when aiming to reach a higher level of institutional sustainability integration.

Capturing stories of integrating sustainability in universities

Rich stories, guided by a sound methodology and a process-oriented focus (Corcoran, Walker, and Wals 2004) and revealing personal insights and emotions, are an invitation to reflect on described experiences against one's own background and perspective. The five European universities selected for this study are members of the COPERNICUS Alliance (CA). They were chosen as case studies that are as diverse as possible in terms of region, focus, and size (see Table 9.7.1). We sent requests to six CA contact

Table 9.7.1 Characterization of case studies

	Kaunas University of Technology	*Daugavpils University*	*Hasselt University*	*Vienna University of Economics and Business*	*University of the Basque Country*
Country	Lithuania	Latvia	Belgium	Austria	Spain
Number of students	9,040	2,200	6,500	25,000	45,000
Focus	Technology, but also social sciences	Teacher education, but also life sciences, social sciences and management	Civic university committed to the Region and World; diverse disciplines	Economics	Collaboration with local society; diverse disciplines

persons and conducted interviews with five individuals (one per university) willing to share their stories and to contribute to the collective effort of advancing the HESD agenda. All interviewees had been working at their universities for a long time and are still intensely involved in the process of integrating sustainability. Therefore, they had extensive knowledge of the internal implementation process at their HEI and could share rich and reflective stories and learnings from their perspective. The interviewees were given the chance to validate the results described later. The gender ratio was three/two in favour of the female gender.

The interviews took place in September 2021 and were conducted and recorded digitally via Zoom by the first author. They were scheduled for 1 hour; the shortest lasted 40 minutes and the longest 2.5 hours. The interviews were semi-structured, with the intention of listening to the stories and adapting the questions and their order if needed (Lune and Berg 2016). The interview questions were formulated so that responses could address the objective of our research; they were discussed and agreed upon by an international interdisciplinary team (the authors of this chapter). Questions and follow-up questions covered the following areas:

- *Personal profile:* interviewee's job profile, duration of employment at the institution, ESD teaching experience.
- *Understandings of SD & ESD:* personal understandings of SD & ESD and (official and/or informal) institutional understandings of SD and ESD.
- *ESD implementation process:* impetus, stages, levels of implementation, whole-institution approach, drivers and barriers, key influences, future plans.
- *Networks:* role of networks for implementing HESD and the development of leadership skills.
- *Personal leadership:* role and learning process within/during the institutional sustainability integration process.
- *Lessons learned:* learnings, suggestions, and coping strategies to share with others, to support transformation towards a whole-institution approach at one's university.

The interviews were partially transcribed and analysed through deductive qualitative content analysis (Mayring 2015), using the categories mentioned earlier. Quotes in this chapter were adapted for grammar and vocabulary, as English was not the first language of the interviewees. To describe the level of integration of sustainability in HE, we used the framework (Figure 9.7.1) based on Sterling and Thomas (2006).

Voices from five European universities

University of the Basque Country (UPV/EHU)

> "After some years, most people from the different faculties have ownership of sustainability topics, [. . .] probably because the process was so participatory."

The level of anchoring sustainability can be described as *build-in* on the way to *redesign*. UPV/EHU aims at achieving a *whole-institution approach*. Sustainability is implemented in teaching at all levels, as well as on campus, in research, and in outreach activities, with some synergies between the sectors (e.g., campus laboratory project-based learning). A holistic SD understanding is supported by the *top leadership level* and formalised in a *strategy*. The understanding of ESD can be described as *education for sustainability,* moving towards *education as sustainability* (see Figure 9.7.1); this is currently steered by a specific project (until now ca. 15 % of all study programmes).

UPV/EHU is only 40 years old. First, sustainability-related programmes and strategies started separately, focusing on environmental topics, inclusion, or gender equality. In 2010, Spain entered the European Higher Education Area (EHEA) system, which "brought a lot of changes" and occupied the university community with other priorities such as adapting all study programmes and using new pedagogical approaches (e.g., cooperative and active learning). After completing this adaptation and being involved in the Basque government's SDG strategy process, as of 2016 the university started to take into account the *2030 Agenda*. In 2017, a new *leadership* team (presidential level) aiming to integrate SD throughout the university was elected. This new team immediately embraced its responsibilities with regard to the 2030 Agenda and started a process of connecting former individual efforts, different disciplines, and different groups of people through a *participatory process* and the appointment of a *sustainability manager*. The sustainability manager works with an interdisciplinary team of five staff members who foster HESD. The team coordinates development of the *sustainability strategy*, *connects staff and students from different disciplines*, supports researchers, and together with the education counselling service, provides *faculty training* to support embedding of ESD across the curriculum. For instance, to further highlight the holistic understanding of SD, an online course on general aspects of SD, in which different experts from different disciplines explain what SD means to them, is offered to the whole university community.

The participatory process involves students, staff, and academics, who in general share a positive attitude toward HESD. However, the interviewee highlighted that top-level leadership was really needed, as "people from different groups [at UPV/EHU] don't see it as their role to start something bottom-up. They wait for top-down support/approval". Gaining these groups' confidence required taking stock of what was already being done (*inventory*) and what the university community envisions in future. For instance, world cafés and online discussion spaces were offered to students. Interestingly, engaging the students, especially online, proved difficult, as they were not used to having a say in such decisions. The leadership team and governance groups participated in well-prepared one-hour meetings. As a result, a *sustainability strategy (2019–2025) with steps and indicators* was developed and broadly accepted.

The status of achievement of the strategy goals is continuously communicated through the university's sustainability webpages and the university's *communication* team. To communicate the strategy, pictogrammes (building upon the SDGs and adding new ones) have been developed and are used in formal, informal, and research documents as well as for study programmes, highlighting what action contributes to which strategy goal.

With the recent change of rector in 2020, the focus has shifted from embedding sustainability in teaching and community engagement to integrating it into *research*. The sustainability communication plan will also be improved by producing more content for social media to reach students better. Moreover, UPV/EHU wants to focus on developing and implementing transdisciplinary projects as well as assessing their contribution to sustainability in Basque society (a first report will be published in 2022).

Hasselt University (UHasselt)

> "There is enough support . . . we don't want sustainability to be imposed on people, top down, instead we want . . . sustainability . . . to be supported by everyone".

For UHasselt, the level of institutional sustainability integration can be described as being at the *build-in stage*. A *strategy* is in place with sustainability as one of four pillars. Furthermore, a *whole-institution approach* is being applied, ultimately aiming for redesign.

UHasselt is a civic university (i.e., committed to serving the local and global communities) and sustainability issues are implicitly anchored in its tradition. Around 2015, the university started a process of discussing what was already being done for SD (*inventory*), supported through an external consultancy (cifal, https://cifal-flanders.org/) that focused on integrating the SDGs. However, what led UHasselt in 2019 to really make HESD explicit was realising that they were the only university in Flanders without an explicit sustainability policy plan. To foster HESD, the new rector (since 2020) framed sustainability as one of four key transversal themes for all activities. This provided the already existing *steering committee* with strategic support for integrating sustainability more strongly and in a coordinated manner: "And that's really the vehicle that made everything possible", as there is now a formalised advisory body. The whole process is very participatory. Every faculty and every programme must have a representative in SD discussions. Representatives participate in meetings and have the duty to share information with their faculty/programme after meetings. This *participatory process* seems particularly important, as the institution experienced drawbacks when a former education policy plan was introduced top-down, without a democratic process. *Communication* is happening mainly via participation and many discussions, which "make sure that there is enough support [from the university community]" for UHasselt's SD efforts.

An *accreditation agency* also served as inspiration for the university to apply "SD-related maturity levels" to their programmes. However, often – due to different *understandings of SD* – some disciplines still do not see the relation between their discipline and SD (e.g., some researchers in the Faculty of Medicine and Health Science initially did not perceive their work as strongly related to SD through provision of health care and well-being). The interviewee explained that this might be due to the former SD understanding being very narrow 10–15 years ago, but this is now changing. To address this challenge the steering group arrived at a *shared and explicit understanding of ESD and SD* including the SDGs, planetary boundaries, the growth-degrowth debate, complexity, a set of competencies, transformative learning, etc. The steering group's theoretical ambitions are very high, but in practice it seems that the background (i.e., disciplinary background, attitude towards SD, former experiences regarding HESD) of academics influences how innovative teaching and learning methods are perceived. Most lecturers and professors lack pedagogical knowledge to apply *education as sustainability* and have never heard of transformative learning, but they have great sustainability content knowledge in their field. Also, students seem to hesitate to be introduced to transformative learning: "We are struggling with that because that's a *cultural* thing. We can try it but when we do, we see that our students hesitate: 'Oh, what's happening? I have to talk?' "

To cope with such difficulties, *support* is being offered by UHasselt for all employees (with such offers as a teacher professionalisation programme, a training for understanding wicked SD issues, a learning community, etc.). Support is also offered by the *government* through an environmental department that collaborates with HEIs, offering an online learning path.

> "But one of the reasons why I think it is tough is because we already have so many changes, and the world is getting more complex [. . .], and ESD is something new that is coming their way again, as something extra. [. . .] We don't want people to be demotivated because it is something new. We are looking for ways in which they can see that they already do that. We just want to give space to elaborate on that. So, we want to give our professors motivation and autonomy to work on sustainability. And that's more in the sense of a driving force instead of . . . imposing it top-down".

What does not make it always easy to implement new topics is that the job of a professor is already very full and often filled with other extra work (for instance, the integration of some college degrees into the university system, which implies a stronger research focus). Apart from this, external drivers to steer HESD have been and are *increased social awareness* (due to local flooding) and the *European Green Deal* (at least for the business faculty).

To put the vision into action, goals have been developed with *indicators* to measure the progress; once they have been applied, external communication will be strengthened accordingly.

Vienna University of Economics and Business (WU)

> "The biggest input has been the rector . . . so the top of the university says: Yes, we want to become sustainable at any cost".

> "So it was money and power. . . . Now this is very sad . . . it was not innovation, cooperation, or participation".

For WU, the level of institutional sustainability integration can be described as hovering between the *bolt-on and build-in* stages. Sustainability issues are strongly integrated into campus sustainability (new, very energy-efficient buildings) and research (as most European-funded projects require integration of SD topics); integration in teaching and learning (e.g., slowly the growth-degrowth debate is finding its way into economics textbooks) and outreach activities are improving. Moreover, the university has a well-established UNU Regional Centre of Expertise (RCE). SD is partly integrated into WU's *mission statement* and anchored at the centre for competencies, with every business student required to participate in a one-year course on SD. However, there is *no formal and shared understanding* of what ESD means; for most teaching staff, it seems to be more like a first-order learning approach, and only pioneers have a deeper understanding and praxis of second- and third-order learning (see Figure 9.7.1.).

The decision to integrate sustainability more strongly at WU was taken by the former president in 2009. This *top-down decision* was then pushed against internal barriers and *without great participation*. To achieve this implementation, the former rector created a *commission* to steer SD. This was not a well-coordinated process, but those involved had discussions around the meaning of SD (some saw it as long-lasting) and working groups. Two years after the initiation, the rector established a *coordination office* for SD and suddenly things evolved. At the same time, with the support of the former rector, an *RCE* was established by an engaged researcher in 2011. The RCE is doing a lot of work steering HESD issues, e.g., giving faculty training, coordinating SD efforts, reaching out to practitioners and society at large, etc. However, the RCE is not an officially formalised and independent centre, and it is not well-known at its institution.

A main driver is that SD has become a cornerstone of the "Leistungsvereinbarung" (performance agreement with the ministry of the state/country) since 2018. Suddenly things are changing: SD pioneers within WU are involved in incorporating their expertise and describing their SD initiatives for the performance agreement. Through this "many pioneers got a boost . . . now they can evolve, they can grow, they can influence".

> "It was very interesting for me that through money, the ministry really has this leverage . . . and suddenly there is space for sustainability".

The interviewee explained that members of the ministry shared that *societal pressure*, influenced by Greta Thunberg's engagement, forced the ministry to prioritise SD issues. Within the WU there was, and is, a lot of fear regarding change: "the effect on an innovative university maybe wouldn't be that big, but on my [rather conservative] university, it is enormous". For example, many carefully planned steps were blocked after a year, and efforts turned to adapting to resistance and trying to make the best out of the situation. Student involvement is not so strong; most students can be described as having a high income and being interested in SD issues when it comes to their health and lifestyle. Only a low number can be called critical thinkers (ca. 15 % of students).

Reflecting on the process, the interviewee sees it as an evolutionary process with some basic mechanisms and a lot of luck and bad luck: a formal strategy would not have led them to where they are now, "I couldn't foresee any trend . . . and now I'm completely surprised". The key drivers were leadership support from the top, political support, and guidelines.

Since 2015, WU has a new president with a background in gender and diversity topics; she is also supportive of SD. In addition, the RCE is striving to become a formalised centre (with some external funding), with the plan of establishing an SDG innovation centre (e.g., for training startups on SDGs); this is supported by the rector.

Kaunas University of Technology (KTU)

> "You can look at very nice results from some projects, but the process is a black box. It somehow happens, but it is not a structured organised process [. . .] it happens, because some people are passionate about that [. . .] and we are getting quite good results".

The level of anchoring sustainability at KTU can be described as situated between *bolt-on* and *build-in*. There are some SD-related courses (e.g., sustainable fashion in the fashion design study programme) and some SD-related institutes (e.g., environmental engineering institute), but no SD-focused study programme. Furthermore, there is some SD-related research (e.g., sustainable management research group) and a few campus sustainability projects, but less outreach and synergies among stakeholders. SD is included in the university's *strategy*, but there are no clear steps and indicators to measure the progress. The interviewee felt that this would be important because, at some point, "you want to enjoy the results" and "look at this 25-year history, how long can you stay in this beginning and vision phase?"

In general, the implementation process can be described as a *bottom-up process*. Although the leadership team welcomes sustainability ideas and initiatives, it does not actively support their implementation. Important changes took place when Lithuania became independent in 1990. In particular, when Lithuania joined the Bologna Process in 1999, European ideas and funds brought in knowledge from international partners, especially from Denmark, Finland, and Norway, and even influenced the university's structure. Within the university, integration of sustainability started with a small group of dedicated researchers from the environmental engineering department, which implemented first environmental projects on campus; 15 years later initiatives were rather isolated, with no cooperation or even knowledge about one another.

Then, in 2015–2016, a new vice-rector of studies joined the leadership team and redefined the teaching and learning vision, introducing a focus on sustainability-relevant knowledge and critical thinking. From September 2019, every student had to enrol either in a course offered by the philosophy department or in a newly launched SD course (designed from 2016 to 2019). To develop the new SD course, an engaged professor connected academics from different disciplines and incentivised interdisciplinary discussions around (E)SD. This *collaboration* was important to connect isolated projects and academics from different faculties. The introduction of the UN Global Compact guidelines (https://www.unglobalcompact.org/; initiated by the same professor), for which existing sustainability initiatives at the university had to be collected, further supported communication among different groups. The interviewee emphasised that at this time *they missed momentum* to further steer a whole-institution approach due to missing top-level commitment. The rector is not a barrier, he encourages discussions, but there are *no institutionalised positions* for the implementation, coordination, and communication of SD; nor is any support available, such as faculty training. "The institution is talking rather than acting [. . .], SD is not a top priority", but more of a horizontal value, with technology and digitalisation being prioritised.

The interviewee described the *lack of sustainability awareness* as a major barrier.

> "You can hide with arguments such as, not enough people, not enough resources; but no. . . it is [because there is] not enough understanding".
>
> "Deep changes require deep thinking/learning".

Disciplinary barriers contribute to people not understanding why they should teach or learn something about SD. The interviewee explained that about 50% of faculty staff – including some of those who now hold formal SD-related positions like head of a faculty or centre – thought SD is more a "nice label", but for the other half it is a serious issue anchored in their values. To develop a *shared understanding of SD* and to learn from each other, the team of the interviewee (a professor) met every week for a long time to discuss (E)SD topics, until they reached a shared understanding. "With this basis, if you push a little bit more, you can have excellent results, but sometimes people are tired of pushing . . . you only have a certain amount of energy . . . I said for myself: Is this for me or for my organisation? [. . .] But sometimes I feel a little bit too tired to be responsible for everything, to push all the time". Further support has been coming from the student union, which has fuelled many HESD activities.

The funding system is an external influence. In Lithuania, funding SD does not play a great role; however, in the European funding system, SD is nearly everywhere, which makes researchers think about how their research relates to SD topics.

For the future, an SD programme is planned. However, this would require capacity and action from the whole university community. In general, the interviewee states that more systemic changes are needed, as people tend to act according to what the system requires.

Daugavpils University (DU)

"It is a luxury to have a charismatic leader".

At DU the integration of HESD can be described as being between the *bolt-on* and *build-in* stage. Sustainability issues and ESD are not implemented in a formal vision or strategy, nor are they strongly supported by the top-level leadership. However, a group of sustainability enthusiasts have succeeded in ensuring that many courses at all levels (BA/MA/PhD) have environmental education (EE) or ESD integrated as cross-curricular issues, especially at the Faculty of Education and Management. (E)SD is also a topic in research; some informal campus sustainability projects exist, but there are few outreach activities.

The discussion about integrating sustainability started 20 years ago and can be described as a *bottom-up process* and "a matter of one individual who thought about these issues". At the end of the ESD decade in 2013, a head of a faculty managed to establish a UNESCO chair on teacher education and continuing education, with ESD as a focus. In a first phase, the head of the UNESCO chair started to develop a theoretical *understanding of (E)SD* issues through different activities. These were more informal conversations by which she slowly tried to engage more people in thinking about (E)SD issues by 1) reviewing research findings on good practices in Scandinavia, Europe, and beyond (also through being engaged in networks); 2) encouraging team members to visit and participate in international conferences and learning from HEIs in other cultural contexts; and 3) inviting every team member to think about their research topic through the lens of sustainability. These efforts were supported by the former science/study rector through financial resources for attending international conferences. Further support resulted from a general reorientation of teacher education in Latvia, which became more competence oriented.

After this, a second phase started, during which an understanding of (E)SD that relates to the Latvian cultural context was developed. The UNESCO chair head tried to engage staff members inside and outside her own faculty in discussions about (E)SD. As a result, SD was conceptualised by the group using the overlapping dimensions (circles) of economic, social, and environmental sustainability, but with culture as the core dimension. Meanwhile, different perceptions of ESD started circulating and an increasing number of people engaged in thinking about ESD. The group of engaged researchers around the UNESCO chair now understand ESD as *education as sustainability*, with emancipatory and transformative learning at its core.

A key driver to integrate ESD in teaching activities of further faculties are SD-related international research projects that are supported by DU's increasing internalisation policy. For the interviewee, lack of time resources due to a high amount of teaching hours was thought to be a key barrier to stronger integration. By contrast, working with an engaged and collaborative group maintained her own enthusiasm despite time pressure.

It is important to acknowledge the history of the HEI during this process: until 1991 it worked under a totalitarian regime. Changing the thinking of the 40+ generation has proved hard. Furthermore, the interviewee described the nature of Latvian people as being introverted: they listen to other experiences and reflect a lot, meaning it takes time for new initiatives to line up with thinking and for actions to be finally adopted.

For the future, the group around the UNESCO chair is striving for more formalisation of HESD integration, with a focus on bringing transdisciplinary projects into action to foster transformative learning.

Common key enablers and the role of networks and leadership

In general, the stories illuminate and bring to life what has been described in previous work on common key drivers and barriers to HESD (Velazquez, Munguia, and Sanchez 2005). The stories presented also correspond well to integration patterns (highlighted in the following in italics) that were recently explored in a meta-analysis (Weiss, Barth, and von Wehrden 2021).

Thus, the cases of the University of the Basque Country and Hasselt University fit into the implementation pattern *"collaborative paradigm change"* and illustrate what power there is in participatory processes and strategically led change processes to achieve a deep integration in a short time. Key drivers are a participatory process in which bottom-up and top-down forces complement each other (see also Trechsel et al. 2018) and where people collaborate by discussing understandings of SD and ESD. Through this they develop a shared vision and strategy with clearly defined indicators. Furthermore, good communication as well as support (i.e., financial/time/human resources, professional development) are important key drivers for achieving a high level of sustainability integration. The attitude towards (E)SD of individuals in top leadership positions and a possible change in these positions are further key drivers. Externally, social pressure, political support, accreditation agencies, and networks help steer the implementation of sustainability in universities.

By comparison, the other cases have fewer key drivers in place. The Vienna University of Economics and Business falls under *"top-down mandated institutional change"*, mainly missing a participatory and coordinated process to engage the whole campus community in a reflective learning process on HESD. Daugavpils University and the Kaunas University of Technology are between *"bottom-up institutional change"* and *"isolated initiatives"*, mainly due to missing internal prioritisation and no real living up to formal statements, a lack of strong top leadership support, and missing dedicated resources.

Something that has not been explicitly researched so far in the context of these processes are the different cultures in which integration happens and which can heavily influence how familiar people are with participating in decision-making processes. Moreover, balancing personal resources (well-being, energy, etc.) while steering or even fighting for more sustainability at one's institution was a challenge explicitly brought up by three interviewees.

Role of networks: learning from the past

Networks were perceived by all interviewees as a strong driver for steering HESD processes at their institution. Different types of networks can be distinguished: national disciplinary networks and associations, regional networks (like the Baltic and Black Sea Consortium or the Baltic University Programme), and European networks (like the CA), or university-internal networks. In Table 9.7.2, the usefulness of networks as highlighted by the interviewees is illustrated.

However, for the interviewees some networks seemed to be more helpful than others. This is especially the case, they argued, when the networks are active, not very formal, and

Table 9.7.2 Usefulness of networks for individuals engaging in steering HESD at their HEIs.

Purpose of network	*Key elements gained*	*Example quote*
Learning	– Information, conferences – Material (good practices) that can be used in teaching, and seminars or workshops – New ideas presented, or new ideas that can be developed collaboratively	"It really speeds up learning of all people in the network [. . .] I feel better equipped". (Int. 2)
Empowerment and motivation	– Relationships, motivation and encouragement by seeing that other people have similar values and shared passions – Trust	"This motivation is needed for everybody"; "If you want to be strong and go long, go together". (Int. 4)
Partnerships	– Co-organization of course programmes, development of projects (research and teaching) • Less competition in international networks • Informal structure (especially for internal, non-formalized networks to cope with internal bureaucracy)	"It is important to not just be a member, but to be an active member and to involve decision-making people into the networking". (Int. 4)
Credibility	– Membership in a well-recognized network creates internal credibility in own HEI	"If I were not a member of the COPERNICUS Alliance, I don't think that I would have achieved as much as I achieved now. And it is because the COPERNICUS Alliance gives credibility to the professors who are involved in it". (Int. 2)

welcome new people and perspectives and offer space for personal relationships to evolve, share, and co-create knowledge or projects. To make networks even more beneficial, the interviewees wish that 1) networks would increase their visibility to reach more people with different backgrounds at different career stages (e.g., early-career researchers) through better-targeted communication; 2) more persons holding formal leadership positions would participate in networks; and 3) more implementation tools, good practices, and teaching/learning material for academics for a diversity of disciplines were openly available at any time. Indeed, in most cases there is little time, not enough examples, and an expert is missing as a contrast with one's own ideas, e.g., regarding ESD in mathematics.

Role of leadership: reflections from the interviewees

The interviewees portrayed in this chapter all took unique (personal) leadership roles in the process of mainstreaming sustainability at their institution. As we need a new perspective on leadership (Ferdig 2007), we share reflections offered by the interviewees about the development of their own leadership skills (Figure 9.7.2). What stands out is that every

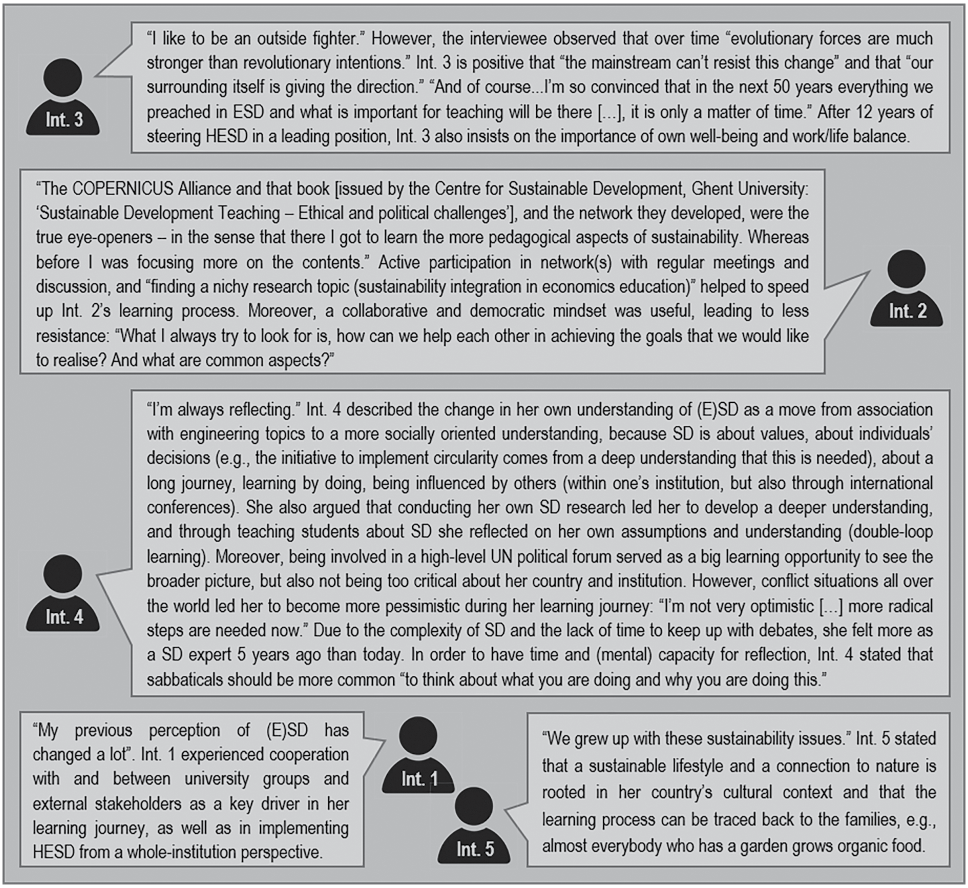

Figure 9.7.2 Role of leadership – Reflections from the interviewees.

learning journey was individual; however, the speakers all shared the same goal, committed to it, and worked collaboratively in their HEI to reach it.

Conclusion

So what can we now do to advance HESD at our own universities? In particular, how can we become the authors of our own leadership stories? The described integration processes invite the reader to reflect on key factors to accelerate integration; they also encourage readers to reflect on what can be done to achieve a paradigm shift and help create transformative learning settings for the deeper integration of ESD we need. In the analysis of our findings, we refer to a meta-study that elucidates which combinations of key influences lead to deeper implementation (Weiss 2021); to our knowledge, this is the first meta-study of the kind, but we expect that more are in the making. Research will thus definitely continue.

What is now urgently needed is action to increase the pace of mainstreaming sustainability in higher education (UNESCO 2021). Often, the final word in an article is reserved for the authors. Since our intention is to emphasise the importance of personal leadership, collaborative and collective working, and joint learning, we explicitly leave the closing words to the interviewees, who share their personal, experience-based suggestions regarding how to drive HESD:

- Start by detecting who is doing what regarding HESD in your own institution and start to understand the culture.
- Find persons with a common interest in your HEI to maintain enthusiasm and support each other; establish relationships and have regular discussions to develop ideas.
- Create opportunities in which everybody can take part and show their talents.
- Find wordings that are understandable to different people and steer conversations on different understandings. You may want to start with easily understandable topics and go deeper at a later point.
- Cater to resistance by focusing on common elements.
- Find ways of supporting people's growth by trying to understand different perspectives, perceived barriers, and finding a solution with them (e.g., if somebody does not feel comfortable with incorporating SD issues into a programme or course, maybe someone else with such a competence can join in: for example, with team-teaching).
- Address and involve persons who hold formal leadership positions. Ideally vote for a president who is equipped with sustainability competencies.
- Engage in sustainability research, as you will gain more credibility and impact in your HEIs.
- Introduce as many students as possible to at least ideas of SD and take them on a transformative learning journey in which they can reflect on their attitude toward SD. Their own interpersonal competency to involve other people will be key to doing this.
- Don't just reflect, but act: tiny, small steps are important and can accumulate to change.
- At some point, you may want to challenge your comfort zone and to take on a (formal or informal) leadership position.

With these insights, we wish to motivate future champions to take on leadership to steer HESD, even if they do not hold a formal leadership position. And with this collaborative effort we hope to increase the quality and reach of HESD.

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9.8

EDUCATION FOR SUSTAINABLE DEVELOPMENT IN CHINA

An observation of policy and practice

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Key concepts for sustainability education

- Education for sustainable development in China was kickstarted by UNESCO in 1998.
- Education for sustainable development has made significant progress in China over the past two decades, but as yet no formal education plan for sustainable development has been developed at a national level.
- The *Beijing Declaration* titled "ESD Towards the Mainstream of World Education" defined five implementation strategies to be adopted in China:
  - Carrying out research on the theory and policy of ESD localization,
  - Carrying out special training in ESD for educators and trainers,
  - Building a national experimental zone for ESD teaching,
  - Building sustainable development schools, and
  - Fostering and disseminating innovative sustainable development learning cases for teenager education.
- Challenges still exist between internationalization and localization in Chinese ESD content.

Introduction

Education for sustainable development (ESD) originated from the international sustainable development movement in the 1980s. In 1987, the World Commission on Environment and Development (WCED) published a report entitled *Our Common Future*, which put forward the concept of sustainable development for the first time. In 1988, from the perspective of sustainable development, the United Nations Educational, Scientific and Cultural Organization (UNESCO) integrated "environmental education" and "development education" to form "education for sustainable development (ESD)", which has become a common concern for the international community ever since. Such commitments to ESD have promoted the dissemination and application of the ESD concept.

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China's ESD has evolved from environmental education (also see Chapter 7.2 in this volume). After decades of localization, ESD now involves extensive practice in multiple fields, specialties, and disciplines, such as politics, economics, environment, education, science, and culture and covers the entire education system from preschool education to adult education, including formal and non-formal education. The development of ESD in China is closely correlated with the international consensus, and China's national education policy reflects this. ESD can be understood as injecting sustainable development as content into education and also be interpreted that education is a means to achieve the goal of sustainable development (Tao, 2015).

The development of education for sustainable development in China

In 1990, environmental protection became a basic national policy in China, and environmental protection education was gradually accepted by universities, middle schools, and primary schools. The United Nations Conference on Environment and Development (UNCED) adopted *Agenda 21* in 1992, which pointed out that education plays an important role in promoting sustainable development and improving people's ability to solve environmental and development issues (UNCED, 1992). In 1994, China published *China's Agenda 21 – A White Paper on China's Population, Environment, and Development in the 21st Century*. The sixth chapter of the document proposed the idea that sustainable development should be incorporated into the whole educational process from elementary to higher education. From environmental education to sustainable development education, ESD, as an imported international educational construct, has experienced three stages of growth in China over two decades.

Start-up stage (1998–2010)

In 1998, entrusted by the Chinese National Commission for UNESCO (NatCom), the Beijing Academy of Educational Sciences set up the "Chinese National Working Committee on Education for Sustainable Development", which was in charge of the implementation of the UNESCO Project on Education for Environment Population and Sustainable Development (EPD Education Project for short). This began a concrete practice to integrate ESD with China's national economic market conditions and promote its localization (Chinese NatCom is a department of the Ministry of Education of China). In 1999, the ESD national working committee formulated the "Guide for China ESD Program" to instruct all regions and experimental schools to conduct ESD program experiments. In the same year, a China National ESD Workshop was held to train ESD teachers. Principals and teacher representatives from ESD experimental schools were trained in the basic theory and operation methods of ESD via thematic reports, special reports, principals' reports, and displays of teaching results. In 2003, ESD was considered an educational process, based on the sustainable development of the economy, society, and the environment. It includes environmental education, physical and mental health education, and the education of scientific knowledge, thoughts, and relevant skills for sustainable development as basic content, and aims to promote the theoretical and practical innovation of all types of education at all levels. In 2005, the NatCom renamed the China EPD Project the "China ESD Project" and extended it to more provinces and regions. From 1998 to 2005, the project carried out a series of programs in primary and secondary schools, which integrated ESD into subject teaching and also enhanced the awareness and ability of principals, teachers, and students in sustainable development, together with the improved quality of school management.

In 2005, the United Nations launched the *United Nations Decade of Education for Sustainable Development (2005–2014)* (*Decade Plan* for short), which put forward education as the key to sustainable development and provided the values, behaviors, and lifestyles needed for sustainable future development and positive social change. By 2008, more than 1,000 primary and secondary schools in 14 provinces, municipalities, and autonomous regions in China had launched ESD practice. Beijing, Shanghai, Guangdong, Jiangsu, Inner Mongolia, and other regions set up local project working committees and accumulated ESD practice experience with Chinese characteristics. Dongcheng District, Beijing, integrated the ESD idea into curriculum; the Putuo District, Shanghai, built a number of ESD experimental schools with a focus on curricula; and the Guangdong Province promoted the innovative practice of ESD in more than 30 experimental schools (Liu, 2011). At the national level, in the early stages, experts on the Chinese ESD project team focused on incorporating knowledge about the environment, population, and health into school education, and later, according to the requirements of the *Decade Plan*, they expanded the ESD content in schools, integrating diverse topics in the fields of society, culture, economy, and environment into curricula content. The project team also regularly organized various activities such as national workshops and international forums to introduce the latest idea and development trends in ESD and presented the innovation achievements of ESD in China.

Nationwide development (2010–2019)

After 2010, ESD in China entered a critical period, shifting its focus from quantity and scale to quality and efficiency. The most significant milestone was that ESD was written into China's *Outline of National Medium- and Long-Term Education Reform and Development Planning (2010–2020)* (*Outline of Education Planning* for short). In 2010, ESD had been formally incorporated into public education policy at the national level and had become an important guiding concept for educational reform and development in China. In 2011, the 5th International Forum on Education for Sustainable Development was held in Beijing with the theme of 'Philosophical Thinking and Educational Reform for Sustainable Development'. The Ministry of Education of China pointed out that to further implement the *Decade Plan* and the *Outline of Education Planning*, efforts should be made to deepen theoretical research and practical innovation in ESD from the perspective of ideology and morality, knowledge architecture, ability training, and behavior formation (Shi, 2011). In 2012, the expert group of the Chinese National Working Committee of Education for Sustainable Development was expanded to the expert group of "ecological civilization and ESD research", which developed ecological civilization and ESD in more than 1,000 primary and secondary schools in terms of curriculum, teaching and learning, students' extracurricular practice, and campus construction.

A series of international documents have played an important role in promoting the development of global ESD. In 2014, the *Global Action Programme on Education for Sustainable Development (2015–2019)*, formulated by the UNESCO World Conference on Education for Sustainable Development, put forward that ESD should be fully integrated into education policies and sustainable development policies, and it was also proposed to mainstream ESD. In 2015, the 70th Session of the United Nations General Assembly officially adopted the *Transforming Our World: The 2030 Agenda for Sustainable Development*, proposing that the goal of sustainable development in education is "to ensure inclusive and fair quality education so that all people can enjoy lifelong learning opportunities". In the same year, UNESCO issued the *Education 2030 Framework for Action*, reiterating the goals of the *2030 Agenda for Sustainable Development* and, for the first time, defining the indicative strategy for implementing ESD, which is to "develop policies and programmes to promote ESD and bring it into the mainstream of formal, non-formal and informal education through system-wide interventions, teacher training, curricular reform and pedagogical support" (UNESCO, 2016).

During this period, China actively set up international organizations to promote the development of ESD. In 2015, the Asia-Pacific Youth Center on Learning for Sustainability was established, aiming to promote ESD in the Asia-Pacific region. In the same year, the 38th Session of the General Conference of UNESCO adopted the decision to set up the International Center for Creativity and Sustainable Development (ICCSD) in Beijing, China. As the world's first UNESCO Category II center with the theme of creativity and sustainable development, ICCSD conducts research, training, communication, dissemination, and demonstration. In 2016, *China's Position Paper on the Implementation of the 2030 Agenda for Sustainable Development* highlighted that "To guarantee the right to education for all, including vulnerable groups, improve the quality of education, and ensure that everyone has the opportunity for lifelong learning" as general principles to promote the implementation of China's agenda for sustainable development (Ministry of Foreign Affairs, 2016). In 2016, the 7th Beijing International Forum on Education for Sustainable Development reiterated the important guiding value of ESD to the world and China and adopted the *Beijing Declaration* titled "ESD Towards the Mainstream of World Education", which defined five implementation strategies to be adopted in the future, namely, carrying out research on the theory and policy of ESD localization, carrying out special training on ESD for educators and trainers, building a national experimental zone for ESD teaching, building sustainable development schools, and fostering and disseminating innovative sustainable development learning cases for teenagers. In 2018, the Institute of Lifelong Learning and Education for Sustainable Development was established in Beijing to promote research, innovation, and practice of ESD.

During the ten years since ESD was incorporated into the national education planning outline, the local practice of ESD has been popularized across the country and China increasingly has participated in international ESD experience sharing. According to UNESCO's *Global Action Programme on Education for Sustainable Development: Preliminary Monitoring Report Focusing on the GAP Key Partners*, China has a large number of teachers and students benefiting from ESD and has begun to actively explore distance learning of ESD (UNESCO, 2018.

Towards localization (2019–present)

China's ESD development came from and keeps pace with international actions. In 2019, the 40th Session of the General Conference of UNESCO adopted *Education 2030*, which defined the guidelines for global ESD and stressed that education directly contributes to the achievement of the Sustainable Development Goal 4 (SDG 4) on quality and inclusive education, as well as all other Sustainable Development Goals (UNESCO, 2018).

Moreover, its program of action emphasized the role of education in promoting the achievement of the sustainable development goals, with the purpose of reviewing the basic purpose and values of education while adjusting and strengthening the direction of education and learning at all stages to promote sustainable development. In 2021, the UNESCO World Conference on Education for Sustainable Development adopted the *Berlin Declaration on Education for Sustainable Development* (*Berlin Declaration*). The *Berlin Declaration* stated that everyone should be provided with the knowledge, skills, values, and attitudes to become change agents for sustainable development in the future and ESD should be integrated into all types and all levels of education and training, so that all individuals are provided with lifelong and life-wide learning opportunities for sustainable development (UNSECO, German Commission for UNSECO, 2021). It also reemphasized that ESD will lay a foundation for progress in sustainable development.

China also takes ESD as part of the strategic theme of its national 2035 Education Modernization Plan. In 2019, according to the requirements of the *Outline of National Medium- and Long-Term Education Reform and Development Planning* and the *Education 13th Five-Year Plan*, 400 experts and principals in China jointly issued an initiative proposing that ESD should be incorporated into the whole process of education as soon as possible and that institutions such as local education administrative departments should actively guide and encourage all types and all levels of schools to vigorously popularize scientific knowledge, laws, and regulations of ecological civilization; develop courses related to ecological civilization; enhance students' awareness of ecological civilization to respect and protect nature; form the idea, knowledge, and ability of sustainable development; and practice a thrifty, green, low-carbon, civilized, and healthy lifestyle (Liu, 2020). China also formulated its ESD for its '2030 Country Initiative', which incorporated ESD into the existing national framework on sustainable development goals (UNESCO, 2021). At present, ESD in China focuses on imparting knowledge to change ideas, values, lifestyles, and behaviors. All types of education at all levels participate in ESD together. ESD develops from school education to informal and non-formal education and gradually becomes the consensus of the whole society. ESD has penetrated lifelong learning, including basic education, higher education, and even civic literacy.

The evolution of China's policy on ESD

China's ESD policy is closely correlated with international policies and has evolved from environmental protection to sustainability and then to 'ecological civilization'. In 1990, environmental protection became a basic national policy in China. The Chinese government put forward that institutions of higher learning should set up majors or courses related to environmental protection in a planned way; primary, secondary, and early childhood education should popularize environmental protection knowledge in combination with relevant teaching content; and all localities and departments should take environmental protection education as important content in the training of students (State Council, 1990). Environmental protection education has become an important part of ESD. After the UNCED, held in 1992, the Chinese government formulated the *China's Agenda 21 – White Paper on China's Population, Environment, and Development in the 21st Century* in 1994, pointing out that the idea of sustainable development should be incorporated into the whole education process from primary to higher education. In 2005, the Chinese government formulated the *Program of Action for Sustainable Development in China in the Early 21st Century*, clearly stating that education can provide strong support for promoting sustainable development and efforts should be made to actively develop all types of education at all levels to raise the awareness of sustainable development at a national level, strengthen the development of human resources and improve the scientific and cultural awareness of the public to participate in sustainable development, add content on sustainable development to basic and higher education textbooks, offer 'science' courses in primary and secondary schools, and build a number of sustainable development demonstration parks (areas) in some colleges and universities (State Council, 2005).

Building a Conservation-Oriented School has been an important practice in the implementation of ESD in China. In 2006, the Ministry of Education put forward a plan to "actively build conservation-oriented schools, and incorporate conservation ideas into organization and management, education and teaching, and campus construction in schools" (Ministry of Education, 2006). In 2010, the Ministry of Education clearly stated in the *Outline of Education Planning* that importance should be attached to ESD, and ESD was officially included in the strategic theme of national education reform and development. It required that all types and all levels of education should serve sustainable development in terms of educational function including: educating students with the values (see also Chapter 2.4 and 9.5 in this volume), scientific knowledge, learning ability, and lifestyle required by sustainable development; cultivate a new generation of citizens with sustainable development literacy; and achieve a balanced, high-quality model of education itself.

In 2016, China released *China's Position Paper on the Implementation of the 2030 Agenda for Sustainable Development* and *China's National Plan on Implementation of the 2030 Agenda for Sustainable Development*, which put forward China's ESD goals, namely to guarantee the right to education for all, including vulnerable groups; improve the quality of education; and ensure that everyone has the opportunity for lifelong learning (Ministry of Foreign Affairs, 2016). In 2017, to accelerate the modernization of education, ESD was written into the *13th Five-Year Plan of National Education Development* according to the *13th Five-Year Plan for National Economic and Social Development* and the *Outline of Education Planning*. In 2019, *China's Education Modernization 2035* plan and the *Implementation Plan for Accelerating Education Modernization (2018–2022)*, were seen as important initiatives through which China could help achieve the global ESD goals. *China's Education Modernization 2035* is the first medium- to long-term strategic plan with the theme of education modernization in China. It refined the *Education 2030 Framework for Action* plan and clearly set the main development goal by 2035 of establishing a modern education system for lifelong learning for all, with universal quality preschool education, balanced compulsory education, overall popularization of high school education, enhanced vocational education, more competitive higher education, and special schooling for the disabled so as to develop a new form of educational governance involving the whole of society. A history of Chinas ESD development discourse in provided in Table 9.8.1.

In 2021, China released the *Outline of the 14th Five-Year Plan*, which emphasized ecological civilization and sustainable development. The fact that ecological civilization was added to China's ESD plans represents a new path developed by combining domestic policies with international ideas. ESD will contribute to the construction of ecological civilization and the realization of sustainable development in China, and it is also an important driving force for the modernization of education in China.

Table 9.8.1 International and China's ESD Documents

	International policy	*China's policy*
1	World Commission on Environment and Development (1987): Brundtland Report: *Our Common Future. 1987.*	*Decision of the State Council on Further Strengthening Environment Protection* (1990)
2	UNCED *Agenda 2l* (Earth Summit Brazil 1992)	*China's Agenda 21 – White Paper on China's Population, Environment, and Development in the 21st Century* (Ministry of Ecology and Environment 1994)
3	UNESCO *International Implementation Scheme for the United Nations Decade of Education for Sustainable Development* (2005)	*Program of Action for Sustainable Development in China in the Early 21st Century* (2005)
4	UNESCO, The First World Conference on Education for Sustainable Development (ESD), *Bonn Declaration* (2009) https://unesdoc.unesco.org/ark:/48223/pf0000188799	*Outline of National Medium- and Long-Term Education Reform and Development Planning (2010–2020)* (2010) (UNESCO Planipolis 2010) https://planipolis.iiep.unesco.org/2010/outline-chinas-national-plan-medium-and-long-term-education-reform-and-development-2010-2020
5	UNESCO *Global Action Program on Education for Sustainable Development* (2014) https://unesdoc.unesco.org/ark:/48223/pf0000230514	
6	World Education Forum *Education 2030 Framework for Action* (2015) https://uis.unesco.org/sites/default/files/documents/education-2030-incheon-framework-for-action-implementation-of-sdg4-2016-en_2.pdf	*China's Position Paper on the Implementation of the 2030 Agenda for Sustainable Development* and *China's National Plan on Implementation of the 2030 Agenda for Sustainable Development* (2016) http://www.chinadaily.com.cn/specials/China'sNationalPlanonimplementationofagenda(EN).pdf *13th Five-Year Plan of National Education Development* (2017) *China's Education Modernization 2035* (2019)
6	UNESCO World Conference on Education for Sustainable Development *Berlin Declaration on Education for Sustainable Development* (2021) https://unesdoc.unesco.org/ark:/48223/pf0000381228	*Outline of the 14th Five-Year Plan* (2021) https://digichina.stanford.edu/work/translation-14th-five-year-plan-for-national-informatization-dec-2021/#:~:text=Informatization%20in%20the%20%E2%80%9C14th%20Five,in%20areas%20such%20as%20deepening

ESD practices in China

For more than 20 years, by introducing international ideas and formulating local education policies, China has localized its ESD in various ways, mainly including three types of practice, local education planning, demonstration schools building, and teacher training.

Local education planning

ESD is one of the important educational issues in all provinces and cities in China. In 2007, Beijing took the lead in integrating ESD into local education planning, instructed by the *Guiding Outline of Education for Sustainable Development for Primary and Secondary Schools in Beijing (for Trial Implementation)* (Beijing Municipal Education Commission, 2017). Since then, ESD has gradually become an important part of China's public education policy, and all provinces and cities have set up regional ESD goals for local development.

In 2010, China announced the *Outline of National Medium- and Long-Term Education Reform and Development Planning (2010–2020)*, which officially defined ESD as a key content of the planning's strategic theme. The outline of Beijing's medium- and long-term education reform and development planning clearly proposed to carry out ESD experiments and build ESD demonstration areas. The *Community Action Plan* formulated in Shanghai in 2020 placed emphasis on four priority areas of action, namely, community health, local environment, community building, and professional competency, aiming to improve citizens' awareness, knowledge, and skills of sustainable development to enhance the role and strength of community education in solving problems of sustainable development in urban areas. There are two main ways to promote ESD. One is to optimize the existing community education practice, and the other is to develop new ESD projects from the perspective of sustainable development (UNESCO Institute for Lifelong Learning, 2021). The formulation and implementation of Shanghai's local ESD plan proved that it is crucial to mobilize and involve all parties concerned, leverage the resources of stakeholders, pay attention to communication and cooperation, and conduct monitoring and evaluation. Shanghai has also developed a monitoring tool for ESD. At present, more than 20 regions in China have integrated ESD into their lifelong education development plans.

Experimental and sample school development

Developing and building experimental and sample schools is an important strategy to promote ESD in China. The Chinese National Working Committee of Education for Sustainable Development formulates and advocates the teaching principle of "subject inquiry, comprehensive penetration, cooperative activities, and knowledge advancing together with practice" (referred to as the *16-Character Principle*) in experimental schools. 'Experimental schools' extensively conducted experiments of the teaching mode of "subject inquiry-comprehensive penetration". More than 100 on-site seminars on the construction of new teaching modes were held, and more than 1,000 excellent cases of subject teaching were selected (Shi, 2010). According to the requirements of ESD, many experimental schools have effectively carried out values education with 'Four Respects' as the core for teenagers, namely, respect for present and future generations, respect for differences and diversity, respect for environment, and respect for resources (Chen, 2009). More than 1,000 primary and secondary schools, kindergartens, and other types of schools have participated in ESD projects.

The main way to build a demonstration school was as follows: the expert group and local education committee jointly organize general ESD training; the local education commission determines the list of experimental schools based on voluntary registration and recommendation by leaders; the expert group guides the candidate schools to formulate and implement schemes of jointly building characteristic schools; and the expert group regularly visits the experimental schools to diagnose and evaluate the implementation process through attending classes, evaluating classes, discussing with principals and teachers, talking with students, and puts forward recommendations for improvement. The expert group, the local education commission, and the experimental school jointly hold an on-site meeting on the construction of the school with ESD characteristics, and phased achievements are widely publicized in local areas. In this process, the project research team developed an evaluation indicator system of ESD in schools to control experimental quality; self-evaluation and other evaluations of ESD school quality were conducted for six aspects, namely, school management, support, guarantee, curriculum, teaching, special education activities, and campus environment construction. The evaluation indicator system has become an effective means to diagnose and monitor the quality of ESD (Wang, 2015).

Improving ESD Teaching and Practice in China

The main measures to boost ESD teaching and practice in China included ESD teacher training, curriculum construction with sustainable development values at the core, ESD projects and experiments, and ESD practice in rural areas (see also Chapter 5.4 in this volume).

<u>Emphasizing ESD education in the training of teachers was also considered important.</u> Since 1999, national ESD training has been conducted in the form of national ESD workshops and international forums every other year. After learning the theory and experience from the national training meetings, representatives from provinces and cities carry out local training to help local principals and teachers understand the latest information on ESD and improve their ESD teaching abilities over time. Besides regular national training courses, special exhibition activities and seminars are held in the ESD demonstration schools, including observing and evaluating classroom teaching, watching the demonstration of students' scientific and technological innovation achievements, and community workers and parents introducing the impact of ESD.

<u>Attaching importance to curriculum construction.</u> Starting with curriculum development and teaching, a three-level curriculum system of nation-, local-, and school-based curriculum has been established to implement ESD. The teaching process focuses on stimulating students' initiative and innovating their learning methods. After ESD was included in the national education development program, the Educational Science Publishing House launched a series of books on ESD. ESD courses with local characteristics have been developed across the country, such as the local textbooks *Environment and Education for Sustainable Development* for primary and secondary schools in Beijing and *The Future of Sustainable Development – Hani Terrace and Teenagers* in Honghe Hani and Yi Autonomous Prefecture in Yunnan.

<u>Improving teaching standards</u>. Teaching projects are implemented in each educational stage to strengthen teaching and students' learning quality. Take Tongji University in Shanghai as an example. UNEP-Tongji Institute of Environment for Sustainable Development (IESD), jointly established by United Nations Environment Programme (UNEP) and Tongji University, launched international master's and doctoral programs. In the past 20 years, it has trained 595 students (from 96 countries and regions) and a number of professionals in

sustainable development (UNEP, Tongji University News Centre, 2022). IESD has become an important base for education, scientific research, training, and foreign exchange on environment and sustainable development.

Focusing on ESD in rural areas. The China Zigen Rural Education and Development Association is a good example. Over the past 30 years, it has carried out various public welfare projects in the fields of basic education, medical and health care, environmental protection, and local culture inheritance in rural areas of China. It developed training courses such as *Creating a Sustainable Village, Teacher Training* and *Rural Revitalization, Sustainable Development Talent Training,* and carried out many training activities to spread the idea of sustainable development and promote ESD, with special attention paid to opportunities for rural girls and women to participate in the development. The association has gathered rich experience in ESD.

A review of ESD in China

The development of ESD in China is a process in which international consensus on sustainable development takes root in China and promotes both innovation and the practice of localized education. Due to its abundant and innovative practice, UNESCO believes that China has set a good example in the conceptualization, localization, and realization of the sustainable development goals. The first *Action Report of Higher Education in China on SDGs*, released by Fudan University in 2021, reviewed the progress and achievements that Chinese higher education institutions had made in the implementation of the UN 2030 Agenda for Sustainable Development from 2016 to 2020. However, ESD has never been an important component in *the curriculum* of higher education.

Over the past 20 years, China has developed an ESD theory that adapts to local conditions and guides its educational practice. According to the publications of the national ESD expert group, including the *Education for Sustainable Development: For the Better Promotion of Education Quality*, *Education for Sustainable Development, The Way Towards Quality Education*, and the *Roadmap of Education for Sustainable Development in China*, ESD is an education program that emerged in the era of sustainable development that aims to help the student to develop the scientific knowledge, learning ability, values, and lifestyle needed for sustainable development and then facilitate the sustainable development of society, the economy, environment, and culture (Shi, 2016). The values of “Four Respects” have been written into the *Guidance for Education for Sustainable Development in China*, which provides valuable support for promoting ESD practice.

The idea of sustainable development in China’s traditional culture has been integrated into ESD practice, which also enriched the local focus of ESD. For example, it is advocated to encourage “Harmony Between Mankind and Nature” and look at the world with a sustainable development consciousness.

ESD practice in China has promoted curriculum construction and teaching innovation. Special topics such as resources and energy, biodiversity, environmental pollution prevention, climate change, and disaster prevention and treatment have penetrated into the curriculum, which enriches ESD teaching content. China pays special attention to the practice of ESD experimental schools, especially their curriculum, teaching and learning innovation, investigation, thematic training, quality diagnosis, and experience demonstration and has gathered the successful experiences from excellent case studies of 200 principals and teachers, 100 ESD demonstration schools, and 5 ESD demonstration areas (Zhang, 2018).

ESD practice has also promoted the green and low-carbon transition of the campus environment. In the teaching process, the school continuously strengthens water-saving, electricity-saving, and food-saving education, so as to guide students to practice efficiency and oppose waste, establish the consciousness of respecting nature, conserve nature, and protect nature, while enhancing the practices of thrifty, green, and low-carbon healthy lifestyles. These efforts have achieved good results in encouraging young people to participate in the construction of a green society and lead, for example, in social green fashion. ESD has engaged all players in education. It has gained more support from the government, schools, families, society, enterprises, and other stakeholders. More than ten sustainable development project platforms have been set up for young people across the country, including practice parks, activity bases, training centers, and research projects (Wang and Gendong, 2020).

The development of ESD in China has improved the awareness of teachers and students of sustainable development, especially cultivating their values for sustainable development and the ability to promote sustainable development. As far as teachers are concerned, the idea of sustainable development has been integrated into pre-service and in-service teacher training programs, which develops not only their general sustainable development knowledge, skills, attitudes, values, motivation, and commitment but also their teaching abilities in sustainable development, so they can help students develop sustainable development thinking through a series of innovative teaching methods and learning practices (Yang, 2019) (see also Chapter 5.4 in this volume).

Through education for sustainability, students have made progress in terms of knowledge, skills, feelings, and values towards sustainable development. They formed an ecological civilization consciousness that respects and protects nature and improves their sustainable development literacy and comprehension. According to the experience of some provinces and cities such as Beijing, the students in experimental schools who have received long-term education on ecological civilization and sustainable development are healthier physically and mentally (Shi, 2022).

China's ESD focus has been aided by international examples as both environmental education and ESD were historically foreign concepts. However, the construct of ESD also has its counterpart in Chinese traditional culture, and the development of ESD in China is closely correlated with the influence of local education policies. Therefore, the development of ESD in China always has both international and local characteristics. While actively introducing international ideas to train teachers, China has always been an active participant in and contributor to ESD. Especially since the implementation of the *2030 Agenda for Sustainable Development* in 2015, China has attached great importance to global cooperation, including hosting international conferences, carrying out cooperative research, and constructing a stable ESD international network. For example, China held international forums in Beijing on ESD and Asia-Pacific expert meetings and attended ESD meetings in Britain, Germany, Sweden, Russia, Canada, the United States, Japan, South Korea, Thailand, Indonesia, and other countries. In recent years, through setting up regional ESD cooperation centers as well as bilateral or multilateral cooperation and exchange platforms, with international cooperation in key areas such as environmental, economic, and social development, China has facilitated the realization of ESD goals, and the importance of building a global community for a shared future.

Conclusion: China's ESD development through internationalization and localization

Internationalization has been a decisive element during China's ESD process. In 2003, ESD was one of the flagship projects in the "Memorandum of Understanding on Cooperation between the Ministry of Education of China and UNESCO", signed by the Ministry of Education of China and UNESCO. Through national workshops and international forums, new ideas and trends in sustainable development and ESD were circulated and ESD innovations were exchanged and displayed. China emphasized the interaction between the development trend of international education and innovation in its domestic education. Over more than 20 years of theoretical exploration and practice, China has learned from research results and experiences and shared textbooks and case studies from the United Nations and its member states, which has enriched its knowledge and practice of ESD but also contributed to the spread of ESD throughout the world. Over decades, China's ESD practice has not only promoted its own sustainable development but has also provided an international case study of education for global sustainable development.

However, China hasn't yet issued any separate systematic ESD planning document at the national level, so ESD is still only a part of the overall education development planning. The incorporation of ESD in a formal national education plan will be very beneficial. If *A Development Plan for Education for Sustainable Development* could be formulated and guided by the principle of lifelong education and ESD integrated into family education, school education, and social education, as well as into all stages of the national education system (from preschool education, primary education, secondary education to higher education), this would promote greater adoption and achievement in ESD practices in China.

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