Teaching and Learning for Change

Education and Sustainability in South Africa

Edited by Ingrid Schudel, Zintle Songqwaru,
Sirkka Tshiningayamwe and Heila Lotz-Sisitka

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AFRICAN MINDS

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INTRODUCTION

CHAPTER 1

Engaging Education for Sustainable Development as Quality Education in the Fundisa for Change Programme

Ingrid Schudel, Heila Lotz-Sisitka, Zintle Songqwaru and Sirkka Tshiningayamwe

Introduction

Since the Industrial Revolution began in the late 18th century, development has provided humankind with numerous benefits, such as modern medicine, housing, transport and communication systems. However, progress and the contemporary model of development has also brought its problems, as non-renewable resources have been over-extracted, and large volumes of waste created, resulting in pollution that has impacted on the health of people and the environment. Most people are now aware that human actions are changing the climate in unpredictable ways. Massive over-consumption of resources and continued environmental degradation are undermining the natural systems we depend on, impacting most severely on the poor and marginalised people in our society. Societies around the world must adapt and change their practices for a low-carbon, more sustainable future.

This book shares research into how curriculum policy, teacher education programmes and teachers themselves are responding to these challenges through the integration of environment and sustainability learning or Education for Sustainable Development (ESD) throughout the South African schooling system. The children and youth who are reached through the current schooling system are those who will be directly affected by the chronic environmental damage that needs to be halted within this generation. These youngsters are going to have to be the agents of change within their own lives and contexts. But for this they have to have a real and deep understanding of environmental sustainability, how they can adapt to change, and how they can mitigate against ecological degradation and social oppressions and exclusions.

An important aim of environment and sustainability learning is that it can give children hope that together we can build a better world. Children, teachers, teacher educators and researchers can use their imaginations and problem-solving skills to creatively develop diverse solutions to our problems, and change how we live for the better. This book should help researchers and practitioners to understand environment and sustainability issues better in order to help teacher educators, teachers, and the young people they nurture to make sense of their changing world. Through this we hope to cultivate a sense of hope, as together, all of humanity will need to explore how to live more sustainably on the Earth, ourselves included.

The book draws on a series of small-scale empirical case studies from South Africa that are nested within a coherent national teacher professional development programme. The four positioning papers leading each of the four sections in the book provide contextualisation and breadth to the case studies. The volume, overall, has the potential to resonate with and inform other national curriculum and teacher education programmes in southern Africa. The issues represented in this book are applicable across the southern African region, and resonate with wider studies in this area in southern Africa (see Lotz-Sisitka et al. 2017) as well as international educational interests in education quality in a complex and changing world.

Links between development, sustainability and education

In this introductory chapter, we position ESD in the broader educational context by rethinking education in terms of its development intentions. At the same time, we look critically at the evolution of development thinking, identifying well-being, equality and restoration of both social and planetary balances as core development considerations. By doing this we are able to raise the question: What constitutes good education? and to consider education quality in the light of a critical perspective on developmental orientations and histories.

New perspectives on education and development

The role of education in society is often at the heart of contestations of what constitutes 'good education'. A key role of education is that it is seen as central to global conceptions of human development and, for example, has been an indicator in gauging levels of human development since the inception of the United Nations Human Development Report series in 1990 (United Nations Development Programme 1990). Perceptions in these human development reports highlight that development is not just an end goal, but a process, an ongoing journey: 'Its centre of gravity has always been about more than just meeting basic needs. It is about empowering people to identify and pursue their own paths for a meaningful life, one anchored in expanding freedoms' (Conceição 2020: 6).

The indicators in the human development reports are seen as intricately interwoven and thus it is not surprising that education and quality of life are often discussed together across many fields. In 2015 the United Nations Educational Scientific and Cultural Organisation (Unesco)'s call for 'rethinking education' admitted that quality of life is not easy to frame, thus making what should be learned equally difficult to package. That is especially true in view of 'a diversity of contexts, concepts of well-being and knowledge ecosystems' (Unesco 2015: 11). What the document was clear about, however, was that 'dominant utilitarian conceptions of education should accede to the expression of other ways of understanding human well-being, and thus, to a focus on the relevance of education as a common good' (Unesco 2015: 32). The authors of this document describe 'common good' as a collective social endeavour and elaborate that a search for the common good is a participatory and inclusive process that acknowledges the above-mentioned diversities in context as well as ways of understanding and engaging in the world.

In reflecting on the evolution of the United Nations Human Development Report series, Conceição, in the most recent 2020 report, explained how, as far back as the first 1990 report, human flourishing was set as the ultimate end of development. He explained how the report asserted that 'development is not about the accumulation of material or natural resources. It is about enlarging people's ability to be and do what they have reason to value, and expanding wellbeing freedoms' (Conceição 2020: 22). The 2020 report also acknowledges past human development reports which have highlighted inequalities in human social development. These include socio-economic and gender inequality – within and across nations – as well as concerns regarding multi-dimensional poverty.

Concern for well-being and a focus on inequality have remained key to the human development report series, but Conceição warns that previous reports have been limited in placing 'people as the ultimate end of development' at the expense of consideration for planetary boundaries, and argues that 'the apposition of people and nature needs to be re-examined' (Conceição 2020: 22). Thus, for the first time, the United Nations Human Development Report engaged, in its 2020 publication, with the social-ecological challenges facing the planet. This statement from the report strongly captures this interest:

> For the first time in our history the most serious and immediate, even existential, risks are human made and unfolding at planetary scale. The [report] argues that this new reality calls for reimagining the human development journey and leveraging the human development approach to support transformational social changes to ease pressures on the planet. (Conceição 2020: 22)

The 2020 report highlights how key biogeochemical cycles such as the carbon, nitrogen and phosphorous cycles, are being dramatically altered, leading to concerns about planetary imbalances that are harmful to people and to all forms of life. Further imbalances are created as development demands outweigh the planetary boundaries (Rockström 2009). Planetary and social imbalances interact and often reinforce each other. The report argues that during times of crisis such as we are now experiencing with the COVID pandemic, those in power can leverage resources to their own advantage in a way that 'perpetuates the pressures on the planet that further drive planetary imbalances' (Conceição 2020: 25). The leveraging of crisis situations to further political and economic power is captured in Klein's concept of 'shock doctrine' (Klein 2014). Besides these oppressive relations between people and planet, there are also social imbalances that 'feed inequalities in human development – which ultimately are gaps in empowerment – constraining the space for deliberative reasoning and collective action' (Conceição 2020: 24). This point highlights the important role of education in supporting deliberation and agency for a new and different world, rather than simply reproducing the knowledge and systems of business-as-usual.

The call for alternative development models is not something new to the world of environment and development, but this explicit recognition of planetary limits is new in the United Nations Human Development Reports. This draws renewed attention to arguments and debates around the risks produced via the modernist development trajectory, first raised by environment and development movements in the 1970s (Meadows et al. 1972), and carried forward in regular world summits on environment, sustainability and development, starting with the Rio Earth Summit in 1992 and followed by more recent global summits focusing on the Sustainable Development Goals in 2015. These latter goals highlight the importance of education both *as* a process of sustainable development and *in* enabling sustainable development. Goal 4 focuses on quality education, with Target 4.7 requiring governments around the world to,

> 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. (United Nations 2015: 21)

This goal positions sustainable development as integral to quality education deliberations, which has substantive implications for current approaches to education.

The call for more sustainable development approaches requires more inclusive, less damaging economic models which need to be implemented along with environmental care and social justice principles and approaches. For example, it has been argued that 'decoupling economic growth from emissions and material use is key to easing pressures on the planet while improving living standards'. Some argue that decoupling requires 'green' economies to shift 'towards more resource-efficient and less emission-intensive production and consumption' (Conceição 2020: 25).

Such decoupling is a worthwhile alternative to pursue, but more radical critiques from economists are asking whether 'relative decoupling' (when economic growth increases at a greater rate relative to resource use and carbon emissions) is viable to achieve significant change. Jackson argues that,

> resource efficiency, renewable energy and reductions in material throughput all have a vital role to play in ensuring the sustainability of economic activity. But … it is entirely fanciful to suppose that 'deep' emission and resource cuts can be achieved without confronting the structure of market economies. (2009: 57)

Jackson highlights how a debt-driven materialistic macro-economy, a social logic and material profligacy that pushes novelty seeking and consumerism at the expense of psychological and ecological health, creates a system of an 'iron cage of consumerism … in which no one is free' (Jackson 2009: 9).

These calls for alternative ways for humans and human systems to relate to the biophysical world on which they depend are not new to the field of education. International declarations on Environmental Education and/or Education for Sustainable Development have emerged regularly since the first meeting in Tbilisi in 1977 (followed by Moscow, Thessaloniki, Ahmedabad, Bonn and Aichi-Nagoya) and have all made this call. To amplify this movement, and as part of the Johannesburg World Summit on Sustainable Development in 2002, a UN Decade of Education for Sustainable Development (UNDESD) was declared and implemented by Unesco from 2005–2014. The UNDESD was followed by the Unesco Roadmap for Implementing the Global Action Programme on Education for Sustainable Development (Unesco 2014), and by Unesco's (2020) most recent roadmap for ESD that strengthens the focus and relationship between education and the sustainable development goals in an ESD Agenda 2030.

In these international environmental education and ESD declarations and roadmaps, the close relationship between a critical development agenda and education continue to evolve and deepen. For example, the most recent ESD 2030 roadmap argues for the importance of critical thinking and sustainability values, given 'the illusion that technologies can resolve the majority of sustainability problems', and argues that 'ESD should encourage learners to explore alternative values to those of consumer societies' as well as understand 'deep structural causes of unsustainable development … in the context of extreme poverty and vulnerable situations' (Unesco 2020: 18).

These calls for different social-ecological models also require us to revisit transformative texts in education which provide insight not only into 'what' but also 'how' we can change. ESD needs more than simply describing limitations and planetary boundaries. This is because 'a focus on thresholds can lead to fatalism, unnecessary precaution and even perverse incentives that could contribute to their transgression' (Conceição 2020: 51). In its new ESD 2030 documentation, Unesco (2020) notes that ESD 'achieves its purpose by transforming society', and states that educational practices urgently need to shift towards supporting learners in all walks of life and sectors to 'undertake transformative actions for sustainability to shape a different future'. This indicates a clear commitment to move beyond mere problem description in education, towards active learning and transformative learning and pedagogy. This entails a fundamental shift in the purpose and direction of education.

As the world emerges from the shock of the COVID-19 pandemic that has rocked societies around the world, it is clear that there is need for recovery in equitable ways, that involve building forward/better/together, rather than simply a return to normal 'as if going back to normal is desirable or even possible' (Conceição 2020: 4).

ESD supports transformative approaches to education that bring the need to address environmental challenges into focus, while also 'revisiting the complex mix of social and economic issues that are intertwined with the cause and impact of these problems' (Unesco 2020: 6). In a southern African context, this requires explicit engagement with social and environmental injustices, and entails a particular approach to education quality that embraces the need for societal change. Lotz-Sisitka and Lupele draw on Tilbury's description of ESD to suggest the need for a dialectical relationship between tradition and innovation in learning processes. They elaborate that 'such a form of education not only involves acculturation into existing sociocultural heritages and histories but also requires a challenging and changing of these cultures, heritages and histories in the face of new challenges outlined above' (Lotz-Sisitka & Lupele 2017: 7).

One of the primary interests of this book is to provide perspectives on education which are closely aligned with these transformative intents and associated new challenges for education systems worldwide. The book introduces the reader to ESD processes where 'reflexive critical deliberation opens the way to contemplating reimagined future possibilities that are outside the risk-producing normative practices of the day' (O'Donoghue 2017: 27). The first section of the book aligns with this perspective on ESD by highlighting the changing, socio-culturally embedded, complex and contested nature of environment and sustainability knowledge. The second and third sections explore process models and alternative assessment models for supporting active, critical and applied learning in classrooms. The fourth section of the book envisages teacher professional development in which the teacher is seen not just as a deliverer of curriculum content, but as a lifelong learner who needs to be open to and prepared for social and educational change.

ESD and new conceptions of education quality

The role of ESD in supporting quality education has been explicitly highlighted in international policy commitments as introduced above. For example, Unesco's vision of 'Education 2030' highlights the role that ESD should play in quality education, involving foundational skills; high-level cognitive, personal and social skills; and local and global contextually embedded reflexivity and responsiveness. This is evident from their description of education quality that,

> fosters creativity and knowledge, and ensures the acquisition of the foundational skills of literacy and numeracy as well as analytical,

> problem-solving and other high-level cognitive, interpersonal and social skills. It also develops the skills, values and attitudes that enable citizens to lead healthy and fulfilled lives, make informed decisions, and respond to local and global challenges. (Unesco 2016: 2)

Lotz-Sisitka (2012) provides a critical framing of education quality which is useful for guiding a transformative orientation to education. She proposes 'learning as connection' (to society and social-ecological context) as an important aspect of education quality. Learning as connection is envisaged as including and doing justice to a number of education quality discourses that shape learning orientations and, ultimately, the outcomes of education:

- *Learning as mastery:* an efficiency discourse where mastery, efficiency and learner achievement and performance are measured against national and international standards.
- *Learning as participation:* an inclusivity/participatory discourse that highlights demographic aspects of inclusivity such as access for all socio-economic groups, all genders and abilities, as well as stressing the importance of including, hearing and engaging all voices in pedagogical processes.
- *Learning as connection:* a socio-cultural discourse (drawing on the work of Vygotsky and Engeström) which emphasises the meaning that emerges at the interface between situated life experiences and existing language and meaning. At this interface, new, more expansive, and potentially transformative meanings become possible as concepts and are expanded via encounters with more abstract concepts in school curricula, as well as a wider range of discourses, experiences and activity.

Lotz-Sisitka's argument, drawing on the EdQual research programme findings (Tikly & Barret 2011), is that, traditionally, education has been dominated by the former two types of educational quality discourse. She argues that in practice, a socio-cultural education quality discourse or a paradigm of 'learning as connection' acts at the interface of the first two examples – drawing them together in a relational way and creating a platform for transformative learning to emerge (see also Lotz-Sisitka & Lupele 2017), while expanding learners' participation and relationality with the world and seeking to master basic expectations of the curriculum or other learning demands. This argument should not be confused with the concept of contextuality as argument in education, but is rather an expansive, transformative learning foundational argument for educational quality (Lotz-Sisitka & Lupele 2017).

A historical perspective on the Fundisa for Change programme

Like many national curricula around the world, South Africa's latest curriculum is rich in environment and sustainability content. Despite the agenda it provides for engaging learners in exploring opportunities for making the world a better place, environmental teaching and learning can be challenging for educators, due mainly to the dominance of existing educational models and approaches.

This book showcases research from the South African national Fundisa for Change programme, which supports the integration of Education for Sustainable Development in teacher professional development and curricula. Fundisa is an isiXhosa word meaning 'teach'. The Fundisa for Change programme thus encourages teachers to 'teach for change'. The book offers an exploration of the ways in which teachers and teacher educators engage with the complexity of environment and sustainability content knowledge, using innovative teaching methods and broadening and deepening assessment practices, thus supporting the call for quality education in service to ecological and social justice.

Before detailing the Fundisa for Change approach to ESD, it is important to touch on the curriculum policy and teacher professional development histories that have shaped the programme. Environmental education was included as a principle in the White Paper on Education and Training and the first post-apartheid curriculum as part of the national curriculum transformation process (Lotz-Sisitka 2004, 2011; Reddy 2011). This gave meaning to the Bill of Rights in the Constitution of the Republic of South Africa (1996), which highlights that every South African citizen has the right to an environment that is not detrimental to his or her health or well-being, along with the need to manage resources sustainably for current and future generations.

Since 1994 South Africa has undergone four major curriculum reforms. The first curriculum change sought to rid the school system of racially offensive curriculum materials inherited from the apartheid era (Maringe 2015). The most ambitious curriculum reform was the introduction of the first post-apartheid curriculum, Curriculum 2005 (C2005), which was built on principles of outcomes-based education. In this curriculum environmental learning was introduced for the first time in South Africa as a 'phase organiser' across subjects (Reddy 2011). Chapter 2 of this book details the further trajectory of environmental content knowledge in the changing South African curricula from this time until the release of the current Curriculum Assessment Policy Statements (CAPS). The Fundisa for Change programme engaged with CAPS design, interpretation and implementation during the period that research for this book was conducted. The CAPS curriculum is still in place today and the purpose of this book is to contribute to its ongoing improvement and development in ways that support quality teaching and learning.

In response to these shifts in the curriculum and wider educational policy, there have been a number of national teacher professional development initiatives in South Africa aimed at supporting teachers to engage with environment and sustainability knowledge and pedagogy in the curriculum. For example, the Learning for Sustainability project was piloted in the Gauteng and Mpumalanga provinces between the years 1997 and 2000 (Janse van Rensburg 2000). Key areas of research in this programme included:

- in-depth exploration and interpretation of concepts and constructs such as 'sustainability';
- context, clarity and pedagogical interpretation of learning theories;
- an understanding of knowledge acquisition and learning;
- an understanding of changes required for teaching and learning in a new education system; and
- supportive professional development models and processes. (Lotz-Sisitka & Olivier 2001: 128)

This was followed by the National Environmental Education Project for General Education and Training (NEEP-GET) in 2000, which also focused on teachers' professional development in environment and sustainability education, with the following achievements:

- improved understandings of environment, and of environment in the curriculum;
- broader exposure to, and knowledge of, available teaching and learning support materials for environmental learning;
- a more in-depth understanding of the contextual nature of environmental issues and contextual approaches to lesson plans; and
- improved understanding of active learning processes. (Lotz-Sisitka 2004: 13)

Despite these achievements, there was still an issue of superficial interpretations of the environmental focus in the learning areas (Lotz-Sisitka 2004). In later research Lotz-Sisitka acknowledged the good practices and positive influence of the above-mentioned projects, but noted that 'very little has been achieved in ensuring that environment and sustainability issues are consistently and coherently integrated into teacher education' (2011: 33).

The Fundisa for Change Teacher Education programme was established in 2011 as a sector-wide programme, with a more systemic approach to strengthening environmental learning through teacher education. The Fundisa for Change approach includes:

- policy and materials review and engagement,
- advocacy,
- expansion of the network of providers and the community of practice engaged with transformative environmental learning through teacher education,
- and strengthening the capacity for professional development of teacher educators and teachers.

Fundisa for Change aims to strengthen and expand the environmental and sustainability content knowledge specified in the subjects offered in the South African national school curriculum (Grades R–12). The programme supports teacher educators in universities and in the environmental sector, as well as Department of Basic Education subject specialists to prepare teachers for engaging with the environment and sustainability knowledge and skills specified in the CAPS.

Education quality perspectives in the Fundisa for Change progamme

Fundisa for Change responds transformatively to education quality challenges

The 2009 review of curriculum change in South Africa commissioned by the Department of Basic Education raised a number of more general quality-related education concerns, which gave impetus to the subsequent development of the CAPS curriculum. Those that were particularly pertinent for the development of Fundisa for Change professional development courses for teachers included:

- a lack of attention to important foundational discipline knowledge and insufficient attention to progression in the different disciplines;
- insufficient time allocated to the teaching of mathematics and languages and inadequate attention given to the role of English as a medium of instruction and to the importance of 'reading to learn';
- the promotion of limited teaching strategies, with over-emphasis on group work and insufficient attention given to appropriate teaching methodologies in line with particular learning areas/subjects;
- and concerns that assessment tasks and criteria need to be appropriate to the subject/learning area, and also to the level at which learning is taking place. (Dada et al. 2009)

In response, the Fundisa for Change programme structured its teacher educator and teacher courses to emphasise the following as three interrelated focus areas for teacher professional development: (1) Content Knowledge (with a focus on environment and sustainability knowledge); (2) Teaching Practice (with a focus on active and transformative learning); and (3) Assessment Practice (to strengthen and transform assessment practice). Figure 1 illustrates this model, showing the Fundisa for Change course design response. The programme took a broader view of knowledge, pedagogy and assessment to include the transformative orientation outlined above, which was named CAPS++ within the programme. CAPS++ interests are those aspects that resonate with, and expand on, the curriculum. That is, aspects that are challenging and that present opportunities for dealing with complexity, criticality, active engagement and higher order thinking; all of which are necessary for the more transformative orientation to education introduced above.

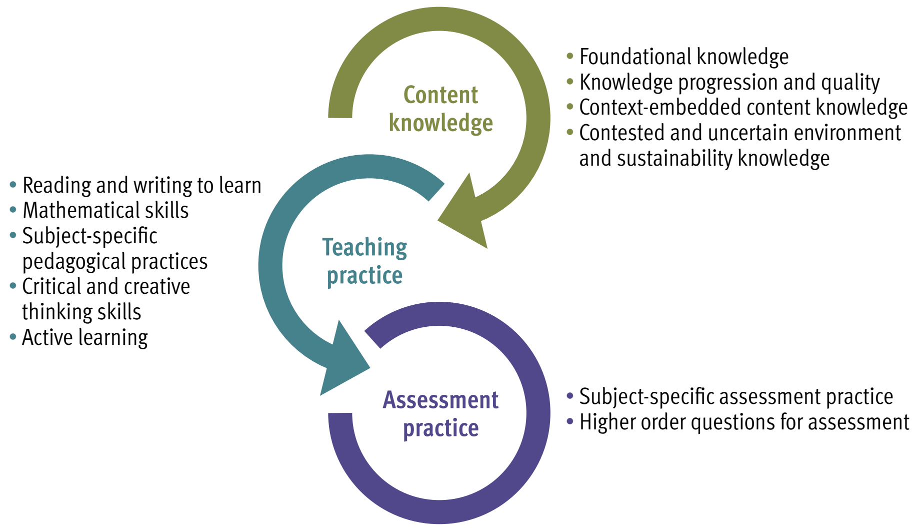

Figure 1. Three foci of the Fundisa for Change teacher and teacher educator professional development courses

The focus on content knowledge responds to the problem of weak foundational subject-discipline knowledge and progression raised in the 2009 curriculum review which recommended,

> a strong, discipline-based approach to school subjects; providing clear, specific, easily understood and measurable curriculum documents linked to textbooks; and providing curriculum statements that specify content at specific year levels, showing conceptual progression over time. (Dada et al. 2009: 38)

This effectiveness discourse has close links to an inclusivity discourse concerning epistemological access for learners already disenfranchised in not gaining access to the 'know that' propositional knowledge, or the 'know how' procedural knowledge of the subject disciplines (Muller 2014), thus affecting their access to powerful knowledge. These knowledge concerns are explored further in Chapter 2 (Schudel and Lotz-Sisitka). Overall, the Fundisa for Change programme has a broader interest in knowledge concerns than current subject-disciplinary boundaries. Lotz-Sisitka and Lupele (2017: 13) argued that 'in trying to create a more sustainable world, we need to have a better look at how ecosystems work and become competent system thinkers'. Such knowledge capital is essential for 'encouraging an active and critical approach to learning, rather than rote and uncritical learning of given truths' (South Africa DBE 2011: 4). Such active and critical approaches to learning are not easily judged within effectiveness approaches to education quality as standardised testing best lends itself to short and measurable responses by learners.

In support of the above, the focus on teaching practice in the Fundisa for Change model (Figure 1) emphasises pedagogies that support critical and creative thinking, active learning, and assessment practices that foreground higher order thinking. These are aligned with the tenets of a 'learning as connection' approach to education quality. Within this perspective of education quality, complexity and uncertainty can be explored and debated in responsive ways, thus enabling 'a more reflexive society in which creativity, flexibility and diversity are released and used as tools to deal with the challenges of "wicked" problems' such as those typically dealt with in environment and sustainability education or ESD (Lotz-Sisitka & Lupele 2017: 13).

This orientation also requires that curriculum be viewed as a contextualising social process (Cornbleth 1990) with locally contextualised knowledge being as important to learners as more abstract decontextualised knowledge. These two types of knowledges come together in quality meaning-making processes. Hence, the focus on context-embedded knowledge in the Fundisa for Change programme (Figure 1; see also Chapter 2 of this publication). The emphasis on contextually relatable knowledge is also influenced by an inclusivity discourse, arguing for expanding the opportunities for meaning making for all learners. This is captured in Daniels' suggestion that teachers and learners need to engage in forms of pedagogy and learning that assist learners to make connections between their everyday knowledge and the scientific knowledge that is on offer in schools in ways that both knowledges develop (2001: 54). Furthermore, Lotz-Sisitka and Lupele argued that learners need to be supported to constantly evaluate what they are learning in relation to the real world and to situations that they have experience of. This is not a conservative form of contextualism, but rather a sophisticated dialectical relationship involving everyday knowledge and school knowledge, or formal learning and experiential learning (Lotz-Sisitka & Lupele 2017: 13).

Meaning making insists on 'a consideration of context-rich but not context-bound explorations of local and global environmental issues and the need for adopting open-ended and futuristic thinking in the context of the dynamism of environmental knowledge' (Schudel 2014: 96). This open-ended approach to knowledge is necessary given the Fundisa for Change acknowledgement that environment and sustainability knowledge is contested and uncertain. This understanding can be traced back to the Learning for Sustainability programme, where Lotz and Olivier argued that such local relevance is important if we are to 'enable learners to understand, respond to, and take action to improve environments and address issues and risks, [which] are likely to be highly contextual due to the complex, diverse and localised nature of many environmental issues and risks' (1998: 95).

Also, in response to weak national assessments in literacy and numeracy in the PIRLS and TIMMS results in South Africa, Figure 1 includes an emphasis in Fundisa for Change on pedagogies that support reading and writing to learn and which engage mathematics and numeracy skills. The former 'requires complex cognitive processes, and a good understanding of the basic conventions of language and how to manipulate, decode and interpret symbols' (Fundisa for Change Programme 2013: 10). The latter involves 'doing calculations and using numbers and mathematical concepts, such as space and time, which are important methods for learning more about the world' (2013: 10). The Fundisa for Change programme works with the understanding that language and mathematics are foundational to the process of meaning making and quality education that includes a focus on environment and sustainability education as required by SDG 4.

Teacher education quality considerations in Fundisa for Change

While the Fundisa for Change programme has worked intimately with the CAPS curriculum and its implementation, another of its objectives has been to strengthen ESD systemically in South Africa through:

- building on earlier policy and advocacy work,
- effective partnerships, and
- improving institutional capacity for teacher professional development.

The importance of effective systems for supporting ESD is highlighted by Unesco which notes the importance of ensuring 'that teachers and educators are empowered, adequately recruited, well-trained, professionally qualified, motivated and supported within well-resourced, efficient and effectively governed systems' (Unesco 2016: 2). Reddy (2011: 25) reminds us that teacher professional development is a complex system 'where varying aspects of the field impact and are in turn impacted on by other aspects and activities in the field by way of complex interactions that are self-limiting and yet open'.

The Fundisa for Change programme develops a holistic perspective on environment and sustainability-orientated learning across the education system. Influenced by the educational fields described in Bernstein's (2000) pedagogic device, the book explores a wide scope of spaces and relations which influence the integration of ESD into the schooling system.

One important relationship is how the scientific and social science research reports (that provide the primary source of knowledge) relate to curriculum, textbooks and the knowledge that teacher educators engage with as they approach the teaching of environment and sustainability topics (Column 1 in Figure 2). This environmental content knowledge (ECK) is recontextualised into curriculum and textbooks, which teachers then apply via their teaching practices with learners (Column 2 in Figure 2).

Through this process, learners come to engage with a range of environment and sustainability related topics or matters of concern (biodiversity loss, climate change, water management, healthy living and more), and through their classroom interactions and activities relate this new knowledge to their prior knowledge and develop their capabilities (knowing and being) for engaging with environment and sustainability concerns in the world (Column 3 in Figure 2).

In this regard, this book elaborates on ECK and how pedagogical content knowledge (PCK) influences the way this is taught and assessed (as depicted in Figure 2). PCK refers to how teachers use their knowledge of teaching to mediate new knowledge, skills and values in classrooms. Many examples of classroom implementation are included in the case studies researched for this book and these illustrate how learners are being supported to come to understand, know, and practice an approach to environmental learning and change which is orientated towards more sustainable and socially just societies.

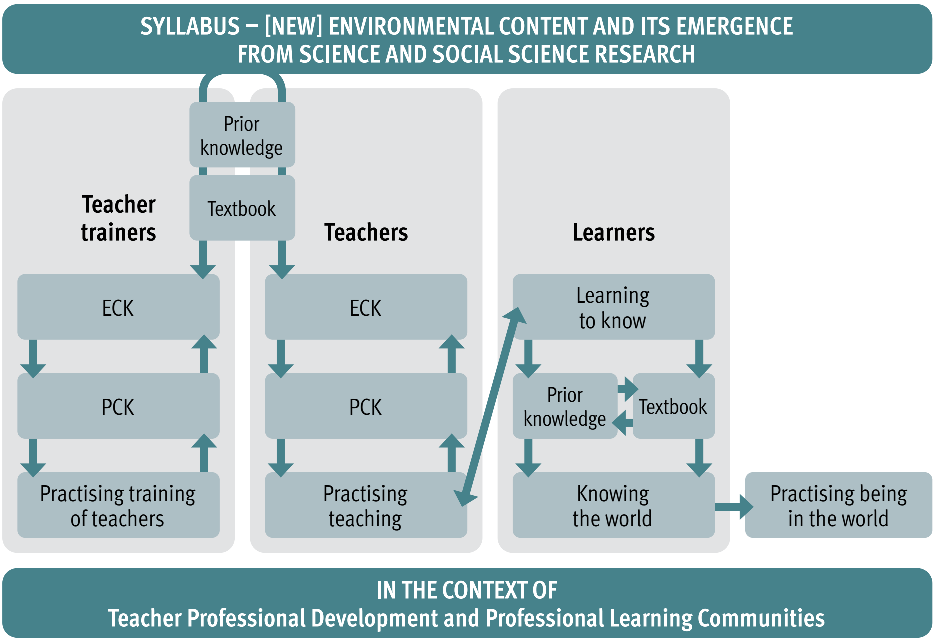

Figure 2. An illustration of the scope of the book in terms of the fields and relations across the education system which influence environment and sustainability-orientated learning

Introducing the Fundisa for Change research in this book

To strengthen the programme objective of facilitating and supporting transformative environment and sustainability-orientated learning through teacher education, Fundisa for Change launched a parallel research programme, funded by the South African National Research Foundation (NRF). The research objective was to gain insight into the processes of transformation required to integrate environment and sustainability-orientated learning into the national system of education. Furthermore, the research programme aimed at exploring the opportunities and challenges of environment and sustainability-orientated learning in the current CAPS, particularly addressing questions of quality education that have driven curriculum change in South Africa in the post-apartheid era as elaborated above.

The three foci of the Fundisa for Change courses introduced in Figure 1, as well as a fourth overarching theme of teacher professional development, became the focal points for the research in the NRF research programme. These four themes have also been used to frame this book, which is a consolidation of research emerging from the programme.

The chapters in this book capture the experience and reflexivity of the editors and authors that have been involved both as practitioners and researchers in the evolution of curriculum innovation and teacher professional development, through Fundisa for Change, over two-and-a-half decades of radical curriculum change in South Africa.

This introductory chapter is followed by four sections. Each section leads with a positioning chapter in which the theme of the section is introduced in relation to contemporary educational and ESD literature. Each positioning chapter is then followed by between two and five empirically researched chapters that pick up particular issues and opportunities identified in the positioning chapters. A broad overview of each section is given below. Further introductions to the individual chapters are given in the four positioning chapters which head each of the four sections.

Section A begins with a positioning chapter exploring the nature of environmental knowledge and its representation as subject-specific content in the school curriculum. This knowledge is described as changing, socio-culturally embedded, complex and contested (Wals & Jickling 2009). Distinctive ways of dealing with this complexity are then discussed. These include understanding the situated nature of knowledge (Haraway 1988); the laminated nature of reality (Bhaskar & Danermark 2006); and the ideological and transformative intent embedded in environment and sustainability knowledge and discourse (Lotz-Sisitka 2016; Price 2016; Schudel 2017). The chapter is followed by case studies that relate to environmental knowledge recontextualisation in the South African schooling system, national curriculum policy, learning support materials, teacher professional programmes and classroom practice. These case studies all deal with different environment and sustainability topics in specific subjects. They include 'water' in the Natural Sciences; 'biodiversity' in the Natural and Life Sciences; 'environmental impact' in the Life Sciences; and 'climate change' across the curriculum.

Section B begins with an exploration of active and critical learning in school classroom practice and emphasises how a focus on dialectical thinking (Bhaskar 1993; Schudel 2017) can expand and deepen the notion of active learning in schools. The positioning chapter is followed by case studies illustrating the power of innovative pedagogies employed in the field of environment and sustainability education or ESD in South Africa, and the elaboration of the notion of pedagogical progression for the mediation of complex concepts and research/field-based strategies in ESD. These chapters explore how active, critical and situated pedagogies interface with environment and sustainability-orientated disciplinary knowledge as it manifests in the CAPS curriculum. Contemporary post-Vygotskian theories of learning (Edwards 2015) are engaged and expanded upon in understanding this interface. Another important theoretical framework used in both this section and the previous one, is practice architecture theory (Kemmis & Heikkinen 2011; Schatzki 2012) which helps authors to theorise and describe the learning interactions – the doings, sayings and relatings of teachers and learners as these emerge from situated learning pedagogical practices. The theory helps authors explain that practices emerge from three practice architecture dimensions, namely the cultural-discursive, the material-economic, and the social-political.

Section C begins with a positioning chapter discussing the importance of developing an appropriate framework for assessing environment and sustainability learning. The chapter begins by reviewing the tendency to move towards competencies in education systems, an influence that is affecting formal education systems across the world, including in southern Africa. The chapter considers the implications of this for assessment practice in environment and sustainability-orientated learning, and focuses on recent developments in assessment theory, especially the work building on assessing higher order thinking as it has evolved out of Bloom's Taxonomy of Learning. The chapter also proposes that there is a need to expand beyond the cognitive framings of assessment and take this work further. It works to provide an adapted version of Fink's (2003) model of assessment of significant learning. It discusses how assessment strategies employed in the field of ESD can support the development of higher order thinking in classroom contexts while also assessing socio-emotional, ethical and applied dimensions of learning, all of which are significant in ESD. This is followed by case studies highlighting the relationship between higher order thinking and the development of curriculum competencies, as well as the role of formative assessment in contributing to quality education in ESD.

Section D begins with an exploration of teacher professional development in ESD in the international and national contexts. This work indicates the importance of giving attention to teacher professional development when introducing new curriculum knowledge, pedagogy and assessment practices, as is proposed by the strong emphasis on integrating ESD into education and training systems worldwide (Unesco 2015, 2020). The chapter shares some of the innovative approaches and models that have been developed in southern Africa and the Fundisa for Change programme to support the integration of ESD into teacher education. This is followed by Fundisa for Change cases describing the development of teacher pedagogical content knowledge, the emergent nature of teaching practice, the importance of professional learning communities in furthering ESD, and the evaluation of teacher professional development in ESD.

Conclusion and taking this research further

In all chapters in this book, the urgency of responding to the environmental crisis is emphasised. There is global agreement that integrating environment and sustainability concerns into education is one of the important longer-term approaches for enabling a more sustainable world order. Hence, as argued via the SDGs, and Target 4.7 of SDG 4 (Unesco, 2030), this needs attention within the schooling system. Building foundational knowledge and encouraging the experience of engaging proactively and positively with environment and sustainability concerns is now recognised as being a critically important dimension of what constitutes quality education. Thus, while the book is relevant to researchers and policymakers in South Africa, it also holds relevance for other scholars and policymakers around the world who have an interest in understanding the dynamics of SDG Target 4.7.

The book argues that we need more knowledgeable teacher educators and teachers to enable quality education with adequate nuance and depth in the schooling system. It outlines the importance of developing and trialing innovative approaches to classroom teaching and assessment that embrace principles of situated, dialectical and social learning for social-ecological change. The book further argues that there is need to give attention to content knowledge, teaching practice and assessment practice, as well as teacher professional development, in enabling ESD to become a key feature of quality education.

The book also recognises that this is not easily done, especially in a complex and changing education system that is already under pressure. In this regard, the chapters' arguments and empirical cases trace engagements with the dynamics of a changing South African curriculum as it has evolved in the post-apartheid era – an era that also embraces the necessity of human rights, social justice, a healthy environment and inclusivity as cornerstone principles of the curriculum (South Africa DBE 2011) while simultaneously insisting on epistemological access, access to social justice, and a more equitable participation in the economy for all citizens. Ultimately, the book argues that we need to focus on the needs of both people and planet through quality teaching and learning.

To this end, *Teaching and Learning for Change: Education and Sustainability in South Africa* draws on a range of theoretical framings that enable thinking and informed practice and acknowledge the complexity and contestation of environment and sustainability challenges. These include situated, relational and dialectical perspectives on transformative, critical and quality teaching and learning. Theoretical framings also include a focus on higher order thinking and assessment of significant learning. The theoretical perspectives are grounded in an understanding of the significance of cultural-historical contexts for teacher professional development programmes and classroom practices. Thus, the book illustrates a rich collection of theoretical ideas that have been tried and tested in research processes, showing their potential to inspire and deepen further cutting-edge research in the field.

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SECTION A

Environmental content knowledge in the curriculum

CHAPTER 2

Strengthening Environment and Sustainability Subject Knowledge: Curriculum Challenges and Opportunities

Ingrid Schudel and Heila Lotz-Sisitka

The emerging field of environmental and sustainability science

This chapter serves as a positioning paper for the chapters that follow in which different environment and sustainability knowledge foci will be explored in the South African Curriculum Assessment Policy Statements (CAPS). As a series of interconnected and cross-cutting complexities, environment and sustainability content knowledge has relevance for, and is widely distributed across, different phases and subjects in the school curriculum (see discussion of environmental content knowledge in Schudel and Lotz-Sisitka, Chapter 1; Lotz-Sisitka et al., Chapter 6; Msezane, Chapter 7). Knowledge that makes its way into education curricula and teaching is produced within the wider scientific context. Bernstein (2000), in his theory of the pedagogical device, refers to this as the 'Field of Production'. A significant knowledge-producing community for sustainability concerns is the global change research community (international and national) (South Africa DST 2010). Examining their research outputs and discourses can provide important insights for the development of knowledge in what Bernstein names 'regions', where singular disciplines such as Science (e.g. climate sciences/biodiversity sciences/water sciences/health sciences), come together with other singular disciplines such as education. Bernstein suggests that a first level of knowledge recontextualisation in the Field of Production occurs in these regions (e.g. where environmental educators or science educators recontextualise the knowledge of scientists).

An essential defining feature of environment and sustainability content knowledge in these regions is that it emphasises the interconnectedness and interdependence of human systems within ecological systems, and one of its core challenges is that the 'quality and availability of the planet's ecosystem services, on which human populations depend, are deteriorating, with serious detrimental consequences for social development and welfare, (South Africa DST 2010: 30). In the environment and sustainability sciences, this social-ecological interconnectedness has been illustrated in different ways, for example:

- Modelling of ecosystems and human well-being (Millennium Ecosystem Assessment 2005) or the relations between human social, economic and political systems and the biophysical environment (O'Donoghue 1993; Raworth 2017);
- Ecological limits have been illustrated and measured through modelling of ecological footprints (Chambers, Simmons & Wackernagel 2000) and planetary boundaries (Rockström 2009); and
- Environmental management models such as the drivers-pressures-state of environment-impacts-response (DPSIR) framework for state of environment reporting by the United Nations.

These models, measures and frameworks from the field of environment and sustainability science have helped in illuminating and monitoring the risks associated with interacting forces that arise in a polycrisis of 'intersections between global warming, ecosystem breakdown, resource depletion, the global economic crisis, poverty and urbanisation' (South Africa DST 2010: 7). It is this first level of recontextualisation that is a key knowledge-building space for environment and sustainability education. In this space, there is a need to develop more complex, systemic understandings of reality (Bhaskar 2010; Hadorn et al. 2008; Wiek, Withycombe & Redman 2001). The complex web of knowledge that this space contains and the ontological and epistemological nature of this knowledge also requires inter- and transdisciplinary engagement (Bhaskar 2010; Hadorn et al. 2008).

A second level of recontextualisation occurs as knowledge from regions is recontextualised from the Field of Production into the 'Official Recontextualising Field' where curriculum policies and guidelines are produced. This knowledge includes key themes usually addressed through Education for Sustainable Development (ESD) such as climate change, biodiversity, sustainable production and consumption, global justice, disaster risk reduction, and poverty reduction (Rieckmann 2017). The knowledge from the environment and sustainability sciences is recontextualised (mainly via Education Department officials responsible for curriculum development in consultation with specialist educators in the field) into the national system of education and training. In the case of South Africa, this was strongly driven by the Environmental Education Policy Initiative and the Environmental Education Curriculum Initiative in the contributions of earlier environmental educators to curriculum development (Lotz-Sisitka & Olivier 2001).

In this book, it is the second process of recontextualisation, in the later CAPS curriculum, that was of interest to Makwena Mmekwa and Ingrid Schudel (Chapter 3) who report on the recontextualisation of biodiversity knowledge from key scientific documents in the field of production to the official recontextualising field (the CAPS curriculum). Some of the processes and challenges of the recontextualisation process across the pedagogic device are discussed in the next section.

Processes and challenges of recontextualisation in the South African curriculum

One of the problems created by this recontextualisation into the schooling system is a tension between support for maintaining strong disciplinary boundaries, and integration to support the transdisciplinary understanding mentioned above. The South African schooling system adopted ambitious strategies for integration under the outcomes-based education system. First, integration was supported through the use of 'phase organisers' to package curriculum content in Curriculum 2005 (C2005) – of which 'environment' was one. Responsibility was placed on teachers to develop their own learning programmes with these phase organisers being one of the complex curriculum design elements they needed to take into consideration. Research in the South African Learning for Sustainability project identified an assumption that teachers would be able to 'access information and resources and know how to interpret these resources in order to introduce learners to the different dimensions of the issues' (Lotz-Sisitka & Olivier 2001: 114). Additionally, there was a problem with the assumption that teachers wanted to accept responsibility for curriculum development and design (Lotz-Sisitka & Olivier 2001). Both of these issues made working with phase organisers a challenge within teacher development programmes.

In a later curriculum, the Revised National Curriculum Statement (RNCS), integration was supported through the permeability of disciplinary boundaries (disciplines were organised as 'learning areas' rather than strongly bounded subjects) and environmental educators shifted their focus to reconceptualise the way in which environment was being interpreted in and across the different learning areas (Lotz-Sisitka 2002). The environmental education community embraced the opportunities offered by this open curriculum structure, but also acknowledged the challenge that different resources were required in relation to different learning outcomes, and also the different contexts in which learning takes place (NEEP-GET 2005). A resource-based approach to environmental learning (NEEP-GET 2005) resulted in the development of learning support materials themed, for example, around water quantity and quality, waste and biodiversity (Mbanjwa 2001; O'Donoghue n.d.; Raven 2006; Schreuder 2005; Schudel et al. 2000). The NEEP-GET highlighted challenges with the design of these materials such as alignment with curriculum design elements and making the mediation role of teachers clear and explicit (NEEP-GET 2005).

Additionally, there were challenges with the use of the materials. Ramsarup's case reports of teachers participating in the NEEP-GET programme highlighted a concern that teachers cannot be assumed to possess the 'symbolic capital to tease out the environmental learning embedded within … learning actions', such as recycling (Ramsarup 2005: 93). Similarly, with the integration of natural resource management in official Life Sciences curriculum documents, Nsubuga argued that certain contexts (such as rural isolation) create greater conceptual and practical 'distance' between the official curriculum documents, their interpretation by teachers and their implementation in classrooms. Resource-based or knowledge-based challenges among teachers, she argued, could affect the implementation of such integration opportunities in classrooms (Nsubuga 2008). All of these problems contributed to difficulties in working with an integrated and theme-based approach to environmental learning.

The next iteration of the National Curriculum Statement (NCS) included three documents: *The Curriculum Assessment Policy Statements* (CAPS), a national policy pertaining to the programme and promotion requirements of the NCS Grades R–12, and a *National Protocol for Assessment Grades R–12* (South Africa DBE 2011c: i). The CAPS heralded a strong return to the disciplinary boundary and a reinstating of disciplines as bounded subjects (South Africa DBE 2011c). This is a central epistemological 'tension' that this chapter explores in more depth (see Vignettes 1 and 2 that follow). Despite these challenges, the Fundisa for Change programme, underpinned by this new curriculum, began working with and expanding on environmental content specific to each bounded subject (Fundisa for Change Programme 2013). This expanded content is one aspect of what the Fundisa for Change Programme refers to as a CAPS++ approach to environmental learning. This book details broad-scope research into subject-specific topics, namely that of Heila Lotz-Sisitka et al. (Chapter 6) who explore the representation of climate change content knowledge in the CAPS, and Sikhulile Msezane (Chapter 7) who explores the extent of the representation of environmental content in all subjects in the Grade 12 curriculum and examinations. Additionally, the book reports on detailed research of specific topics in specific subjects, namely that of Dorelle Isaacs and Lausanne Olvitt (Chapter 4); Makwena Mmekwa and Ingrid Schudel (Chapter 3) who focus on the topic of biodiversity; and Gavin Heath and Rob O'Donoghue (Chapter 5) who focus on water catchment management.

A second problem created with recontextualisation of environment and sustainability content in the South African CAPS is that it has resulted in 'fragmented representations' of environmental knowledge in the form of topics that cross a range of schooling levels and subjects, and these appear to have been put together in a manner that lacks conceptual coherence, progression or a clear overall epistemological and/or pedagogical framework (Songqwaru 2012; see also Lotz-Sisitka and Mandikonza, Chapter 6 in this book). As reported by Songqwaru and Shava, this lack influenced the focus of the Fundisa for Change programme, which teachers reported as enlightening them regarding 'conceptual progression and connections within and across the grades' (2017: 216).

A third problem of recontextualisation can occur as it is relocated from applied fields where knowledge is constructed for addressing environment and sustainability needs in particular contexts. Wiek, Withycombe and Redman indicate the applied nature of environment and sustainability knowledge in their explanation that:

> The field's development is a response to existing and anticipated complex problems including climate change, desertification, poverty, pandemics, war – all featuring high degrees of complexity, damage potential, and urgency, and all having no obvious optimal solution. To solve these and other 'wicked' sustainability problems, the field generates, integrates and links use-inspired knowledge to transformational action in participatory, and adaptive settings. (2001: 203)

As Bernstein explains, 'unmediated discourses [applied discourses in the field] are transformed into mediated, virtual or imaginary discourses [in more or less strongly bounded disciplines]' (Bernstein 2000: 33). As knowledge is relocated it can become disembedded from, and lose, its spatio-temporal context: that is, it can lose its historicity, cultural roots, and resonance in specific geographic locations and scales as they range from local to global. It is textbooks and learning support materials, and their appropriate selection for specific needs, that play an important role in re-embedding abstracted knowledge as it is taught in classroom contexts. Studies of environmental learning in the RNCS that have explored these challenges include those of Ramsarup (2005) and Nsubuga (2009). This potential problem with recontextualisation links closely to a tension about the relationship between discipline-based and everyday knowledge, and even though the CAPS' strong discipline-based approach has tended to downplay the importance of everyday knowledge, this chapter argues for its importance for environmental learning: that is, through the discussion of knowable and situated knowledge as it emerges from Vignette 3.

The re-embedding of abstract knowledge needs to occur by re-connecting with the spatio-temporal roots of the knowledge, but also through projecting into possible contemporary and/or future spatio-temporal resonances. This is where the transformative and visionary potential of environment and sustainability knowledge becomes important. For example, O'Donoghue reports on situated learning processes in which 'participants engaged in matters of concern and developed intervention experiments towards change projects that were sustained, narrated and shared as transgressive learning and innovation towards a sustainable future' (O'Donoghue 2017: 27).

However, supporting the construction of transformatory and visionary knowledge raises a fourth problem for recontextualisation in a national curriculum and that is how to introduce learners to cutting-edge ideas and practices such as alternative globalising economic thinking (Raworth 2017), or alternative local farming practices (Machobane & Berold 2003), without imposing pre-determined behaviours for learners – an approach to ESD which has substantive critiques (O'Donoghue & Lotz-Sisitka 2002; Lotz-Sisitka & Schudel 2006). A resource that directly addresses this problem is the *Handprint Action towards Sustainability* series produced by O'Donoghue and Fox (2009). This series illustrates case studies of local learning and situated stories of change in real contexts. Such materials are important for illustrating sustainability practices that can be trialed and adapted for different contexts. These materials are representative of the third level of recontextualisation that occurs in Bernstein's pedagogical device: that is, the Pedagogic Recontextualising Field (Bernstein 2000) where knowledge is further recontextualised by the development, selection and adaptation of textbooks and other materials to support teaching and learning as outlined in the curriculum. Vignette 5 in this chapter is an illustration of another such set of materials supporting transformative and visionary knowledge construction.

Another process that occurs during recontextualisation as explained by Bernstein is that: 'No discourse ever moves without ideology at play. As this discourse moves, it is ideologically transformed' (Bernstein 2000: 32–33). Particularly for ESD, and in the light of the 'new normal' sparked by the COVID crisis, there is a need 'to trigger structural transformations in today's economic and social systems by promoting alternative values and contextualised methods' (Unesco 2020: 9). In the outcomes-based schooling systems (as adopted in C2005 and the RNCS), a principle highlighting the importance of paying attention to the relationship between human rights, inclusivity, and environmental and social justice was an explicit ideology underpinning both curricula. This principle is an important driver for integrating ESD as an 'holistic approach to reshaping education to address sustainability challenges' (Unesco 2020: 47). Yet, from research in the context of training with teachers, Ramsarup noted that the principle was interpreted in a reductionist manner, with inclusivity discourse dominating training materials and interpretations by educators. This, she found, was 'threatening the holistic engagement with the first principle', 'ideologically driving the recontextualising of the first principle' and 'subsequently narrowing the policy discourse and its intent' (Ramsarup 2005: 99). The two post-apartheid curricula emphasised the importance of knowledge (in the narrow sense of the word, simply meaning curriculum content), skills and values, thus highlighting the importance of the cognitive, psychomotor and affective domains of learning. It is particularly around the 'values' aspect of learning that one would expect this principle to come into play, yet if the principle is not fully understood or embraced, then one would not expect meaningful environment and sustainability values deliberations to emerge in classroom contexts.

The CAPS curriculum has the same basic principle underpinning all subjects, but no longer emphasises 'values' as an explicit aspect of learning. Ramsarup's research illustrates that an isolated principle does not guarantee infusion into specific subjects and topics. This raises the question of how much this principle has influence in CAPS-driven knowledge practices today, especially given that values are no longer highlighted, and thus potentially undermining the affective domain of learning. Ramsarup's research underpins the fifth and final problem of recontextualisation introduced in this chapter, and that is that values driving the environment and sustainability sciences in the Field of Production might become less and less explicit as they are taken up in the fields of official and pedagogic recontextualisation. This is equally true for critical engagement with these values, if curricula do not explicitly provide content that necessitates such engagement. The role of values in the CAPS curriculum is explored in Chapter 4 of this book by Dorelle Isaacs and Lausanne Olvitt. Their chapter considers the different ways in which teachers see biodiversity as possessing either intrinsic value, or value to humans as a resource. Vignette 4 in this chapter further supports the argument for the importance of explicitly working with the values-based underpinnings of environment and sustainability knowledge.

In the light of the five problems with recontextualisation identified above, five vignettes are presented below that draw on the authors' experiences of working with environmental and sustainability content in a variety of teacher education programmes. At the same time these vignettes illustrate particular characteristics of environmental knowledge across a variety of subject disciplines and school levels.

Working with environmental and sustainability content knowledge

Deepening knowledge and increasing rigour through laminated systems with specialist foundations

The previous section discussed how the CAPS curriculum has been structured around strongly bounded subjects. As subject specialisation increases, the challenge for environmental learning is how distinct content across a laminated science and social sciences system can support understanding of environmental sustainability. This includes understanding life-support systems and processes, social and economic systems, and personal and social well-being that are all part of a holistic understanding of environmental issues and risks.

Specialised disciplines give us access to different laminations of reality (such as different specialisms in the sciences and social sciences) as described above. Additionally, specialisms provide us with different ways of accessing and describing that reality: that is, different languages for describing reality. Not only is descriptive 'know that' propositional knowledge required, but also 'know how' procedural knowledge (Bertram 2009; Muller 2014: 263). The latter is concerned with knowing how we come to know. Specialist subject knowledge requires attention to both of these. For example, the sciences and (more rarely) the social sciences might make use of experimentation in closed systems; or, both sciences and social sciences might make use of descriptive modelling, for example, describing ecosystems and well-being as in the international Millennium Ecosystem Assessment (2005) elaborated in the introduction to this chapter.

Mathematics might give us a strongly quantitative way of describing reality, or systematic ways of visualising reality; while the arts might use metaphor, analogy and images. Environmental learning requires a combination of these different laminations and languages in order to give the most complete picture and to find, triangulate and make judgements on claims of truth.

The vignette below illustrates environmental learning in which the sciences and social sciences are employed in creating a laminated holistic social-ecological perspective on bees in the Foundation Phase classroom while deepening and strengthening these perspectives through mathematics and languages.

Vignette 1: Cross-curricular, bee-themed lessons for Foundation Phase schooling

In a demonstration of theme-based curriculum planning, Foundation Phase pre-service teachers are introduced to a series of Grade 3 cross-curricular lessons on bees with an environmental focus. The lessons are driven by the Life Skills subject but also draw on mathematics and language skills in developing and deepening understanding. Lessons cover bees and other insects and how these play different roles in their relations with humans (at times helpful and at times harmful). This, together with a humorous poem about a mosquito that bites boys' bottoms and another poem titled 'Don't bother any butterflies' is intended to help address fears learners might have about insects and other 'creepy-crawlies' while developing a healthy respect for certain situations in which relationships between humans and insects might prove harmful on both sides (English Home Language lesson).

Mathematics and a focus on 'line of symmetry' helps learners to look closely and to see and describe with more detail and accuracy. Lessons also cover the science of how bees make honey and help to pollinate flowers – many of which belong to plants that go on to become food for humans. Further lessons are intended to develop respect for bees: first through an emphasis on how hard a bee needs to work in order to make a single drop of honey, and second through a focus on how bees make use of the best shape for making their honeycomb (both of these are predominantly Mathematics lessons). Other lessons are intended to develop empathy through a focus on how water, land and air pollution affects bees and other insects, for example, through lessons focusing on how a water strider would drown if trying to 'walk' on water polluted with soap; how important scent is for bees and how air pollution might affect this; and how long some waste takes to break down (using the procedural knowledge of experimentation in the sciences). Additionally, there is a lesson developed around a story in which a greedy king accumulates vast amounts of gold from the Earth and forces bees to make exorbitant amounts of honey for him to eat. He gets his comeuppance when the bees rebel and the Earth splits and swallows him into its lava centre. This Home Language lesson highlights the problem of exploitation of Earth's resources by human beings. Finally, there is a lesson in which learners are supported to try out environmentally friendly gardening practices in order to encourage helpful insects to visit their gardens.

The benefit of environmental learning in the Life Skills subject is that specialisation into different science and social sciences subjects has not yet occurred in the first three years of schooling. Bhaskar and Danermark's (2006) notion of a laminated system can give us insights into the different types of knowledge that are combined in this Life Skills subject and that would be needed in order to more fully understand a particular phenomenon. These authors describe a laminated system as 'a system that refers essentially to several different levels of reality' (Bhaskar & Danermark 2006: 280). An example of the use of this system for discussing a particular topic is suggested by Lacey and Lacey's reflection on the laminated nature of seeds as:

> (a) Biological entities: under appropriate conditions they will grow into mature plants from which (e.g.) grain will be harvested. (b) Constituents of various ecological systems. (c) Entities that have themselves been developed and produced in the course of human practices. (d) Objects of human knowledge and empirical investigation. All these need to be considered when investigating risks and the potential of alternatives. (Lacey & Lacey 2010: 193)

These laminations of reality can be determined in the particular context of study. For this study, five laminations have been used as identified in Figure 1 below. This figure demonstrates how the bee-themed lessons described in Vignette 1 touch on these five laminations of reality.

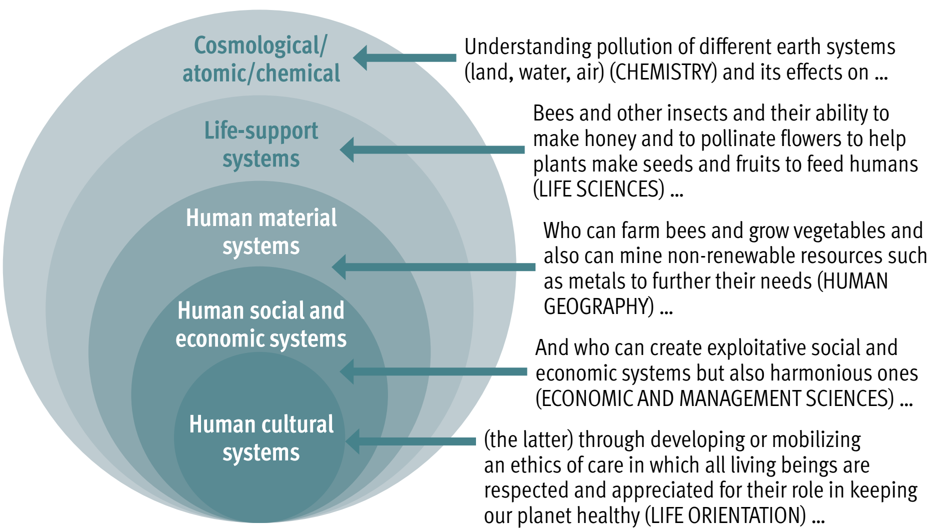

Figure 1. Positioning bee-themed lessons within a laminated system

Figure 1 shows the role of the different sciences (Chemistry and Life Sciences) and social science specialist subjects (Human Geography, Economic and Management Sciences, Life Orientation) in enabling a fuller understanding of the interdisciplinary and laminated nature of environmental and sustainability knowledge. The embedded nature of the diagram is also significant – illustrating that to understand each lamination you need to understand that it emerges from the previous level. For example, without healthy life support systems farming systems cannot be successful.

The vignette also provides insight into the important role that Mathematics and Languages play in providing the power of description, power of persuasion and power for imagining new ways of doing and being. Mathematics is used to help learners develop a keenness of eye, and a sense of wonder about insects using numbers and shapes. Language is used to describe and detail as well to critique, question and re-describe.

Transcending disciplines through transdisciplinarity

The preceding vignette has demonstrated the importance of specialist knowledge. It is equally important, however, not to allow subject specialisation to lead to epistemic monocultures and atomisation (Schudel 2017; Tikly et al. 2020) in which we are denied a full picture of environment and sustainability challenges. For example, O'Donoghue, Kibuka-Sebitosi, Tshiningayamwe and Palmer explain how much of the environmental knowledge 'appropriated from indigenous peoples and their knowledge practices has come back to us in scientific disciplines and curricula [epistemic monocultures] but in such a form that the "Africanness" is not easily recognised and identified with' (O'Donoghue et al. 2019: 5). Additionally, they argue that 'abstract propositions (reified and disembedded perspectives) such as biodiversity and climate change … are difficult to relate to the intergenerational lived experience as felt sustainability concerns of the day' (O'Donoghue et al. 2019: 2).

Modern curricula need to be able to offer both depth and detail for nuanced understanding of environmental challenges and sustainability practices, while ensuring that boundaries are not too strictly drawn, so that dialogue between knowledges and disciplines can ensue. For example, dialogue between disciplines is critical for the CAPS human-rights-based conceptualisation of environmental health and social justice, as evidenced in the generic curriculum principle which respects 'human rights, inclusivity, environmental and social justice' (South Africa DBE 2011c: 6), as discussed in the introduction of this chapter.

Different disciplines enable different perspectives on phenomena, thus giving depth and rigour to understandings of complex problems. This 'multi-disciplinary' approach may still need important cross-cutting considerations to help draw the different disciplines together. Such cross-cutting considerations can transcend the specific topics identified by independent subject disciplines, thus providing a more holistic perspective on the complexities being considered. Examples of this can be seen in the work by Murray (2005) in the analysis of the Namibian curriculum, where natural resources and their management, poverty and inequality, society and governance, development and the environment, health and the environment, and globalisation were identified as cross-cutting themes in the curriculum. Similarly, Lotz (1996), identified cross-cutting themes in an action research project with primary school teachers, where they developed a series of materials to support Foundation Phase learning. In these materials the group identified the following themes: understanding the patterns of change; discovering how living things fit into their surroundings; cause and consequence; conservation action to make the world a better place; interrelationships and interdependence; diversity; and place.

When working with complex environment and sustainability knowledge in curricula, the challenge is finding, highlighting and deepening these cross-cutting concerns and making them an explicit focus in classroom deliberations. The next vignette highlights how environment and sustainability topics require teachers to apply such cross-cutting thinking in order to fully understand social-ecological nuances in different contexts.

Vignette 2: Introducing indigenous knowledge in order to understand human impact

In the 'Human Impact on the Environment' topic in the Life Sciences CAPS curriculum, Grade 11 learners need to explore 'indigenous knowledge systems and the sustainable use of the environment, e.g. devil's claw, rooibos, fynbos, the African potato (Hypoxis) and Hoodia' (South Africa DBE 2011b: 52). Hoodia, which was used by indigenous African people – the KhoiSan – to treat indigestion and minor infections, is now widely employed as a natural appetite suppressant to support weight loss in modern societies. Rooibos, a tea that was used for many centuries by indigenous African peoples, is now a widely cultivated commercially sold tea available around the world. These cases raise questions about the appropriation of indigenous knowledge by foreign pharmaceutical and health food companies and the rights of indigenous people to own and benefit economically from their own knowledge. The widely publicised cases of indigenous communities' attempts to gain intellectual property rights over these plants and to cultivate and commercialise them, raise stimulating and challenging questions in classrooms around healthy alternatives, cultural and biological heritage, dignified work opportunities, work for women, stimulating local economies, resilient alternative practices in the face of climate change, and responsible agricultural practices.

The cases discussed in Vignette 2 illustrate that not only does environment and sustainability knowledge require a laminated and disciplinary understanding of reality, but also gives a sense of the many cross-cutting concerns that span debates in environmental discourse and which transcend disciplinary boundaries. The notion of transdisciplinarity used in this chapter is influenced by Bhaskar's explanation that transdisciplinarity requires 'new concepts, theories and modes of understanding. This will necessitate epistemological transdisciplinarity, involving the exploitation of pre-existing cognitive resources drawn from a wide variety of [antecedently] existing cognitive fields in models, analogies, etc.' (Bhaskar 2010: 6). This is a notion distinctly different from interdisciplinarity, which provides a cumulative perspective from different disciplines, rather than a perspective that transcends the limitations of disciplinary boundaries.

The Sustainable Development Goals (SDGs) (United Nations 2015) are a useful frame for illustrating how certain topics, even if in one specialised subject, can require a sophisticated and transdisciplinary perspective on the world. Figure 2 illustrates how cases of indigenous knowledge and its responsible (or irresponsible) use can be brought into play across many of the sustainable development goals: good health and well-being; life and living; gender equality; climate action; responsible consumption and production; sustainable cities and communities; and decent work and economic growth.

Figure 2. Transcending disciplines through an SDG framing of social-ecological interactions

Environmental knowledge as knowable and situated

If environmental knowledge has the kinds of complexities described above, then we are faced with the danger of becoming so unsure about how to describe a complex world that we cannot take decisive action to change that world for the better. Complex social-ecological systems require the capacity to identify rigorous scientific principles, beyond a narrow and positivist perception of science and social science.

Vignette 3 illustrates how people can become divided over the facts, figures and realities of environmental concerns, thus highlighting the need for spaces in curricula for debating the rigour of environment and sustainability content in curricula.

Vignette 3: Interview between a climate change denialist and a 'science guy'

One of our activities exploring the nature of science introduces science education students to an interview between Fox News Channel presenter, Tucker Carlson, and Bill Nye, popularly known as 'Bill Nye the Science Guy'. This interview illustrates how a narrow perspective on science can be manipulated to defend climate change denial.

Carlson opens with a welcoming statement: 'We are coming to you live from outside the US capitol building where President Trump will address a joint session of Congress in fewer than 24 hours. You may hear construction noise behind us during the show. That is because there is construction going on. There always is in Washington. The richest city in America. And we want to thank you for that. For sending your tax dollars here. It's built a pretty nice place.' Moving to his interview with Nye on climate change he asks: 'Why the change? Is it part of the endless cycle of climate change or is human activity causing it?' When Nye answers that climate change is definitely caused by humans, Carlson aggressively insists: 'I am asking a very precise question. To what degree is climate change caused by human activity. Is it 100% of climate change that is caused by human activity? Is it 73.4%? If it is settled science, please tell us to what degree.' Nye does not answer this question because to try and do so in an open system would be nonsensical and unscientific. He replies: 'The word "degree" is a word that you chose.' Nye highlights repeatedly that it is the rate of change which is unprecedented. Carlson then insists on knowing to what degree the **rate of change** is caused by humans. Exasperated, Nye answers: '100%. If that is the number you want.' Fixated by numbers, Carlson then asks: 'Without human activity how long would it have taken for us to have reached this level of warmth in our climate?' It is impossible to answer this nonsensical question, which puts 'us' into a scenario in which we are trying to establish what would have been different without 'us'. Nye replies: 'It's not clear that it would have happened. In other words, humans have changed the climate so drastically that we have avoided another Ice Age.'

Failing to win the numbers game, Carlson then insists on knowing **when** the Ice Age would have started if it hadn't been for human activity, to which Nye replies by stating that the question is irrelevant. Arguing constantly for specific figures and precise times, which no science based on modelling in open systems would ever claim, Carlson is appearing to fall back on one of his opening remarks that: 'The essence of science is extreme skepticism.' His extreme skepticism is so extreme that it disallows the use of the best available data to attain the best possible description of the truth.

Having failed to out-argue Nye up to this point, Carlson changes tack and asks something less quantitative and more qualitative: 'What would the climate look like, right now, without human activity?' When Nye answers with a long list of examples of agricultural and ecological systems that have been disrupted by climate change since the 1750s (the beginning of the industrial revolution), Carlson finally loses control of the interview, angrily retorting: 'You don't actually know because it is unknowable' and following later with 'So much in this you don't know. You pretend that you know. But you don't know. And you bully people that ask you questions.' He ends with 'I am open-minded. You are not. And we are out of time unfortunately.'

How is this intense divide on climate change that is played out in the vignette possible? I suggest that one reason (the next will be discussed in the next section) is simply bad science. No good science would claim that our knowledge of the world is in direct correspondence with (an exact replica of) the world. This is supported by a critical realist view of science which acknowledges that 'there is no way of knowing the world except under particular, more or less historically transient descriptions' (Bhaskar 2009: 99). Scientific modelling can only be based on the best available data to attain the best possible description of the truth. To throw out an extensively well-researched explanation of climate change because of an insistence on exact figures shows limited understanding of the powers of science, and restricts science's capacity for qualitative descriptions of the world. To throw out well-researched explanations of the effects of climate change because they are 'unknowable' as claimed by Carlson, is problematic. 'Knowability' is a complex dilemma. We cannot know everything that has happened in the past, nor can we fully know the status quo, because we rely on selected data and limited sets of data. Neither can we accurately predict the future – predictive models can never be completely knowable because they are in the future.

Drawing on a critical realist perception of knowledge, Scott (2013: 9) explains that: 'Knowledge is always fallible, and this applies equally in cultural, epistemological or practical settings. As a result, fallibility cannot just be equated with inadequacy or insufficiency, but also implies that no epistemic certainty can be guaranteed.' This means that we can (and must) use the best available data to describe climate trends through modelling techniques. Equally, we must use our laboratory-based knowledge of the greenhouse effect to gain a basic understanding of the physical and chemical powers that are capable of driving these climate change trends. Price explains that by their very nature, ecological models can never entirely be proven, but that 'rather than denying the truthfulness of their models, ecologists would be better off explicitly embracing transcendental realism' (Price 2019: 34). Transcendental realism acknowledges that there is more to what is 'real' than what is experienced. The empirical evidence gathered by science over time to explain the warming power of greenhouse gases is sufficient to argue that this same power will be exerted on a planetary scale and have real effects in terms of global warming.

Additionally, when empirical evidence of change is found (e.g. the qualitative stories presented by Nye of changes affecting local economies) then this evidence highlights the urgency and seriousness of climate change predictions, even if the measured changes are not a direct match to the predicted changes. 'Knowing the world' is not only about numbers and modelling, as Vignette 2 demonstrates. Situated knowledges, which need to acknowledge 'stakes in location, embodiment and partial perspective' (Haraway 1988: 584) are critical places to start with making decisions on which we can act. Haraway furthers her argument by saying that unlocatable knowledge is irresponsible knowledge (1988). Unlocatable knowledge is another form of bad science. We see the importance of these situated knowledges in the located and embodied stories Nye tells of climate change effects which are demonstrated in the non-suitability of certain places for crops; the persistence of pests; and changing snowlines (with economic consequences for farmers and local communities – on which extended narrative could elaborate).

Climate models highlight change and uncertainty with a trend towards negative consequences. Common sense would dictate that we do not wait for such trends to be fully proven (even if this were possible) before we heed their warnings – since by that time it would be too late anyway to act (Price 2018). What we need is enlightened common sense as inspired by Bhaskar's critical realism, which insists on 'a serious philosophy that we can act on, and one moreover that is relevant to the pressing challenges we face and that ideally at least can illuminate a way forward' (Bhaskar 2016: 2).

Explicitly values-based

In the previous section, it was suggested that one reason for the intense divide on climate change is 'bad science'. Another is conflicting ideologies. Unesco describes a study 'in which policy documents of ten countries shows that ESD is mostly associated with the teaching of scientific knowledge on environment. This is not enough to bring the transformative power of education to its full force' (2020: 9). This same document suggests that one aspect of learning includes the social and emotional, for which it is necessary to 'build core values and attitudes for sustainability, cultivate empathy and compassion for other people and the planet, and motivate to lead the change' (Unesco 2020: 17). It is for this reason that environmental content must be presented in such a way that ideologies can be uncovered and deliberated. The situated stories told by Nye are a stark contrast to Carlson's introductory remarks in his show, in which Washington DC, completely dislocated from the local economies affected by climate change, is painted as a 'nice place' built by the taxes from these distant economies. The question for environmental educators then becomes: How do we make judgements on which to build environmental actions? A 'nice place built by taxes' appears to be used by Carlson to suggest, before the interview even begins, that any argument for reduction in carbon emissions could jeopardise the comfortable capitalist economy that creates the wealth and splendor underpinning America's seat of power.

Critical realism insists that phenomena need to be described using ontological realism (the real possibility of the greenhouse effect leading to global warming), epistemological relativism (the real possibility of different interpretations of reality by different people such as Carlson and Nye) and judgmental rationality (the real possibility that certain interpretations of reality are either untruthful misrepresentations of reality, selectively descriptive or simply manipulative to serve a particular cause). The three tools of ontological realism, epistemological relativism and judgmental rationality are described in first wave critical realism (Bhaskar 2016).

To better understand rational judgement we draw on both critical realism and situated knowledges, although this may be problematic for some who argue that the notion of situated knowledges is not entirely commensurate with critical realism. There are two reasons suggested for this schism: first, the suggestion that critical realism fails to acknowledge that judgmental rationality itself requires situated judgmental rationality; and, second, a suggestion that critical realism's insistence on generalisability is problematic (Smirthwaite & Swahnberg 2016).

Yet Bhaskar's second-wave dialectical critical realism and the notion of the concrete universal helps to resolve both of these concerns. A concrete universal approach to ethics is one that is considerate of universal rights and freedoms, dynamic and changing, holistically considerate of implications for all, and context-sensitive in the sense that 'all individuals, though sharing a common humanity, [are treated] as ethically different' (Hartwig 2007: 74). This suggests that there are general or universal perspectives which can be proposed and emphasised, but that is only if all humans (and all other life forms) are treated respectfully and with sensitivity to their contextual needs and realities. This is not intended to recommend a relativist approach to knowledge, which values all knowledges as equally valid, nor to posit simplistic integration of incommensurate knowledges. It is important not to make the mistake, as Haraway says, of 'easy relativisms and holisms built out of summing and subsuming parts' (1988: 585). In other words, a response to Smirthwaite and Swahnberg's concerns is a notion of *situated* and *ethically defensible* generalisability.[1]

The notion of concrete universality (or situated and ethically defensible generalisability) can be usefully employed in processes of situated judgmental rationality. Thus, a 'nice place built by taxes' can only be considered to be nice if the economies that build it are nice to ecosystems, nice to small-scale farmers, nice to vulnerable economies, and more. Such 'niceness' might be termed 'sustainability' – a universal right or freedom that environmental educators can subscribe to. Environmental knowledge is explicitly values-based and needs these tools to make judgements in order to guide future action. This notion can be seen to be consistent with Haraway's conception of situated knowledges, which she describes as 'positioned rationality' requiring 'the joining of partial views and halting voices into a collective subject position that promises a vision of the means of ongoing finite embodiment, of living with limits and contradictions' (1988: 590).

The next vignette illustrates the importance of being able to draw on the notion of concrete universals in ethics deliberations when instances of oppression and exploitation are represented in curriculum content.

1 Neither generalisation nor universalism should be confused with totalisation. Haraway argues that both relativism and totalisation deny the 'stakes in location, embodiment, and partial perspective' (1988: 584). Thus, both relativism and totalisation, as defined by Haraway, are unhelpful positions for representing environmental content in curricula.

Vignette 4: Exploring sustainable development in the Geography curriculum

The following are extracts from a Grade 12 Geography textbook used in South African classrooms, in which mining was discussed under the topic of Economic Geography. The topic is opened with an extract from a newspaper describing an internationally reported case of strikes and violence at Lonmin's Marikana platinum mine in South Africa. The article notes the 'high cost' of these incidents, namely 44 deaths, many of which occurred when police opened fire on workers demanding higher wages. The article moves on to explain that as strikes spread to other mines, they could have wider financial ramifications for South Africa. The major part of the article goes on to discuss loss of investor confidence and effect on the GDP.

The textbook then continues with a bullet list of the following 'Challenges to mining':

- Climate: high temperatures in areas such as Hotazel and Kuruman make mining very difficult, as costs of cooling the mineshafts are high.
- Distance: large distances between the mines and the harbours or towns have increased costs.
- Foreign dependency: we need overseas buyers, as only 15% of our minerals are sold locally.
- Labour: high costs in training and housing, as well as strikes and tribal fighting, have all affected productivity.
- Water: water shortages and underground water flooding are real problems.
- Price: if the price of gold drops, mines close and jobs are lost.
- Minerals: these are non-renewable resources. In some mines, the minerals have been exhausted.
- Accidents: explosions and the collapse of tunnel roofs cause loss of life and skills.

In Vignette 2, discussion centred around some of the cross-cutting themes that emerge within environmental discourse. Sustainable development (or 'environment and development', as in the Namibian curriculum analysis described in the above section on transdisciplinarity) is one of the cross-cutting themes that can be found in the CAPS curriculum in different subjects and phases, linked to topics such as: natural resource management and sustainable use (Economic and Management Sciences, and Social Sciences); responsible use of mineral resources (Technology, Natural Science, and Economic and Business Sciences); renewable energy (Natural Sciences and Technology); impact of development on environment (Agricultural Sciences, Technology, and Economic and Management Sciences); and waste management (Natural Sciences and Business Sciences). In Geography Grades 10–12, the focus on sustainable development intensifies with critical exploration of the concept of development, from the perspective of economic, social, sustainable, appropriate scale and spatial aspects; to modelling of different frameworks for development including 'sustainability models with their economic, social, and environmental elements', and a focus on limits to development such as natural resource limitations and environmental degradation (South Africa DBE 2011a: 34).

Vignette 4 is in stark contrast to the sustainability principles highlighted in these Geography curriculum intentions. Sustainability discourse requires a perspective on economics that includes social-ecological relationships. Yet, the section on economics, in this textbook, takes the position of a lopsided, solely economic representation of an extractive human-environment relationship – namely mining. Environmental concerns are limited to 'resource restrictions' and social issues are undermined to the point where even 'loss of life' is couched, together with 'loss of investor confidence' and 'loss of skills', as an economic concern. This tendency for economics to overshadow critical sustainability concerns is not surprising given the acknowledgement by Unesco that,

> There is wide agreement that it is challenging to reconcile economic growth with the principles of sustainable development, as far as current industrial and production patterns continue. Ever accelerating production and consumption deplete natural resources, produce unmanageable amounts of waste and lead to a rise in global temperatures. (Unesco 2020: 58)

Both Vignette 4 and the Carlson/Nye debate in Vignette 3 highlight that when different perspectives on science and different ideologies collide, it becomes hard to achieve consensus on the way forward. Irresponsible knowledge needs to be recognised and named, as do ideologies that underpin oppressive or exploitative relationships. Only then will we be able to find, or better still, create, situated stories that are capable of 'sustaining the possibility of webs of connections called solidarity in politics and shared conversations in epistemology' (Haraway 1988: 584).

Transformative and visionary

The preceding two vignettes highlighted the need to name and oppose oppressive and exploitative relations in an ideologically explicit way. Bhaskar refers to such relations as Power 2 relations, constituted by 'exploitation, domination, subjugation, oppression, repression and control' (Bhaskar 1993: 176). The judgmental rationality engaged in order to critique these relations is important to contrast with a relativist 'anything goes' outcome in environmental deliberations. This is because relativism 'leads to the inability to act, since how can we act if we cannot choose between better or worse?' (Price 2007: 107). Once clearly untenable relations are named, the transformative imperative of environment and sustainability content in curricula is foregrounded. The following vignette describes a teaching pack used to explore 'carbon footprinting' – a significant sub-topic under the theme 'Human Impact' in the South African Life Sciences (the same topic discussed in Vignette 2). It is significant because, out of 34 sub-topics listed under 'Human Impact', this is one of only four sub-topics that specifies or implies the need for alternative practices. This need for alternative practices is suggested by the 'concept of "carbon footprint" and the need to reduce the carbon footprint' (South Africa DBE 2011c: 51).

Vignette 5: Using footprinting to support transformative and visionary knowledge practices

A footprinting pack named 'The African Ecological Footprinting Game', developed by the Environmental Learning Research Centre, was commissioned by the Danish international aid organisation (IBIS). The pack has been used with Life Sciences pre-service teachers to address the curriculum sub-topic of carbon footprinting.[2] This pack has a series of information sheets and activities as follows:

- Information sheets that discuss the significant components of an ecological footprint, namely, energy, materials and waste, food, living space, travel, water and biodiversity. The information sheets also highlight the realities and specificities of a footprint in an African context.
- A set of nine question cards, which are used to calculate the carbon footprint and reflect on the broader ecological footprint. The footprint calculates the square area of land or sea needed to sustain an individual or country with the resources consumed and to absorb the waste produced. This is then compared with the amount of available land and sea if this was equally divided among all the people on Earth (with 'sufficient' area set aside to preserve ecological biodiversity).
- A set of 'Think About' cards, which are intended to stimulate discussion around environmental sustainability, especially issues regarding social and environmental justice and ecological health.
- A set of 'Action Option' cards which suggest individual and systemic options that might be considered for reduction of a carbon footprint.
- A collection of resources with ideas for, and case studies of, alternative sustainability practices.

The activities described in the vignette highlight the ecological limits of the planet, which humans are exceeding, and the inequalities and environmental injustices associated with exploitation of natural resources (thus deepening environmental knowledge). They critically examine some of the contextualised complexities and

2 Ecological footprinting is a broader concept than carbon footprinting, and the described pack covers the detail of carbon footprinting and elaborates to consider other ecological impacts of human activity.

trade-offs associated with sustainable development (strengthening situated knowledge and capacity to critique values and lifestyle choices), and explore both individual and systemic alternatives to support the capacity to 'live lightly' on the Earth (strengthening visionary and transformative knowledge).

The latter requires the ability to move beyond simple 'impact' – a Power 2 relation between humans and their ecological foundations. It entails an exploration of alternative Power 1 relations as posited by Bhaskar and described by Hartwig as:

> The general causal powers of human agency whose characteristics entail the possibility of human emancipation, such as our capacity to investigate, communicate, plan, construct moral and ethical systems, feel and care for others, and come to agreement based on judgmentally rational argument directed at practices that transform our lived circumstances. (Hartwig 2007: 372)

The resources described in the vignette with ideas for and case studies of alternative sustainability practices provide important situated stories of change such as are seen, for example, in the *Handprint Action towards Sustainability* series described in the introductory section of this chapter. The importance of supporting visionary knowledge at the schooling level is highlighted by ESD's dependence on the role of youth in change practices and Unesco's suggestion that,

> it is young people who are becoming increasingly vocal and active, demanding urgent and decisive change and holding world leaders accountable, in particular to address the climate crisis. They have, and continue to envision, the most creative and ingenious solutions to sustainability challenges. (2020: 32)

We suggest that for modern curricula to have relevance for the youth of today, they need knowledge resources that can support and guide this creative energy.

Conclusion

This chapter has noted the social-ecological and complex nature of environment and sustainability content knowledge. It has highlighted problems arising in the recontextualisation of this knowledge from its transdisciplinary site of production, to the creation of a strongly discipline-bounded curriculum, to its interpretation, mediation and facilitation by textbook and materials developers. The five problems of recontextualisation discussed in the chapter are:

- Tension between support for maintaining strong disciplinary boundaries, and integration to support the transdisciplinarity that is key to environment and sustainability understanding.

- Fragmented representations of environmental knowledge in the form of topics that cross a range of schooling levels and subjects.
- As knowledge is relocated it can become disembedded from and lose its spatio-temporal context and, subsequently, its potential for meaning-making and application to urgent contemporary environment and sustainability problems.
- A change orientation is complex for a national curriculum, but needs to include cutting-edge ideas and practices such as alternative globalising economic thinking or alternative local farming practices.
- Values driving the environment and sustainability sciences might become less and less explicit as they are taken up in official curriculum and pedagogic discourse – as might critical engagement with these values if curricula do not explicitly provide content that necessitates such engagement.

The vignettes highlighted some thinking tools to help ESD practitioners to strengthen their knowledge practices. Laminated systems were used in response to the first vignette to illustrate how different disciplines can be used to explore environment and sustainability phenomena without conflating subject disciplines (a response to Problem 1). The SDGs were used in response to the second vignette to show how cross-cutting concerns can be brought together around particular environment and sustainability topics (a response to fragmentation described in Problem 2). The response to the third vignette used the notions of situated knowledges and the concrete universal to demonstrate how environment and sustainability can and must be 'knowable', and also how it can be situated in local and global contexts (a response to the problem of spatio-temporal disembeddedness described in Problem 3). The fourth vignette highlighted the importance of explicit values-based orientations to knowledge construction (a response to Problem 5). Finally, the fifth vignette illustrated the importance of content knowledge that enables Power 1 relations in response to oppressive Power 2 relations (a response to Problem 4).

The chapter has focused on knowledge selection and organisation, and the ideologies and intentions underlying these processes. We are aware that the intended curriculum is only a foundation from which teachers' and learners' own knowledge construction emerges. This emergence is influenced by sets of 'conditions that enable and constrain learning' (Brown 2009: 5). The power of such conditions in influencing learning is illustrated, for example, in Chapter 5 in which Gavin Heath and Rob O'Donoghue explore the use of theory of practice architectures as a tool for investigating how cultural-discursive, material-economic and social-political architectures (Kemmis et al. 2014) influence the emergence of student teachers' knowledge of water catchment management in the teaching of Geography. Additionally the impact of context on teacher learning is a focus in Section D of this book.

This chapter positions the other five chapters that have been selected for this section of the book on environment and sustainability knowledge. In addition, it serves as a foundation for Section B of this book in which the pedagogical implications of the described characteristics of environment and sustainability knowledge are explored. For example, the threads of situated, values-based and transformative knowledge are also explored in Section B from the perspective of teaching and learning. Section C picks up the threads of discipline-based knowledge and transformative intent in ESD. Finally, these three sections are pulled together in Section D which offers teacher professional development perspectives from the Fundisa for Change research programme.

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CHAPTER 3

Investigating the Nature of Biodiversity Knowledge in Natural Sciences Curriculum and Textbooks

Makwena Mmekwa and Ingrid Schudel

Background and context

In 1992, the international Convention on Biological Diversity (CBD) emphasised biodiversity as a measure for sustainability and recognised communication, education and public awareness as important for the successful implementation of the Convention's aims (CBD 1992). In 2002, the United Nations Decade of Education for Sustainable Development (2005–2014) included biodiversity as one of its key priorities (Unesco 2005). Later, Unesco's (2014) Global Action Plan on Education for Sustainable Development highlighted biodiversity as 'critical content', to be included in national curricula for holistic and transformational education.

In 2015, the United Nations included a concern for biodiversity in the Sustainable Development Goals, making a commitment that:

> We recognise that social and economic development depends on the sustainable management of our planet's natural resources. We are therefore determined to conserve and sustainably use oceans and seas, freshwater resources, as well as forests, mountains and dry lands and to protect biodiversity, ecosystems and wildlife. (United Nations 2015: 13)

In reporting on these goals at an international level, the United Nations (2019) notes small successes in the 'Life on Land' goal with declining rates of forest loss (note: not declining *loss*, but declining *rates* of loss) and some innovative conservation strategies. However, in general, species extinction continues at an alarming rate (in fact, it is accelerating); coverage of protected spaces in key biodiversity areas is increasing, but insufficiently to meet targets and at a decreasing rate; and land degradation continues to increase while affecting the lives of one billion people. The 'Life below Water' goal has some positive achievements in conservation and management of marine resources and the possibility for improved management of land-based pollutants and marine debris. However, ocean acidification – named as 'the silent killer' or 'global warming's evil twin' (Bach et al. 2017) – is accelerating with an estimated increase (at the current rate of carbon emission) of between 100 and 150% by the end of the century (United Nations 2019).

The crisis of biodiversity loss described above indicates that understanding fauna, flora and their habitats is insufficient to understanding human impact and to support agency for social-ecological change. A more transformative response to human interactions with biodiversity is implied in the latest Convention on Biological Diversity's Aichi Target 19, which states that by 2020 knowledge, the science base and technologies relating to biodiversity, its values, functioning, status, trends and the consequences of its loss, need to be improved, widely shared, transferred and applied (Dhandapani et al. 2019). Education is seen and acknowledged as an important tool to achieve sustainability as well as biodiversity protection through the transformation of human attitudes towards nature (Ehrlich & Pringle 2008).

At a national level, South Africa contains extraordinarily high levels of biodiversity, in terms of species richness and local endemism (Siegfried 1989). Hence, South Africa has an important position and a practical role to play in the protection of global biodiversity. South Africa, like other developing countries, experiences a conflict between biodiversity conservation and economic development. Over 12 million South Africans depend on the natural environment to meet their needs (Driver et al. 2012). This results in overharvesting of biological resources as one of the main causes of biodiversity loss in the country (South Africa DEA 2014). The State of South Africa's Biodiversity 2012 report warns that if Gauteng, KwaZulu-Natal and North West Province keep losing natural landscapes at the current rate; to cultivation, mining, urban expansion and other causes; these provinces will have almost no natural habitat left outside protected areas by 2050 (SANBI 2013).

South Africa is party to international biodiversity conservation initiatives and has national policies aimed at conserving biodiversity such as the National Environmental Management Biodiversity Act. This Act provides for the management and conservation of South Africa's biodiversity within the framework of the National Environmental Management Act 10 of 2004.

From a national educational perspective, as reported in Chapter 2 (Schudel and Lotz-Sisitka), 'environment' was a phase organiser in the post-apartheid Curriculum 2005 (Chisholm 2005). This enabled integration of topics such as biodiversity into different learning areas through this cross-curriculum approach to curriculum design.

In the Revised National Curriculum Statement (RNCS), the Senior Phase (Grades 7, 8 and 9) included biodiversity constructs under the 'Life and Living' strand, which stated that: 'Life and Living focuses on life processes and healthy living, for understanding balance and change in environments, and on the importance of biodiversity' (South Africa DoE 2002).

The 2012 CAPS inherited the interest in environmental concerns and included environmental knowledge content (see Chapter 2). Specific environmental content knowledge such as pollution, climate change and biodiversity is incorporated in various subjects including Natural Sciences. In the Grade 7 Natural Sciences CAPS, biodiversity is presented as a concept to be explored through topics presented in the first term. Biodiversity includes: 'plants, animals and microorganisms, and their habitats [that] make up the total biodiversity of the Earth'. Grade 8 has topics that address biodiversity, specifically interactions and interdependence in ecosystems. Grade 9 outlines topics related to biodiversity in Term 4 in the 'Planet Earth and Beyond' knowledge strand, with sub-topics such as the greenhouse effect (South Africa DBE 2011).

As can be seen, South Africa includes this important topic in its curriculum to some extent. However, very little has been achieved with regard to ensuring that environmental issues such as loss of biodiversity are consistently and coherently implemented in the school curriculum (Lotz-Sisitka 2011). Kadji-Beltran (2002) acknowledges that, as with any new topic, project, or programme, the implementation of biodiversity in the educational system depends on a number of factors. These might include how the curriculum structures content knowledge for biodiversity initiates. Part of this chapter's purpose is to narrate the scope, depth, progression, valuing and contextualisation of biodiversity content knowledge with regard to continuity and discontinuities as it is recontextualised across these curriculum spaces.

The study on which this chapter reflects is framed by the following research question:

> *What is the nature of biodiversity knowledge presented in the Senior Phase Natural Sciences curriculum and selected textbooks in relation to international and national scientific documents?*

Theoretical tools of the study

The Pedagogic Device is an attempt to describe the general principles which are central to the transformation of knowledge; namely the principles of distribution, recontextualisation and evaluation (Bernstein 1996). The Pedagogic Device is made up of a number of fields in which these principles play out (Bernstein 1990).

Important for this paper was the specific principle of recontextualisation. This principle helps with understanding how knowledge is recontextualised as content is developed from the scientific field in which it is generated and reproduced in the pedagogic discourse of the curriculum and textbooks supporting curriculum implementation. Bernstein describes firstly the Field of Production (FOP), where new knowledge is constructed and compiled by scientists. It is then recontextualised (delocated and then selectively appropriated or transformed as it is relocated) through Official Pedagogic Discourse (OPD) in two recontextualising fields. The first of these is the Official Recontextualising Field (ORF) which is created by the official recontextualisers (curriculum developers). Further recontextualisation occurs in the Pedagogic Recontextualising Field (PRF) when knowledge is recontextualised by textbook writers and teacher educators (Bernstein 1990). The Field of Reproduction (FOR) is where recontextualised discourses are transformed a second time for general consumption, and where pedagogy and curriculum are actually enacted in schools (Apple 2003). Of interest for this chapter was the content of biodiversity knowledge presented in the Natural Sciences curriculum and how this related to the commonly used Grade 7–9 Natural Sciences textbooks. The study focuses only on the ORF and PRF, and further insights into biodiversity knowledge in the FOR can be read in Chapter 4 by Isaacs and Olvitt.

Methodology

This study was a social realist investigation that shifts the focus from 'whose' knowledge to an emphasis on 'what' knowledge (Lilliedahl 2015). It also shifts from viewing knowledge in terms of its construction to its production, within the relatively independent scientific fields (Young 2008). According to Maton and Moore (2010), knowledge is the very basis of education as a social field of practice. It is the production, recontextualisation, teaching and learning of knowledge that makes education a distinct field (p.2). The study also has a social realist interest in placing knowledge as an object at the centre of thinking about education.

Document review was used as the main method for this study. The Millennium Ecosystem Assessment (MEA 2005) and Life: The State of South Africa's Biodiversity 2012 (SANBI 2013) were used to identify the scope and depth of biodiversity knowledge in the FOP. The CAPS policy document and three Grade 7–9 textbooks (one per grade across Grades 7, 8 and 9) were also used to look at how the identified biodiversity knowledge had been recontextualised. The South African national curriculum catalogue allows for a maximum of seven textbooks per subject. However, the textbooks have not been specifically identified as the purpose of the study was not to evaluate the textbooks per se, but to highlight the process of recontextualisation from curriculum to textbook and to sensitise future textbook writers to specific aspects of biodiversity content knowledge. For data tracing, the policy documents were labelled CAPS 7, 8 and 9 respectively and the textbooks were labelled T7, T8 and T9.

The study relied on content analysis of documents as its analytic technique. Downe-Wambolt (1992) defined content analysis as a research method that provides a systematic and objective means to make valid inferences from verbal, visual or written data in order to describe specific phenomena. Content analysis can be used on all types of written texts no matter where the material comes from (Berg 2001; Burnard 1991; Catanzaro 1988). According to Cohen, Manion and Morrison (2007), content analysis takes texts and reduces and interrogates these through categories and emergent themes.

For analysis, the study required an understanding of what is meant by 'biodiversity'. The study used Lévêque's (1997) representation of biodiversity at three different levels: species diversity, genetic diversity and ecosystem diversity. To explore the possible scope and depth of biodiversity knowledge in the scientific community, the first phase of analysis in the study identified biodiversity themes that emerged from an inductive analysis of the Millennium Ecosystem Assessment (MEA 2005), and a South African biodiversity document, *Life: The State of South Africa's Biodiversity 2012* (SANBI 2013). The following features of biodiversity knowledge emerged from the analysis of these documents: ecosystem services, biodiversity loss (including threats to and extent of biodiversity loss), conservation and restoration.

Having outlined these themes, the study included a further internal analysis of the curriculum and Grades 7–9 textbooks. To do this we drew on Bernstein's notion of horizontal and vertical discourse to construct an analytic frame for reviewing the **scope, depth, progression, valuing and contextualisation** of biodiversity knowledge. According to Bernstein (2000) the structure of knowledge is just as important as the content of knowledge. Thus, the first three analytic categories were the **scope** and **depth** of the content, and the **progression** of that knowledge from grade to grade. Progression is critical in South African curriculum design due to historical concerns with previous curricula which experienced 'compromised conceptual learning and progression within subjects' (Dada et al. 2009: 24). The interest in scope and progression is consistent with Bernstein's notion of 'vertical discourse', which describes that aspect of a curriculum where knowledge is 'coherent, explicit, [with] systematically principled structure, hierarchically organised' (1999: 159).

Also relevant was Bernstein's (2000) notion of 'horizontal discourse' which he describes as 'a set of strategies which are local, segmentally organised, context specific and dependent, for maximising encounters with persons and habitat'. Ellery (2016: 50) elaborates that horizontal knowledge structures 'develop through competing claims that have an ideological base and are thus much more dependent upon *who* is making the knowledge claim, rather than on *what* is the claim'. Ideological considerations as well as 'who' questions regarding the context of knowledge development and the value of indigenous knowledge are evident in the Natural Sciences curriculum which requires an approach to learning that highlights:

- knowledge in local contexts, while being sensitive to global imperatives;
- the different cultural contexts in which indigenous knowledge systems have developed;
- the contribution of Science to social justice and societal development; and
- the need for using scientific knowledge responsibly in the interest of ourselves, society and the environment. (South Africa DBE 2011: 9)

The ideological interest in this study is captured in the analytic category of **valuing**, and the 'whose knowledge' interest by the analytic category of **contextualisation**.

Research findings

Biodiversity knowledge in international and national documents

The international Millennium Ecosystem Assessment (MEA) and the national SANBI scientific reports analysed for this study present knowledge that allows us to understand the value of biodiversity in the environment as well as how human beings interact with it. They present knowledge of the relationship between diversity and human well-being and the services we get from ecosystems. Among these services that give insight into the value of biodiversity are: supporting services (including soil formation and nutrient cycling); provisioning services (such as food, medicine, health and others); regulatory services (including climate and flood regulation); and cultural (including aesthetic, spiritual, and more) (MEA 2005). There is also coverage of how the loss of biodiversity may damage the Earth's ecological balance, thus disturbing cycles of rain and drought, seasonal temperatures and nutrient exchange. The concept of restoration is covered through cases of re-establishment of habitats, landscapes and biodiversity that have been altered or destroyed. The two documents also describe natural ecosystems in protected areas, national parks, biological reserves and other conservation sectors, thus highlighting the theme of 'conservation' in these documents as well. This analysis indicates that besides **defining biodiversity** and basic **ecological knowledge** (which we expected to find in the curriculum); increased depth of biodiversity knowledge available in the FOP includes **ecosystem services**, **threats to biodiversity** and **conservation and restoration**. These five themes became the themes used in narrating the content of the curriculum and textbook. This analysis is presented below.

Biodiversity knowledge in the CAPS and textbooks

Defining biodiversity

In the Natural Science Senior Phase, there is no explicit distinction between the three components (genetic diversity, species diversity and ecosystems diversity) of biodiversity. However, an important foundational concept for understanding genetic biodiversity is the topic of 'variation within species', which links to the notion of genetic biodiversity in Grade 7. The CAPS and the textbook define species as 'a category within the classification system'. The Grade 7 CAPS uses the concept of biodiversity without fully or explicitly defining it in its explanation that 'plants, animals and microorganisms, and their habitats make up the total biodiversity of the Earth'. The textbook expands on this foundational knowledge by explaining and giving examples of aquatic and desert biomes and how animals and plants need to be physically and behaviourally adapted to survive in these biomes. It illustrates this point through contextualising pictures, such as of the gemsbok, camelthorn tree and social weavers that live in the Kalahari Desert.

Neither the Grade 8 nor 9 CAPS elaborate on a definition of biodiversity. However, the Grade 8 CAPS introduces the notion of, and defines, ecosystems, while the Grade 9 curriculum gives more detail on the notion of species under the topic of cells, explaining that: 'DNA is unique to each person; this variation accounts for differences within species'. Both the concepts of species and ecosystems are therefore introduced at the Senior Phase, but without employing them to define biodiversity specifically.

Ecological knowledge

The Grade 7 textbook extends this initial understanding of ecology and introduces the notion of vulnerability of species through the statement that 'survival of living organisms depends on ecosystems: access to water, air, food, space, favourable temperatures and protection from enemies'. However, ecosystems have still not yet been noted as a concept that Grade 7 learners should know.

In Grade 8, under the topic 'interactions and interdependence within the environment', the concept of ecology is introduced as the study of interactions of organisms with one another and with the physical and chemical environment. The CAPS lists four levels of ecological interactions: populations, communities, ecosystems and the biosphere. The textbook elaborates by defining each of these levels. The level of community is illustrated through a picture showing elephants and thorn trees as part of the community of the Kruger National Park.

In Grade 8, the sub-topic, 'feeding relationships', covers relationships between producers, consumers, herbivores, carnivores, scavengers, insectivores and decomposers. The CAPS and textbook extend this into knowledge about energy and nutrient flows. They follow this with ecological knowledge about food chains, food webs and trophic levels.

Ecosystem services

Examples of the notion of ecosystem services in Grade 7 are limited. One example is a 'did you know box' in the textbook, giving a contextualising example under 'living organisms'. This insert illustrates provisioning services, namely a description of how the seedpods of the camelthorn tree, *Erioloba acacia*, are made into a nutritious porridge and eaten by local people.

The Grade 7 CAPS also provides foundational knowledge for understanding regulatory services through the topic of 'pollination' under 'sexual reproduction'. An important human-environment relationship covered in this section is how pollinators play a key role in the production of food crops (such as maize) for humans. This example is a problematic one as maize is pollinated by wind, not pollinators such as insects, birds or mammals (the examples of pollinators given in the curriculum). The textbook explains pollination and adaptations by plants for pollination by wind and insects but does not highlight the human-environmental relations in terms of pollination of food crops which might have been elaborated using accurate examples such as beans, pumpkin or many other examples.

In the Grade 8 CAPS and textbook, relationships between humans and the environment are highlighted in the main topic, Interactions and Interdependence within the Environment – although humans are not necessarily always included in this notion of interdependence. The textbook only acknowledges humans within this interdependent system by including a number of examples that begin to illustrate ecosystem services:

- An explanation of how some micro-organisms are used by people for making certain foods (such as yoghurt) and medicines such as penicillin (provisioning services).
- Examples of indigenous plants which often contain ingredients that can be used for medicines (provisioning services).
- Discussion of how nature reserves give people great pleasure and are tourist attractions (cultural services).
- Description of the role of wetlands in filtering and cleaning water, controlling and reducing its flow (regulatory services).

The Grade 9 CAPS policy document did not continue with this focus on ecosystem services content.

Threats to biodiversity

The Grade 7 CAPS does not explicitly deal with threats to biodiversity, but without understanding the multitude of different types of living organisms on Earth and the notion of 'variation' (the foundational knowledge described above), learners might struggle to understand the significance of individual species and whole groups of organisms becoming extinct.

The textbook, however, implicitly opens up the notion of 'threats' and includes a section on how exotic plants can become alien invaders. This concept was broadened by a case study on 'Humans and Aliens and how Port Jackson, *Acacia saligna*, was introduced to the Western Cape from Australia and it resulted in habitat loss'.

The Grade 8 curriculum has extensive coverage of threats to biodiversity, even if not explicitly labelled as such. The CAPS includes a focus on how organisms that are 'unable to adapt to changes within the environment die out and become extinct'. The concept of extinction is broadened by the textbook, which explains that species that are less well adapted in the environment do not reproduce, disappear from the ecosystem and become extinct.

In the Grade 8 textbook, the energy flow sub-topic helps learners to evaluate the effect of removing an organism from a food web. This helps to underpin an understanding of biodiversity loss and to make judgements about the complex network of interactions in an ecosystem. For example, the question was posed: 'What will happen to the population of rats and mice if they are not being preyed upon by hawks?' Other questions were: 'What could happen to the population of mongoose because of the change in population size of the rats and mice? Could the loss of hawks affect the population of hadeda ibis? What other populations might be affected by the loss of the hawks in this food web?'

The Grade 8 CAPS includes a focus on understanding that an ecosystem can only accommodate as many organisms as its resources (food, water and shelter) can carry, and will fail if it does not remain in balance. According to CAPS, 'adaptation is the change in the structural, functional and behavioural characteristics of an organism'. It states further that adaptation allows the organism to survive as it adapts to changing conditions within the environment. The textbook presents knowledge on how structural and behavioural features of animals and plants enable them to survive in their habitat. Under the topic of adaptation, the textbook used in this study elaborates on the concept of 'indigenous' and explains how indigenous animals are better suited for our environment, naming examples of South African fauna and flora that are of value to humans, such as bat-eared foxes that eat pests such as rats and white ants. These notions of balance and adaptation illustrate the vulnerability of ecosystems and thus are critical to a foundational understanding of threats to biodiversity.

The CAPS and textbook further mention knowledge that is foundational to understanding biodiversity loss: namely how natural factors, which include extreme changes in patterns of weather and climate such as floods, drought and extreme and sudden changes in temperature, can harm ecosystems. In Grade 8, the relationship between humans and environment is noted, and the CAPS describes humans as 'interfering' and provides examples of 'litter … pathways … and cutting of firewood'. Furthermore, the textbook explains human factors that cause disruption of the world's ecosystems. For example, people cause harm when they remove the animals and plants that were in balance with the ecosystem, through hunting, poaching, burning and cultivating land. Later in the textbook, acid rain is mentioned as a threat that destroys life in many rivers and damages plants.

The Grade 8 CAPS prescribes an assessment task where learners 'evaluate disruptions to an ecosystem giving causes, effects and solutions'. The textbook gives an activity for learners to investigate examples of human interferences in their area. The concept of biodiversity threats is also broadened by discussions in the textbook using examples of research case studies that can be explored by learners. The first research study is about lack of food in a game reserve due to drought in Tsavo National Park, Kenya; the second covers habitat destruction due to farming; the third involves conversion of Brazilian rainforest into grass for cattle ranching and reduced migration due to fencing in game reserves; the fourth is about the need to cull elephants in Kruger National Park; the fifth considers the effect of hunting which brought about the extinction of the quagga in the Karoo; and the last is about mining, specifically the effect of titanium mining on coastal sand dunes.

Notably, all the biodiversity knowledge presented up to this point in the Senior Phase Natural Science curriculum falls under the knowledge strand of 'Life and Living', which forms the backbone of the Life Sciences subject in Further Education and Training. The examples that follow of mining and the greenhouse effect fit under the

'Earth and Beyond' knowledge strand, the backbone for Geography; and the example of waste and recycling falls under the knowledge strand 'Matter and Materials', the backbone of Chemistry. These strands and their link to biodiversity are now discussed in more detail.

The Grade 9 CAPS prescribes the topic of 'threats' caused by mining in South Africa. According to CAPS, there is large-scale mining activity in South Africa which causes significant environmental impacts such as creation of mine dumps, pollution of water resources, damage to places with high tourist or cultural heritage value, and loss of farming and wildlife habitat. While biodiversity loss is not explicitly discussed here, these environmental issues can be directly related to biodiversity loss. The textbook repeats the lists of environmental issues associated with mining.

The Grade 9 CAPS prescribes knowledge, supported by the textbook, of how 'greenhouse gases trap ultraviolet radiation', which then warms the air closest to the surface of the Earth like inside a greenhouse. However, this is a misconception and ignores the subtlety of the role of ultraviolet and infrared in global warming. The CAPS and textbook list the most common greenhouse gases as carbon dioxide, water vapour and methane, and mention that an increase in greenhouse gases leads to global warming. The textbook further adds that the greenhouse effect is a natural phenomenon and that it warms the atmosphere sufficiently to sustain life, going into a bit more detail than what is outlined in the CAPS.

Both the Grade 9 CAPS and the textbook present knowledge for understanding the effects of climate change on human health, photosynthesis, life cycles and population size of species. The textbook adds that global warming is a potentially life-threatening problem on Earth. Both CAPS and the textbook explain that global warming could lead to climate change, rising sea levels, food shortages and mass extinctions. Mass extinction is one aspect of biodiversity loss, but does not capture all the nuances and aspects of biodiversity loss.

Conservation and restoration

No discussion of conservation or restoration actions are prescribed in the Grade 7 CAPS or textbooks.

Under the topic 'Conservation of ecosystems' the Grade 8 CAPS includes knowledge for managing ecosystems and preservation of wetlands. For example, the policy prescribes knowledge that 'environmentalists and others work towards managing ecosystems, such as control of alien vegetation'. The textbook includes a focus on how natural habitats that are conserved can generate money which can be used for the maintenance and development of protected areas. The textbook contextualises this by describing the Maloti/Drakensberg Transfrontier Conservation Area, which was established to protect the special ecosystems of the area and the water supply which originates there. This document also lists how individuals can contribute to conservation in various ways, such as through appropriate waste disposal that includes recycling and re-using.

The Grade 9 CAPS does not prescribe conservation and sustainability with respect to biodiversity. However, the textbook presents content about the Department of Minerals and Energy regulations regarding ecological health within the mining industry in South Africa. It includes knowledge on what can be done to slow global warming. It states that governments need to take drastic action to cut back the use of fossil fuels, although this is not easy because the economy depends on electrical power. It is in Grade 9 where the important foundational knowledge of the social-ecological complexity of sustainability is implicitly addressed.

Summary of findings and emerging recommendations

The chapter introduced its interest in the scope, depth, structure, nature and contextualisation of biodiversity knowledge. Table 1 below shows the **scope of concepts** under the five dimensions of biodiversity identified as relevant for a **depth understanding** of biodiversity. Each of these concepts is considered in terms of **progression** in the Senior Phase curriculum for Grades 7, 8 and 9. This makes it possible to see how one concept builds on the other. Finally, Table 1 gives examples of how the different concepts are **contextualised** by both the CAPS and the textbooks.

Table 1. Summary of Grade 7, 8 and 9 CAPS curriculum and textbook analysis

CONCEPTUAL DEPTH	CONCEPTUAL SCOPE	PROGRESSION Grade			ILLUSTRATIVE EXAMPLES CAPS OR TEXTBOOK (TB)
		7	8	9	
Concepts used in Defining Biodiversity	Species	✔	✘	✘	
	Biome	✔	✘	✘	Aquatic & desert examples (Grade 7 TB)
	Ecosystem	✘	✔	✘	
	Variation within species	✔	✔	✔	
Further Ecological Concepts and Principles	Ecology and interaction	✘	✔	✘	
	Interdependence (populations, communities, ecosystems, biosphere)	✘	✔	✘	Elephants in Kruger Park (Grade 8 TB)
	Feeding relationships (food chains and webs)	✘	✔	✘	Bat-eared foxes, ants and rats (Grade 8 TB)
	Food pyramids and trophic levels	✘	✔	✘	
	Energy flows	✘	✔	✘	
	Nutrient flows	✘	✔	✘	

CONCEPTUAL DEPTH	CONCEPTUAL SCOPE	PROGRESSION Grade 7	8	9	ILLUSTRATIVE EXAMPLES CAPS OR TEXTBOOK (TB)
Ecosystem Services	Provisioning	½	½	✘	Camelthorn seeds used for human porridge (Grade 7 TB); micro-organisms for food and medicine & plants for medicine (Grade 8 TB)
	Cultural	✘	½	✘	Tourism (Grade 8 TB)
	Regulatory	½	½	✘	Pollination (Grade 7 TB); Wetlands for purifying water (Grade 8 TB)
Threats to Biodiversity	Survival and adaptation	✔	✔	✘	
	Habitat loss	✔	✘	✘	Port Jackson invasives causing habitat loss (Grade 7 TB)
	Species extinction	✘	✔	✘	
	Food web disruption	✘	✔	✘	Effects of removing populations from food web (Grade 8 TB)
	Natural threats	✘	✔	✘	
	Human threats: litter, cutting trees (CAPS); hunting, poaching. cultivating, acid rain (TB)	✘	✔	✘	TB cases: Drought in nature reserve, habitat destruction and farming, rainforest loss in Brazil, elephant culling, hunting quagga to extinction, mining & effect on dunes.
	Greenhouse effect (affects biodiversity)	✘	✘	✔	
	Mining of minerals (Environmental impact)	✘	✘	✔	
Conservation	Ecosystem management	✘	✔	✘	Maloti/Drakensberg Park (Grade 8 TB)
	Ecosystem conservation	✘	✔	✘	Wetland preservation (Grade 8 CAPS)
	Individual re-use and recycling	✘	✘	✔	
	Global warming mitigation	✘	✘	✔	

✔ present; ✘ absent; ½ present but only implicitly

From Table 1 we can see that, regarding conceptual scope, key ecological concepts are introduced in Grade 7. These then form the foundation for understanding more complex relational interactions, as ecological concepts and principles are introduced in Grade 8. Grade 8 thus stands out as a particularly important grade for environmental learning, where the understanding of ecological principles offers an important foundation for forming arguments about human impact in Grade 11.

Also significant for understanding human impact in Grade 11 are the Grade 8 emphases on particular human activities that all have some impact on biodiversity (hunting, poaching, drought, farming, rainforest destruction and mining), and the addition of waste management and global warming in Grade 9. In Grade 9, these ecological principles form an important foundation for knowledge of ecosystem conservation and management. Thus, there is a logical progression from grade to grade and an increase in depth of knowledge from basic understanding of ecological principles to understanding the consequences of disruption and how human agents can respond and impact positively through restoration and conservation.

In order for the full potential of the scope and depth of the curriculum to be met, however, the incremental progression from grade to grade is something that needs to be drawn to the attention of teachers. For teacher training, this highlights the criticality of implementing revisions from grade to grade and for teachers to be reminded that they should use the concepts taught in previous grades to help learners to build understanding and arguments. There are suggestions that perhaps this critical aspect of curriculum progression is not being implemented in classrooms as indicated. This is evidenced, for example, by the 2015 National Senior Certificate diagnostic report which suggests that 'teachers might be neglecting to cover basic concepts effectively in the process of progressing to higher-order aspects of topics' (South Africa DBE 2016: 6).

Another progression concern raised in this study is the problematic explanation of the greenhouse effect as described in the findings. Global warming is a concept that is becoming more and more integrated into different subjects in the higher grades, including the Life Sciences. This is an example of misleading information that could result in the kinds of confusion around global warming described by Lotz-Sisitka and Mandikonza in Chapter 6 and Chitsiga and Schudel in Chapter 9. Recommendations from this study are that curricula and textbooks need to be carefully read, as well as offer a more accurate representation of global warming, as evidenced in the following extract:

> Energy from the sun enters the Earth System in the form of short-wave [ultraviolet] radiation … Only about half of the radiation arrives at the Earth's surface. Because the Earth is much colder than the sun, it radiates some of this absorbed energy back into the atmosphere in the form of long-wave [infrared] radiation. The atmosphere, which is made up of various gases including carbon dioxide and water vapour, selectively absorbs this longer wavelength radiation. These gases in turn re-radiate this energy back into the atmosphere and then back towards the Earth. (Vogel et al. 2013: 20)

Accuracy is not the only aspect of the curriculum affecting progression here, but also subject boundaries. The socio-ecological nature of environmental learning requires complex understandings that move across disciplinary boundaries. Natural Sciences includes topics conventionally seen within the Earth Sciences and climate change is one of these. In the Grade 7–9 CAPS the topic is within the knowledge strand 'Earth and Beyond' which evolves in higher grades into Geography. It is notable that, for learners of the Life Sciences higher grades who are not concurrently taking Geography, this brief introduction to climate change is their only engagement with the topic until the Grade 11 segment is introduced as part of a range of 'human impact' topics. Thus, an emerging recommendation is that continuity in the topic of climate change be explored from a Life Sciences perspective, as the prevailing situation might also explain why this topic, when examined in the final year of schooling, is poorly achieved.

Table 1 also illustrates the important role of the textbook in contextualising the curriculum concepts. The CAPS curriculum rarely makes reference to case studies that contextualise biodiversity. Notably, the examples provided by textbooks appropriately span specific species, specific ecosystems, specific relationships and specific management areas. In one case, an example from beyond South Africa, in Kenya, is given. Another case uses an example from outside Africa, that is, the Brazilian rainforest. While there are obvious time limitations in the curriculum coverage, there may be room for suggesting other African case studies, and particularly comparative studies between South Africa and other countries. This would serve to celebrate not only the local biodiversity but also the extensive global biodiversity. For example, if wetlands are studied, it may be instructive to compare the South African Ramsar protected sites with other wetlands around the world that have similar status. The international document studied in the FOP for this research is an example of where curriculum and textbook developers could conduct research for ensuring a local, regional and international contextualisation of biodiversity studies.

This leads to reflections on the ideologies inherent in biodiversity knowledge. For example, while the textbook makes implicit deference to South African biodiversity, the CAPS makes no explicit reference to the importance of recognising biodiversity that is indigenous to South Africa. The notion of 'alien' vegetation is introduced, however. This seems an illogical omission in the CAPS curriculum as one would need to know what the concept 'indigenous' means before one can understand what is 'alien' in relation to this. Therefore, a further recommendation from this study is for the progression of the concept of 'indigenous' to be carefully tracked in the next curriculum revision.

A second aspect of the ideologies inherent in the biodiversity knowledge presented in the CAPS and textbooks is how humans are presented as 'interfering' (which might have similarities to the survivalism discourse discussed by Isaacs and Olvitt in Chapter 4). This is problematic for two reasons: first, seeing humans as 'interfering' problematises human engagement in their environment, rather than highlighting a more positive human role in sustainability practices. Sustainability practices could bring a crucial changed perspective to the 'conservation and restoration' focus of Grade 9, and also to relationships between people and environment in the earlier grades.

Second, it is problematic because 'interference' implies the separation of humans from nature – a long-disputed perspective in the environmental field; whereas the focus should rather be one that is 'committed to achieving sustainable development in its three dimensions – economic, social and environmental – in a balanced and integrated manner' (United Nations 2015: 6). The international and national documents studied for this research as representative of the FOP for biodiversity knowledge illustrate how ecosystems provide the conditions for a healthy environment in which humans are accepted and able to draw on its resources (MEA 2005; SANBI 2013). This is where the second fundamental difference between the FOP, ORF and PRF in the pedagogic device becomes clear.

Conclusion

This chapter has conducted a detailed analysis of biodiversity knowledge in a specific curriculum and supporting textbooks. To do so, it has illustrated a methodology for document analysis that includes a focus on recontextualisation across the pedagogic device as combined with an internal analysis of the scope, depth, progression, valuing and contextualisation of curriculum concepts within the ORF and PRF.

Using this analysis strategy, it has made recommendations for curriculum and textbook revision in South Africa regarding checking for progression of the concept of 'indigenous', and for accuracies and continuity (especially around climate change knowledge). It has made suggestions for ensuring a balance of local, regional and international coverage of contextualising case studies and suggested that the perspective of humans as 'interfering in nature' ought to be reviewed and reconsidered. These latter two reviews could be achieved by drawing on key documents in the FOP. We suggest that this kind of coherence across the pedagogic device is critical if the logical structure of the parent discipline is to be made visible to learners (Abrie 2016).

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CHAPTER 4

An Exploration of what Grade 7 Natural Sciences Teachers Know, Believe and Say about Biodiversity and the Teaching of Biodiversity

Dorelle Isaacs and Lausanne Olvitt

Introduction

This chapter shares the findings of a small-scale qualitative research project that investigated what three Grade 7 Natural Sciences teachers know, believe and say about biodiversity (Isaacs 2016). The study was sparked by the researcher's interest in environmental learning and the importance of school curricula in preparing children to take care of their local and global environments.

Biodiversity refers to Earth's rich variety of plants and animals. It has been described as 'the complex web of life' that includes diversity at genetic, species and ecosystem levels (Gurr et al. 2012: 4). The concept came to prominence in 1992 when the United Nations' Convention on Biological Diversity defined biological diversity as 'the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems' (United Nations 1992: Article 2).

South Africa is celebrated for its biodiversity. The South African National Biodiversity Institute (SANBI) reports that the country is home to an estimated 67 000 animal species and over 20 400 plant species. This diversity of species occurs within nine biomes (such as the fynbos, Nama-Karoo and forest biomes) and a total of 458 types of terrestrial ecosystems. South Africa also boasts exceptional marine biodiversity, including 150 marine ecosystem types (such as kelp forests, sandy shores and shallow reefs) (SANBI 2019).

Alarmingly, numerous scientific reports confirm that Earth's biodiversity, including South Africa's, is deteriorating faster than ever before recorded in human history (United Nations 1992; MEA 2004; IPBES 2019; SANBI 2019). This is cause for concern because 'nature plays a critical role in providing food and feed, energy, medicines and genetic resources and a variety of materials fundamental for people's physical well-being and for maintaining culture' (IPBES 2019: 3). Aside from the obvious consequences for human well-being, biodiversity loss raises important questions about human values and our moral obligation to restore – or at least prevent the further loss of – biodiversity. Quality teaching and learning about biodiversity at school is therefore a very important building block for children's ability to understand and care for the natural world that sustains them.

In the Grade 7 Natural Sciences Curriculum Assessment Policy Statement (CAPS), biodiversity is presented as a concept to be explored during Term 1. Biodiversity is allocated three and a half weeks of teaching, covering the following: biodiversity (the classification of all living things); the diversity of animals; and the diversity of plants (South Africa DBE 2011: 13). Biodiversity as a topic is preceded in Term 1 by one week of teaching about the biosphere, which includes the lithosphere, hydrosphere and atmosphere where all life exists. However, despite its inclusion in the formal curriculum, biodiversity as a concept and topic for classroom teaching is not well understood or well taught by many teachers. Research by Songqwaru (2013) reported that many of the Life Sciences teachers in her study had content gaps and lacked confidence in teaching environment and sustainability content knowledge. This led them to rely heavily on textbooks even though, in some schools, teachers had access to only one textbook.

It is against this backdrop that Isaacs's study set out to answer the following research question: What do Grade 7 Natural Sciences teachers know, believe and say about biodiversity and the teaching of biodiversity?

Four sub-questions guided the inquiry:

1. What knowledge do teachers have of biodiversity?
2. How do the teachers represent biodiversity: for example, which biodiversity narratives and metaphors are evident in their discourses?
3. What beliefs and values of biodiversity do the teachers hold?
4. What accounts do the teachers give of why they teach biodiversity in the way that they do?

The following section outlines the main theories and concepts that were significant to the study and which guided the data analysis. Thereafter, we describe the research methodology, present extracts from the data and provide a discussion of the research findings and conclusions.

Guiding theories and concepts

The wide-ranging foci of the research questions required a range of theories that could guide interpretation of the data. Shulman's (1987) work on teacher cognition, especially teacher knowledge, was helpful in analysing the teachers' biodiversity knowledge, whereas literature on environmental discourses and metaphors was needed to analyse what was said about biodiversity. Many of the teachers' narratives revealed their values and ethics, and so the researcher turned to a framework developed by Kronlid and Öhman (2012) to analyse different environmental ethics positions. These guiding theories and the concepts associated with them are outlined below and summarised in Figure 1.

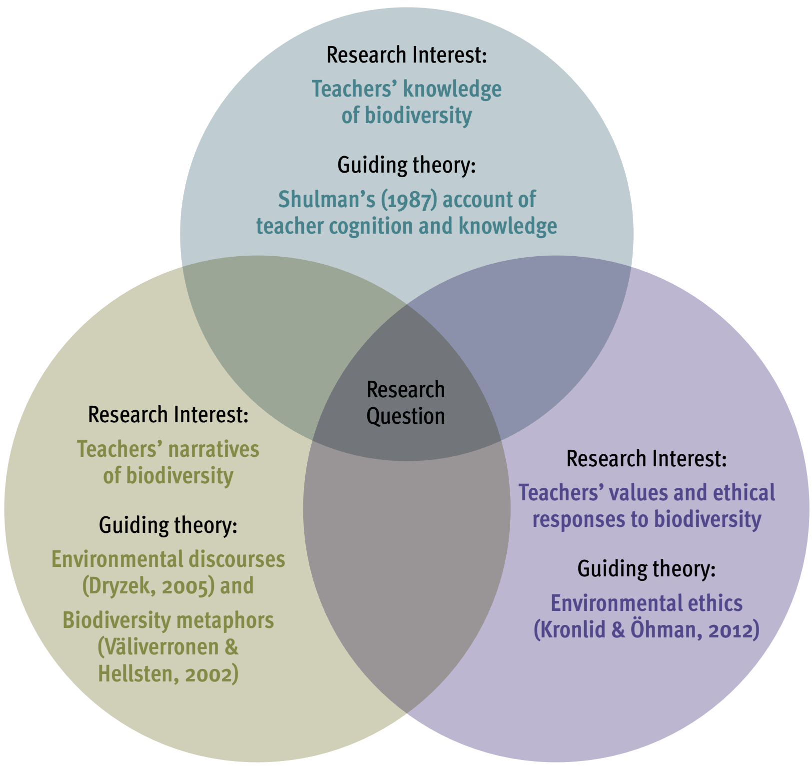

Figure 1. Schematic of different theories used in the study to guide analysis of different aspects of the data – all centred around the Research Question

Knowledge as a key dimension of teacher cognition

As far back as 1986, Lee Shulman, an American educationist specialising in teacher education and cognitive psychology of instruction, argued that the knowledge base of education is growing, that knowledge is a vital part of teacher education, and that it should be available for teacher practice (Shulman 1987). Shulman proposed that,

> the teacher must have not only depth of understanding … but also a broad liberal education that serves as a framework for old learning and a [capacity for facilitating] new understanding. (1987: 9)

Shulman identifies four main sources for a teacher's knowledge base. These are:

a) *Content knowledge in subject disciplines*. This refers to the knowledge, understanding and skills that a teacher has. This content knowledge is derived from accumulated literature on the content as well as historical and philosophical background to the content knowledge and alternative theories about it.
b) *Learning and teaching support materials and the education system*. This includes textbooks and school resources, curricula, the structure of the school and its governance, the teaching profession and its rules, teacher unions, and finance. Significant organisations like the school governing body, the staff and the unions' perceptions of biodiversity may determine to what extent the teacher will receive support for biodiversity teaching, especially in terms of going on field trips, and purchasing resources like projectors and internet data to access biodiversity information. Teachers commonly acquire biodiversity content knowledge from the prescribed textbooks, although more extensive knowledge is available through multimedia resources and local experts.
c) *Social and cultural phenomena*. This includes any developmental, social (including research), or cultural phenomena that may impact on teaching, teachers and education. Teachers who have access to developmental programmes such as Fundisa for Change will be exposed to biodiversity knowledge and effective teaching methods. Teachers may also participate in citizen science projects and access databases such as the IUCN Red List of Threatened Species.
d) *Wisdom of the teaching practice*. This includes teachers' values and principles that guide their practice. Learners will be influenced by how teachers dispose of their waste at school, how they manage water, what living things they bring into the classroom, how they respond to fauna and flora that they encounter, and what they grow and maintain around the classroom and in the school grounds.

Environmental discourses

Discourses are established ways of talking and writing about the world; they use certain commonly understood concepts, words, styles of narration and imagery. Once aware of the range of discourses that occur in society, a careful listener can identify, for example, a *Christian* discourse, a *racist* discourse, a *feminist* discourse, and so on. Because discourses reflect the views, judgements and differences of groups of people, they provide a good starting point for reflection and deliberation.

As environmental concerns such as climate change and biodiversity loss come to prominence in society, environmental discourses are developing and receiving more critical attention (Olvitt 2016). The research study elaborated in this chapter drew on John Dryzek's (2005) analysis of environmental discourses to get a better understanding of how the three teachers represented biodiversity concepts such as ecosystems, food chains, habitats and biodiversity loss. The study drew on four environmental discourses which are introduced below: Apocalyptic discourse; Sustainable Development discourse; Survivalism discourse; and Promethean discourse (Dryzek 2005).[1]

Apocalyptic Discourse

Apocalyptic refers to environmental catastrophe due to the ignorance or greed of humans and their desire to dominate and control the natural world. The apocalyptic or doomsday discourse portrays nature as threatened by human expansion and greed and is characterised by use of metaphors such as 'population bomb' and 'war against nature' (Väliverronen 1998; Väliverronen & Hellsten 2002). Within this discourse, biodiversity could be represented as all forms of nature (oceans, forests, grasslands, and so on) that are battling to survive in the face of human destruction. Such a discourse can lead to a sense of hopelessness, but it can also lead to action. The main advantage of the apocalyptic discourse is that it seems to be a powerful trigger for people to protect the environment. One of its disadvantages is that people may be left feeling hopeless, fearful and paralysed to act.

Sustainable Development Discourse

The discourse of sustainable development emphasises connections between the environment and the economy and uses metaphors such as 'we are all in the same boat' and 'spaceship earth'. The well-being of people and natural ecosystems now and into the future is tied up with politico-economic systems. Within this discourse, biodiversity is commonly represented as a vital *resource* for human survival and development. An illustration of this can be seen, for example, in the way the Millennium Ecosystem Assessment (MEA 2005) emphasises the importance of ecosystems in providing regulatory, supporting, cultural and spiritual 'services' to humans.

Survivalism Discourse

According to Dryzek (2005), the discourse of Survivalism is based on the understanding that Earth's resources are limited and that, although economic growth is important, economic systems function *within* ecosystems – which are finite. Therefore, if people's

1 Of course, in society we seldom encounter environmental discourses as neatly as they are described here. They are sometimes quite subtle, and more than one discourse can be evident in a single text (Olvitt 2016).

activities exceed the Earth's carrying capacity, ecosystems will be destroyed and people will not survive. The main proponents of the Survivalist discourse are experts in economics, politics and the sciences, for example, scientists who would prefer a hierarchical, authoritarian government and administration to ensure that Earth's resources are used responsibly.

Promethean Discourse

The Promethean discourse takes its name from Greek mythology where Prometheus stole fire from the god Zeus and this gave him the power to control the world. In contrast to the Survivalism discourse, people who subscribe to the Promethean discourse believe in humanity's ability – together with technology – to solve any problem. They assume that nature has an over-abundant supply of resources and that nature is always giving and creating, despite how badly people treat nature. Users of the Promethean discourse believe in economic growth above all, and see the natural environment as a material resource that is there to serve the economy.

Biodiversity metaphors

Since the 1960s, biodiversity has been an important concept within all environmental discourses. Of interest to environmental educators is how the concept of biodiversity gets used, by whom, and for what purpose. This section focuses on common metaphors that are used in environmental discourses when referring to biodiversity.

Metaphors function as conceptual tools for conveying abstract ideas in concrete, accessible ways. They contribute to discourses and are used to help people make sense of the world (Nerlich 2010). According to Väliverronen (1998), metaphors in environmental discourses (such as the 'ozone hole' and 'the greenhouse effect') are able to influence social conduct and perception, and they perform important communicative and connective functions. Communicatively, metaphors help to create common ground between scientists, politicians and teachers for making sense of difficult concepts such as biodiversity. In a connective role, metaphors connect different disciplines and institutions, making biodiversity knowledge common and shared.

Biodiversity is a complex concept and so scientists and educators often make use of metaphors to convey the concept of biodiversity and its importance. Väliverronen and Hellsten (2002) reviewed the most popular metaphors used in representations of biodiversity since the 1990s:

- One metaphor represents biodiversity as 'the library of life' or 'the book of life', which implies that the natural world is a collection of knowledge and information that can build links between scientific knowledge, political action and popular images.
- Biodiversity is also often spoken of in terms of 'bioprospecting' or 'biotic exploration' which evokes images of exploration, breaking new

ground or exploring new frontiers, and a sense of 'there's more out there that we don't know'.

- Biodiversity is also frequently referred to as a 'web' or 'network of relations' between humans and non-humans. It is thus seen as a system of relations of which humans are an integral part (Väliverronen & Hellsten 2002).

A Framework for considering teachers' values and ethical responses to biodiversity

Another important aspect of this study was to understand the teachers' sense of personal connection to biodiversity: did it matter to them? Did they feel personally compelled to protect biodiversity? Did they seek to develop their learners' ethical commitment to protect biodiversity? For this, the researcher drew on Kronlid and Öhman's (2012) framework for analysing ethical responses to the natural world.

Many environmental ethics frameworks represent anthropocentrism (a human-centred position) and bio- or ecocentrism (a nature-centred position) as a simplified 'either/or' debate. In an effort to move away from over-simplified or unrealistic analysis, Kronlid and Öhman propose a combination of *value-orientated* and *relation-orientated* environmental ethics, based on three moral questions:

a) **Who or what is the *moral object*?** I.e. what is the focus of people's concerns that drives them to take moral action for nature? For example, if someone refuses to chop down a big old tree in their garden, is it because they care about the tree (for its own sake), or the shade that the tree provides, or the birds that nest in the tree, or because the tree has cultural significance (where culture is the moral object), or ecological significance (where integrity of ecological systems is the moral object)?

b) **What are the human-nature relationships like?** For example, are people's relationships with nature seen as intergenerational? Are they local, national or global? Are they based on a view of people as stewards of creation, or people as a humble part of a complex web of life, or people who have dominion over natural resources to exploit according to their needs?

c) **How is nature valued?** For example, do people value nature because natural resources meet human needs or human desires? Or is nature valued because people are part of nature, or because nature is dynamic and has the potential to transform people and society?

When applied to the case study data, Kronlid and Öhman's framework was useful because it offered a perspective on the teachers' values and ethical positions regarding biodiversity and the way they approach teaching biodiversity.

Research methodology

The study focused on three Natural Sciences teachers from three primary schools in Port Elizabeth in the Eastern Cape province of South Africa. All three teachers worked in government no-fee schools that fall under the Port Elizabeth Education District. All three schools had high learner enrollment of between 1 000 and 1 200 learners with a staff of between 30 and 33.

Permission to conduct the study was granted first by Rhodes University and subsequently by the Eastern Cape Department of Basic Education. The three anonymised teachers and the Natural Sciences Senior Education Specialist all gave their voluntary informed consent to participate in the research.

The case study data was generated using three qualitative research methods: (i) classroom observations (one session per teacher, when teaching the topic of biodiversity during Term 1); (ii) semi-structured interviews (with the three teachers and a Department of Education official); (iii) document analysis (a review of the CAPS Natural Sciences Grade 7 policy documents and relevant extracts from the Grade 7 Natural Sciences textbooks used by the teachers).

The raw data generated from these methods was coded according to the following analytical themes:

- Teachers' knowledge about biodiversity
  - Teachers' representations of biodiversity
  - Biodiversity narratives
  - Biodiversity metaphors
  - People-nature relationships
  - The moral object
  - Intrinsic or instrumental value
  - Anthropocentric or non-anthropocentric
- Teachers' beliefs about, and values of, biodiversity and the importance of teaching biodiversity
- Teachers' decisions/reflections on their approach to teaching biodiversity:
  - Own classroom practice
  - Contextual factors

Case Study 1: Lance at Seaview Primary School

Lance is a qualified Commerce teacher with seventeen years' experience teaching English, Economic Management Science and Social Sciences at high school level. However, for the past two years he has been teaching Grades 6 and 7 Natural Sciences at Seaview Primary in Port Elizabeth. The school is situated in a low-income, high-density suburb that is surrounded by a sprawling informal settlement with very low levels of biodiversity. Learners are exposed to high levels of poverty, violence, gangsterism and abuse. The school is fenced, with two police reservists manning the gate daily from 8.00 a.m. to 3.00 p.m. to protect learners and teachers from crime and gangsters.

Lance's views on biodiversity were influenced by childhood experiences such as camping and visiting natural areas. In his opinion, he had good Biology teachers at school and was socialised to respect animals and all living things. Lance's environmental discourse suggests that, although humans threaten nature, there is cause to be optimistic about the future. He said, 'The Earth is still busy proving itself … each day [scientists] discover new species and they are just becoming more and more as time goes by.' He did not seem aware of the rapid rate of global biodiversity loss and the consequences for a sustainable future. Lance's positive view of the natural environment was further illustrated by his description of biodiversity as 'bright, life and continuity' and 'biodiversity is like jelly tots [multi-coloured sweets], different colours, different flavours, it's just like species of animals' (Isaacs 2016).

Lance feels that the two days' training he received the previous year was not enough to prepare him to teach the CAPS curriculum. He also feels limited by the school's lack of resources (such as microscopes) which affects his teaching of biodiversity. Before his lesson on biodiversity, Lance consulted his CAPS document to see what he had to teach and then used one textbook to support his lesson. The textbook defined biodiversity as, 'all living things on the Earth, all the plants, animals and micro-organisms and their habitat together forms biodiversity on Earth'. This definition does not refer to ecological systems or interconnectedness. The pictures of animals in the unit on biodiversity resembled passport photos, that is, a snapshot of the animal only. They did not reveal the animals' relationship to other animals, humans, vegetation or the climate. Similarly, Lance only spoke of animals and plants in isolation and not in relation to each other. In his lesson, the learners identified different animals, birds and fish. After he gave a definition of biodiversity, Lance taught classification and the distinguishing characteristics of animals and the five Kingdoms. He asked the learners to identify the life processes of the five Kingdoms, as depicted in the textbook.

Case Study 2: Pam at Palm Plains Primary School

Pam has been a primary school teacher for 22 years. She currently teaches at Palm Plains Primary School in a middle-class suburb in Port Elizabeth. Although it is a mainstream school, about 45% of the learners have special educational needs which places a strain on the tuition.

Pam reflected that her childhood in the rural Eastern Cape laid the foundation for her understanding of biodiversity. She was surrounded by livestock and it was easy for her to go to the river to catch crabs and insects, which she stored in bottles to show her teacher. Pam notes that it is difficult for her learners to do the same because there are no rivers or open spaces near their homes in the high-density suburbs.

Pam obtained her biodiversity knowledge mostly from the Grade 7 Natural Sciences textbooks she uses to teach the topic. She recognises that biodiversity has intrinsic value but, more importantly, biodiversity should be protected because it provides for human needs. Pam believes that human beings are individually responsible for biodiversity because God ordered people to be responsible for all that He created. However, like Lance in Case Study 1, Pam believes that there is an abundance of natural resources and that animals will always be there. She explained in an interview that, 'the animals won't decrease in number, the animals will always be there … because reproduction is still there'.

Pam believes that teaching biodiversity is like teaching 'the old Biology'. For the observed lesson, she drew on three textbooks which she believes are well aligned with CAPS. A general feature of all three textbooks was their provision of very clear definitions and detailed examples of vertebrate and invertebrate species, but always in isolation. Biodiversity is thus constructed as a list of living organisms to be classified, not as a complex ecological phenomenon that includes human beings.

So, guided by CAPS and the textbooks, Pam's lesson focused on classification, in particular classification of vertebrates in the Animal Kingdom. She did not define biodiversity at all. Before she asked the learners to classify the pictures of animals into the five classes, she taught the characteristics of the five classes of vertebrates.

Case Study 3: Mandy at Omega Primary School

Mandy, a Natural Sciences teacher with 25 years' teaching experience, teaches at Omega Primary School situated within a low-cost housing development on the outskirts of Port Elizabeth. She completed her schooling and teacher training in the rural Eastern Cape during the early 1990s when primary school science teaching was approached very differently.

Similarly, to Lance and Pam, biodiversity was a new knowledge area for Mandy and most of what she knows about the topic comes from the CAPS-aligned textbooks that she uses. She felt that she had not been sufficiently prepared by the Department of Basic Education to teach biodiversity.

Mandy defined biodiversity as, 'the variety of living organisms in a particular area', and later as a 'good picture … all about plants and animals'. She appeared to value biodiversity primarily because it meets humans' needs and stimulates economic activity. For example, she explained that 'we need [animal skins] to make leather jackets, to make us warm', and 'we get food from plants … sell some of these, export some of the food'.

Mandy feels that although the biodiversity topic was not difficult for Grade 7, it was too long, with many new concepts for the learners to grasp. In her lesson, Mandy used sentence strips to help learners understand the definition of biodiversity. After that, she had the learners classify the plants and animals. She then taught the difference between plants and animals; she introduced the Plant and Animal kingdoms and then, within the Animal kingdom, defined vertebrates and invertebrates. She taught the five classes of vertebrates before giving the learners an activity where they had to identify vertebrates in the five classes. Mandy used two textbooks extensively for biodiversity knowledge and activities.

Research findings

This section summarises the main research findings in relation to the initial research question: 'What do Grade 7 Natural Sciences teachers know, believe and say about biodiversity and the teaching of biodiversity?'

Finding 1: The three teachers' biodiversity knowledge was rudimentary and mostly limited to what they accessed in the textbooks.

The teachers in this study had all learned about the concept of biodiversity for the first time at the CAPS training and through reading the CAPS document. One teacher believed that biodiversity is the 'old Biology'. This was echoed by the Senior Education Specialist for Natural Sciences who suggested that the biodiversity content is the same as the previous curriculum and that only the process skills of grouping, sorting and classifying were 'new'. The teachers' biodiversity knowledge seems limited to facts about plants and animals. In the classroom, the teachers did not notice or correct some of their learners' misconceptions about biodiversity. For example, during the lesson on classification, Lance accepted learners' claims that octopus and dolphins are fish. Although they are marine organisms, they are not fish and exploring the reasons for this could have provided a good learning opportunity about animal classification – had the teacher had the necessary content knowledge. In another instance, one of the teachers implied that humans are responsible for the growth of plants.

An important aspect of teachers' subject content knowledge is their ability to represent the subject content matter to their learners (Wilson et al. 1987). In other words, teachers should be able to explain the subject matter in different ways using metaphors, analogies, examples and illustrations to enable their learners' understanding of the subject content concepts. This study found that biodiversity content knowledge was poorly represented by the teachers' own illustrations or examples, possibly due to their own limited knowledge of biodiversity. The teachers relied heavily on generalised pictures in the textbooks to illustrate biodiversity knowledge to their learners.

Finding 2: Teachers' reliance on the textbooks seemed to limit the depth, scope and criticality of their biodiversity teaching.

A review of the textbooks used by the three teachers indicated that the textbooks generally foregrounded the development of concepts related to biodiversity but did little to situate learners' understandings of biodiversity in the global or local context. They were also found to present biodiversity as an information-rich topic that concentrates on facts about plants and animals. One textbook, used by two of the teachers, presents scientists as the holders of biodiversity knowledge. As such, people's connections to biodiversity, either as beneficiaries or as the source of threats to biodiversity, were not addressed.

In teaching about biodiversity, all three teachers were guided by the textbooks to focus almost exclusively on vocabulary, definitions of the basic biodiversity concepts, and classification of plants and animals. This is in line with what the curriculum demanded of them, even though it falls short of acknowledging the complexity, dynamism, interdependencies and significance of biological diversity. The CAPS for Natural Sciences emphasises process skills of sorting, grouping and drawing; the textbooks align very closely with this policy and thus also focus only on the development of learners' process skills. This is contrary to international perspectives on teaching biodiversity which emphasise the importance of an integrated approach to the relationships of plants, animals and people, and to pedagogies that stimulate learners to ask questions, deliberate, find solutions to problems, and examine cause and effect.

Finding 3: The teachers held a positive view of biodiversity and valued it partially for its intrinsic value but primarily for its instrumental value in inexhaustibly meeting human needs.

The study found that all three teachers were inclined towards a Promethean environmental discourse, that is, they viewed biodiversity as abundant and assumed that the 'supply' of plants, animals and their by-products will always be available to people. The metaphors that the teachers used reflected their perception of biodiversity as continuous, good, beautiful and economically stable. All three teachers valued biodiversity but in different ways, for different reasons: for its systemic, transformative and demand value, and because it meets basic human needs (Kronlid & Öhman 2012).

All three teachers expressed the belief that humans dominate over other forms of life on Earth, although one expressed concern that such domination is not good for the environment, while another was of the opinion that, although people's self-interest, business, economic and religious interests do result in animals being killed, there is no need for concern since animals reproduce. All three teachers seemed to identify effective governance as the key to what was needed to manage biodiversity, protect species and ensure an economically stable environment. Interestingly, there was little evidence that these values influenced how the teachers taught the Grade 7 curriculum because they generally adhered quite rigidly to the process skills and narrow content knowledge as required by CAPS.

Conclusion and recommendations

The main conclusions that can be drawn from this study are that the teachers did not have a sound or extensive knowledge base in terms of biodiversity, and that their approach to teaching biodiversity was heavily influenced by the CAPS and the selected textbooks. Against this backdrop, the study recommends that:

- The Natural Sciences CAPS as well as textbooks should reflect a more systemic or integrated approach to biodiversity knowledge, recognising the dynamic nature of biodiversity and the interrelations and interdependence of the ecological systems that make up biodiversity –

including relationships with humans.

- Natural Sciences teachers should be supported in broadening their own understandings of biodiversity and biodiversity loss based on up-to-date local and global examples. This would enrich not only their teaching of biodiversity but their ethical connection to it.
- Teachers should also be encouraged and supported to enhance the basic textbook material and develop learner activities that encourage more active, critical and solutions-orientated engagement from a sustainability perspective.
- Getting involved with practical, citizen-science biodiversity projects could contribute to generating local, relevant biodiversity knowledge that would also benefit learners and teachers.

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CHAPTER 5

Supporting Student Teachers to Teach Catchment and River Management in Geography

Gavin Heath and Rob O'Donoghue

Introduction

The inclusion of new environmental knowledge in the South African Geography Curriculum and Assessment Policy Statement (CAPS) has meant that many student teachers are unprepared to teach a systemic process like catchment and river management, which concerns the management of water catchment basins and the rivers within. New environmental knowledge, by definition, involves systems thinking towards a grasp of social-ecological systems, notably cause and effect processes, and circularity within a system. A social-ecological system is the complex relationship between the social and ecological processes on a parcel of land. The need for such systems thinking is implicit in the catchment and river management component of the CAPS (South Africa DBE 2011). The teaching of a case study of a catchment management system (which is the management system that governs a water catchment basin) has never been included in any previous curriculum.

Water management has developed on a widening scale into the 21st century in South Africa, but there was little comprehensive data on catchment management systems until 2017. It was only in July 2017 that a draft catchment management strategy was published. Hence it is not surprising that no curriculum case studies exist since there was no data to base them on (Meissner et al. 2017). An internet search in June 2020 uncovered no trace of any catchment management strategy for the more densely populated and, arguably, more significant eastern catchments of the country.

This study analyses the navigation of social-ecological systems thinking in the curriculum topic of catchment and river management by student teachers at a South African university. The data was generated during field work within teaching practice in the northern Drakensberg foothills of KwaZulu-Natal, South Africa. The first author of this chapter (henceforth referred to in the first person in descriptions of the case study), besides convening a specialised course on catchment and river management for the student teachers before their teaching practice, also acted as a university tutor (assessor) to the students during the fieldtrip-based teaching practice. My role as convener or lecturer ended before the teaching practice experience, however.

The aim of the chapter is to identify and probe the translation of social-ecological systems theory into the CAPS catchment and river management topic through teacher training and student teaching practice. The research design sought to examine the emergence of social-ecological systems thinking and identify challenges to the inclusion of social-ecological systems thinking in the curriculum. It is hoped that this chapter will aid and inform the teaching of catchment and river management, especially in rural contexts where issues associated with this environmental challenge are becoming a critical concern for future sustainability.

Systems thinking, which is an approach that understands systems as its central focus, has emerged as one of the priorities in Education for Sustainable Development (ESD) (Wiek et al. 2011). This is mirrored by a widening of the field from fluvial or water-based processes and physical geography to 'social-ecological' perspectives and catchment management. The scope of the research on systems thinking and ESD with student teachers in the Geographical Sciences was as follows:

- What evidence of social-ecological systems thinking is apparent in the student teachers' field-work-based lessons?
- What issues are associated with the translation of social-ecological systems theory into teaching practice?

By addressing these questions, the study intends to inform continuing work on the integration of social-ecological systems thinking in teacher training programmes, as the need for a wider grasp of changing environment and sustainability concerns becomes increasingly important in schooling.

Curriculum and pedagogical content

The teaching of catchment and river management has had an uneven history in South Africa. It was not mentioned at all in the first post-apartheid curriculum, the National Assembly Training and Education Department (NATED) Interim Syllabus (South Africa DoE 1995). This curriculum, however, did contain emphasis on systems thinking and natural systems. In the next iteration of the National Curriculum, the 2003 National Curriculum Statement, catchment and river management was mentioned as a sub-topic under South Africa and fluvial processes. No other details or specificity was given (South Africa DoE 2003). It took until 2011 for the curriculum planners to spell out exactly what catchment and river management should cover:

- Catchment and River Management (3hrs) (Under Geomorphology, Grade 12 in Term 1);
- Importance of managing drainage basins and catchment areas;
- Impact of people on drainage basins and catchment areas;
- Case study of one catchment area management strategy in South Africa. (South Africa DBE 2011: 43)

Globally, there are now numerous publications and programmes that have started to provide salient pedagogical guidance on the teaching of catchment and river management, informed by complex social-ecological systems thinking. For example, the United Nations Educational, Scientific and Cultural Organization (2010) offers useful practical guidance on mountain water management systems. An Australian initiative, Streamwatch, contains many helpful pedagogical and other suggestions on how to take care of streams and rivers (Streamwatch 2012). In South Africa, the Mini-Stream Assessment Scoring System (mini-SASS) programme has developed social learning pedagogies that enable adaptive catchment management via citizen science (Vallabh et al. 2016).

Social-ecological systems and practice architecture lenses for the study

The term 'social-ecological system' derives from Berkes and Folke (1998). Social-ecological systems thinking and practice is a rapidly emerging area of study in the sustainability sciences, and is influenced by theorists on transdisciplinarity and complexity. Regarding complexity and social-ecological systems, the analysis in the study was influenced by Hahn, Schultz, Folke and Olsson (2008).

The social-ecological system model posited by Hahn et al. (2008) was originally proposed as a model for a wetland outside Stockholm in Sweden that was impacted by major human interaction, but it has since found currency all over the world. The model is based on five core concepts, namely:

- external drivers, change and surprise;
- social norms and rules;
- management: actors and organisations;
- ecosystem functions and dynamics;
- knowledge systems and social memory.

The anchor concept in the model is ecosystem functions and dynamics, which are influenced by external drivers of change and surprise. Simultaneously, the anchor concept is influenced and affected by human interactions, namely: social norms and rules; management actors and organisations; and community knowledge systems and social memory. The model was chosen because the study site in the northern Drakensberg was relevant to all five core concepts. It also aligns with new environmental knowledge in the curriculum. This model, which is informed by (and informs) social-ecological systems theory, was helpful in answering the first research question:

> What evidence of social-ecological systems thinking is apparent in the student teachers' field-work-based lessons?

Practice architecture is a theory whereby the system or architecture of practice, or the way things are done, is systematically analysed. Mahon, Francisco and Kemmis describe practice architectures as 'a contemporary account of social reality that focuses on practice' (2017: 2). Schatzki posits that practice architecture is a system within which 'practices are organised nexuses of actions' (Schatzki 2002, in Kemmis 2009: 27). Kemmis et al. (2014) illustrate practice architecture in a model where sayings, doings and relatings (practices) are shown to emerge, respectively, from arrangements of cultural-discursive, material-economic and socio-political architectures. By understanding these three arrangements, one can analyse how the landscape of architectures is influencing the practices. Practice architecture was thus viewed as an appropriate lens to shed light on some of the factors influencing the translation of social-ecological theory into the teaching practice context for this study. This helped to answer the second research question:

> What issues are associated with the translation of social-ecological systems theory into teaching practice?

Methodology

The study was designed as a case study of a teacher education process, and was undertaken in the upper uThukela catchment basin between Bergville and the Royal Natal National Park in central KwaZulu-Natal. Consent was obtained from the five student teachers as well as the three schools in order to meet ethics requirements for research with human participants.

My role was that of a university tutor, supervising students on teaching practice. This was complicated by my other role as facilitator of the teaching practice experience. Moreover, in a previous phase of research, I lectured the same students in a specialised course on catchment and river management, in addition to lecturing them during the regular Postgraduate Certificate in Education course. The specialist course was intended to prepare the students to teach the topic of catchment and river management in the curriculum. My interest was to see how social-ecological systems theory translated into a context that is representative of many other South African communities. In my case the context was informed by the education I had received in environmental and geographical science and regional planning, as well as by my recreational pursuits in mountainous areas and my own ecology-based values.

Data were generated from student teacher lesson plans and reflective reports, which comprised the teaching practice record. Additionally, formative assessments written by me (the university tutor) were used to shed light on the systemic (in terms of social-ecological systems) elements in the lesson plans that the students developed for teaching the topic.

Two lenses were employed to answer the above-mentioned research questions, namely the social-ecological systems lens (the Hahn et al. model) and the practice architecture lens, to review the teaching of social-ecological systems thinking in relation to catchment and river management in a rural schooling context. In terms of the social-ecological system, following the Hahn et al. (2008) model, the following components were used to analyse the data from the student teaching practice records: external drivers; change and surprise; social norms and rules; management in the form of actors and organisations; ecosystem functions and dynamics; and knowledge systems and social memory. For practice architectures, the data was analysed in terms of the following arrangements: cultural-discursive; material-economic; and social-political.

Findings

The sections below report on the findings in relation to the two research questions.

Evidence of social-ecological systems thinking

This section presents data in relation to the first research question (What evidence of social-ecological systems thinking is apparent in the student teachers' field-work-based lessons?). It reports on the five aspects of systems thinking identified by Hahn et al. (2008). Regarding the first component of the model, external drivers, change and surprise, the significance of this became apparent during the student teachers' field work with the learners. The weather was a major external driver, affecting the level of the uThukela significantly following a cold front (mid-latitude cyclone) that passed through the area in the first week of teaching practice. A thunderstorm with lightning affected one field work lesson, forcing the student teacher, university tutor and learners to move quickly to a classroom.

The second component of social-ecological systems thinking, social norms, was noted by students in their reflective reports. One student reported on how environmental issues and risks emerging from local practice had been incorporated into the lesson. She explained that: 'There was evidence of pollution, erosion, mining and mis-utilisation of the riparian zone … This questionnaire was to give learners a clear picture of how the community has damaged the environments of the river banks and have impacted on the water quality and state of the natural environment.'

Management by actors and organisations (the third social-ecological dimension), or the lack thereof, was given prominence in the student teachers' lessons during the fieldtrips. In particular, the teaching of a catchment management strategy case study (a requirement in the CAPS) proved difficult for some students in terms of clearly illustrating scale and zoning in a catchment. One student noted: 'I should have provided with a strategy that would manage the whole catchment not the small areas of a catchment … therefore I had to repeat the lesson … The lesson was supposed to be orientated around one strategy in a catchment … The objectives did not orientate around a specific catchment management strategy.' In these two quotes, the student teacher is referring to a single catchment management strategy, which uses zoning to separate land use, for a particular catchment.

On occasion, activities were orientated around the impacts of people on catchment basins, whereas they needed to be orientated around a catchment management system. In particular, activities needed to be re-aligned to a bigger scale for a catchment management system because the whole catchment, not just a small part of it, is the focus. This was seen in the following comment from a lesson assessment form: 'Re-align to a macroscale for a catchment management system.' Human impacts would also fall under management in the sense that management decisions, or the lack of them, contribute to the negative effects that people can have on a catchment, as evidenced in this feedback comment to one of the teachers: 'A good section but please understand the nuances of human impacts: dams, IBT (interbasin transfer) (mostly negative).'

It appeared that key understandings and concepts regarding the management of social-ecological systems and catchments, which the student teachers conveyed to learners, were sometimes confused and related in disassociated ways during the field-work-based teaching practice: for example, the sketch maps that the student teachers drew provided evidence of scale confusion, and no understanding of the boundaries of a catchment basin. Geographic discontinuity was evident when one student confused the zoning of the catchment during a class mapwork activity.

From an ecosystem perspective (the fourth dimension of social-ecological thinking), students focused on the river basin. The mini-stream assessment scoring system (SASS) experiment was used in an appropriate and successful manner most of the time. However, there were two areas where a need for improved understanding became apparent. First, a student confused atmospheric concepts (in that the student thought a catchment gave all the oxygen people need). Second, there was some inappropriate use in terms of systems thinking (in the misconceptualising of scientific processes, such as a student confusing an area that had been made wet by a leaking tap for a wetland). I emphasised that on a fieldtrip it is also very important for learners to measure what is seen (human impacts on catchment areas needed to be measured using experiments, observation and measurements). An ecosystem perspective was evidenced by the statement in a reflective report that: 'My learners were very happy about this activity (the mini-SASS) and enjoyed it as they were looking for the different animals in the river. They were very disappointed by the result as they showed that the Thukela River was not healthy.'

Regarding the dimension of knowledge systems, one student explained that 'the lesson was to focus on using indigenous knowledge and also extracting the knowledge that the learners carry with them in terms of protecting and preserving the rivers.' Significantly, one student teacher noted that 'the spring was not even recognised by members of the community hence I [taught] my learners ways of conserving and managing springs.' This implies that, while one can have the intention to mobilise indigenous knowledge, in some cases a community may not be forthcoming in sharing information about what might be a precious resource which has cultural or core survival significance in the area.

Practice architecture relationships in teaching practice

This section seeks to answer the second research question (What issues are associated with the translation of social-ecological systems theory into teaching practice?).

Material-economic architectures

The three secondary schools in which the students were teaching serve a very poor community with high unemployment. None of the schools had a library and the nearest one for learners was the municipal library in Bergville, 50km away. The schools were sparsely furnished, with only chairs and desks, a blackboard and a teacher's desk furnishing the classroom. There was no educational material on the walls. The fieldtrip lessons were characterised by low learner turnout at times. Rural poverty undoubtedly affected the turnout, and this in turn affected the successful delivery of the content. For this reason, I suggested to one student teacher that she use the strategy of repeating her lesson, in a classroom format, to the whole class. The student teachers were limited by only being able to teach on Saturdays, as the timetable during the week did not allow for the length of time needed for a fieldtrip.

The fieldtrips were held in two severely degraded quinary catchments, with very visible evidence of overgrazing and poor land management in the form of denuded slopes and erosion gullies (dongas). A quinary catchment is the smallest scaled catchment there is, being the fifth level catchment after primary, secondary, tertiary and quaternary catchments. This poor land management (sand mining occurred while I was there supervising the students) has had many other effects such as sheet erosion. This affected the enjoyment (and the motivation) of the fieldtrip for all concerned, including the student teacher, me as the assessor, and the learners, as no one enjoys degraded surroundings.

The one quinary catchment in which two of the three high schools were situated, was ideally placed for student teachers and learners to analyse and understand the social-ecological system framework. The very important uThukela river also runs through it from the sheer escarpment above to the inhabited areas underneath. Land use differentiation occurs as the protected area (Royal Natal National Park) is reasonably pristine. However, just across the river; sand-mining, extensive road building, and pollution occur.

The other quinary catchment, in which the second high school was situated, is very different in character as it is far from a protected area. This catchment also does not have a major river running through it but only tributaries of the uThukela. The Khombe river lacks the stature, in terms of width and current, of the uThukela. However, the student at School C did not take his learners to this river but to an even narrower stream closer to the school. This affected the lesson in that learners did not appreciate the dimensions and effects of a significant river.

Cultural-discursive architectures

The social-ecological systems discourse that the students had been exposed to before the teaching practice would have influenced their general understanding of what to include in lessons. I assumed, as a point of departure, that the students would have been fully conversant with the theories of social-ecological systems, as well as catchment and river management. This was after they had attended a dedicated course on those two topics. Indigenous knowledge systems were not referred to explicitly. Rather it was couched in terms such as 'what we have learnt from our families and communities'; nonetheless, it did play a role.

The Curriculum and Assessment Policy Statement provided a major underpinning architecture to teaching practice experience, as it was the CAPS that informed the lessons to be taught. In particular, fieldtrip lessons had to cohere around a particular sub-topic under catchment and river management. This was evidenced by one of the comments on a lesson assessment form: 'Don't confuse or mix the subtopics – the [fieldtrip] lesson must cohere around one subtopic (Impact of people on catchment areas, and importance of catchment areas mixed).' Moreover, in the case of the catchment management strategy case study prescribed by the CAPS curriculum, the curriculum can be said to be ahead of reality as only one catchment management strategy has been drafted in South Africa, and that is not in the eastern half of the country. National and provincial education policy influenced the norms and standards expected in lessons, as in the performance criteria stated in the lesson assessment form.

Social-political architectures

The altered power relationship between me and the students affected how I related with them in that my role prior to assessing the lessons had been a facilitative and enabling one. I had to adapt to being a critical assessor and the students also had to adapt to considering me in a new role and light. A particular concern of mine was to ensure lesson coherence around the particular sub-topics in catchment and river management, and to ensure that the correct geographical terms and concepts were used. In addition, I was a complete outsider to the community of the area, in that I did not understand the vernacular language, nor was I aware of some of the cultural and social precepts that may have been present while I was there. However, I felt welcome and enjoyed my experience there.

Regarding the presence of political authorities and management, there was no evidence of any land or other kind of management at all, which is a political function. No government offices, including police stations, were visible during the fieldtrips. The area should actually comprise a buffer zone adjacent to a formally protected area, according to environmental law as mentioned below, but this is not the case. No activities damaging to the formally protected zone are normally permitted in a buffer, with only farming allowed in the next zone that occurs, the transition zone. This is supported by the uKhahlamba Drakensberg Park World Heritage Site (UDPWHS) Integrated Management Plan (Ezemvelo KZN Wildlife 2012). From what I and the student teachers observed, these principles are not being followed, nor are illicit activities being discouraged within the stipulated five/ten-kilometre border zone from the Royal Natal National Park (an integral part of the UDPWHS) boundaries. However, it should be borne in mind that the area has a long and contested history, with an initial resettlement of surrounding communities to this area during the colonial era (the Upper uThukela Location) (Pearce 2006). The area also experienced at least one major incident of political violence and a failed apartheid-era plan to move people from the area (Wright & Mazel 2007).

Discussion of the pedagogy of catchment and river management

To answer the first research question (What evidence of social-ecological systems thinking is apparent in the student teachers' field-work-based lessons?), the student teachers' capital, in terms of social-ecological systems thinking, was not easily translated into rural classroom settings. For the ecosystem element, the mini-stream assessment scoring system experiment was used by student teachers in lesson topics such as the impact of people on a catchment basin, and the importance of catchment basins. As mentioned above, there were some misconceptions around ecosystems such as misunderstanding oxygen production and wetland formation. There was also a need for spatial skills and concepts necessary for a more coherent or holistic grasp of fluvial systems and river catchments as interacting social and ecological systems and processes.

The data informing this chapter suggested that there was an issue with student teacher knowledge both in terms of grasp of the content and the pedagogic challenge of working with systemic concepts (Hahn et al. 2008; Norberg & Cumming 2008) in a rural teaching and learning context. Poorly developed geospatial reasoning directly affected landscape and scale literacy (which requires being able to interpret and apply an understanding of geographic scale, as in map scale) on the part of the students. Regarding management actors and organisations, students misunderstood what a catchment management strategy involved, and did not reference the management entities enough in their lessons.

What was significant were the insights that students drew from their own experiences and social backgrounds. These insights included indigenous knowledge systems; references to the purifying nature of rivers; and the fact that the rivers were a community possession to be protected. Their major strength was the social side of social-ecological systems thinking, that enabled them to mediate their learning from the strengths of their social awareness (the social norms element shows that students were concerned by how little the community understood of the importance of the catchment, and how they treated it).

Some also used heritage knowledge/indigenous knowledge systems (as mentioned above in regard to the purifying qualities of rivers) to illustrate ecological concepts (Hahn et al. 2008). In this regard, there did appear to be a willingness on the part of students to mobilise indigenous knowledge systems, but this was hampered by the community not being aware of, or not volunteering knowledge of, life support systems such as springs.

Partial understandings and associated misconceptualisations were factors in obstructing a systems-approach to the study area as well as the social-ecological elements of the curriculum being taught. Widespread and deep-seated issues did impact the teaching and learning process. These affected both the social-ecological systems focus of the field work context (teaching catchment and river management in a deep rural environment) and the academic performance of the student teachers in their teaching practice.

The findings above showed that, regarding social-ecological systems thinking, the teaching and learning process was non-linear and complex. For example, the most prominent external driver was the weather, which informed the level of the rivers after a cold front and also disrupted a field work lesson due to a thunderstorm. In a number of cases, lessons had to be repeated and the student teacher was counselled on the topic and systems coherence of a lesson.

To answer the second research question (What issues are associated with the translation of social-ecological systems theory into teaching practice?), a number of contextual factors, as elaborated in the summary below, worked together in unison to ensure that the process was highly complex, circular, historical and social (the last two factors comprised feedbacks) (Norberg & Cumming 2008). Circularity refers to the ongoing and repetitive complex processes within a system, while feedbacks refer to continuing influences from both history and society. The key trends point to a multi-contextual teaching and learning environment affecting the teaching practice. The summary of the material-economic architectures shows the following factors at play: (a) the three schools' environments were very poor and environmentally degraded with the schools themselves being sparsely furnished, (b) the fieldtrip lessons had very low learner turnout and had to occur on Saturdays, (c) the quinary catchment closer to the protected area was more ideal for fieldtrip lessons than the other site, on the other side of the common watershed.

Regarding the cultural-discursive architecture factors, social-ecological systems discourse predominated with indigenous knowledge systems being referred to obliquely. The Curriculum and Assessment Policy Statement underpinned the structure and content of the fieldtrips with other national and provincial policy providing the norms and standards.

In terms of the factors of social-political architecture, there was a different power relationship between myself and the students to that which had been experienced previously. In addition, I was an outsider to the community belonging to the study area. I was especially focused on ensuring lesson coherence and correct geographical terminology on the part of the student teachers. There was no evidence of any land or any other political management at all in the area. The buffer adjoining the formal protected area was not respected at all in terms of environmental law, and the area as a whole has a contested history with at least one serious case of political violence.

Conclusion

This study explored how social-ecological systems thinking was taught by student teachers while on a field-work trip, after having attended a specialised course on catchment and river management. The students were responsible for teaching the three sub-topics of the catchment and river management section of the current South African Senior School curriculum. The work on this challenging section of the curriculum was undertaken as a process of learning and re-learning (for those students who needed to repeat their first teaching practice lesson) with student teachers who were teaching in a rural schooling context. The study has the potential to inform interventions in poor and rural schools where there are significant issues with the preparation of teachers to teach the new environmental knowledge in the curriculum.

Recommendations from this case study are that varied and broad responses to the noted multi-contextual challenges are needed in order to prepare and equip student teachers for the demands of the new environmental knowledge in the curriculum. In this case, Bachelor of Science graduates with majors in Environmental Science and Geography did not yet fully understand and conceptualise the social-ecological systems approach inherent in the curriculum. The practice architectures' (cultural-discursive, material-economic and social-political) analytical lens used to review the pedagogical context of teaching practice suggested that there were multiple contexts and influences in the rural setting where the schools were situated. There were also different institutions affecting practice such as a university and the Provincial Department of Education. Certainly, difficulties with geographic concepts such as scale, boundaries and atmospheric processes had a significant influence on teaching and learning. Therefore, when setting curricula, education department curriculum specialists need to cater for widely differing social contexts of teaching and learning to take account of what is actually occurring in the field. In particular, field work needs resources and specialised teaching aids that all three schools in the study did not have.

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CHAPTER 6

Making Sense of Climate Change in a National Curriculum

Heila Lotz-Sisitka, Caleb Mandikonza, Shanu Misser and Kgomotso Thomas

Introduction

This chapter draws on three recent South African reviews of climate change education that have been undertaken by the authors: one in partnership with the United Nations Educational, Scientific and Cultural Organization (Unesco) and the South African National Biodiversity Institute (SANBI) in 2016 which produced a national case study on Climate Change Education in South Africa (Lotz-Sisitka & Mandikonza 2016); another that was undertaken for the Department of Environmental Affairs in 2018 for the Third National Communication on Climate Change for the United Nations Framework Convention for Climate Change (Lotz-Sisitka et al. 2018);[1] and a more recent review undertaken in the context of a research seminar series hosted by Rhodes University focusing on climate change education in South Africa (Lotz-Sisitka 2021). The chapter also draws on perspectives being developed in the Fundisa for Change Keep it Cool Project (VVOB/GreenMatter 2021) and from wider studies being undertaken for the international Monitoring and Evaluation of Climate Change Education programme (McKenzie 2020) and the International Science Council's Transgressive

1 Part of this study was published in the South African Third National Communication to the United Nations Framework Convention on Climate Change (UNFCCC) (Chapter 5, RSA 2019). Here we draw on the wider data set in addition to the published work in the South African TNC report to the UNFCCC (RSA DEA 2019).

Learning in Times of Climate Change research programme (Macintyre et al. 2018).[2] Drawing on these reviews which are both conceptual and empirical in nature, the chapter raises key issues around how we 'make sense of' dealing with climate change in a national curriculum context, with implications for curriculum development and teacher education praxis.

South Africa is located on the southernmost part of the African continent with a landmass of approximately 1 221 000 km^2 and is bordered by the Atlantic Ocean on its west coast and the southern Indian Ocean on its south and east coasts (RSA 2011a). It has a coastline of more than 2 500 km, a semi-arid and warm climate with strong gradients in both temperature and rainfall leading to a wide variety of regional and local climatic conditions. South Africa is a water-scarce country and it has been classified as highly vulnerable to water supply limitations (RSA 2011a).

The economic history of the country is built primarily on its mineral wealth and primary sectors such as agriculture, and one of the issues pertinent to climate change education, is the fact that South Africa's economy is heavily dependent on coal and energy supply, is carbon-intensive, and currently insecure. Also pertinent to climate change education is the broader context of post-apartheid transformation, which the country has been pursuing since 1994 in which issues such as poverty, unemployment, poor quality and unequal education and training systems, and associated social ills are the focus of most policy initiatives. Progress has been made, but significant development challenges remain. Patterns of the past continue, especially when it comes to inequalities, which foregrounds a need for including a social justice perspective in climate change education. Despite the fact that there are more economically active people, and more historically disadvantaged people are now benefitting from the economy, high social inequalities persist. The Gini coefficient is between 0.66 and 0.69, still one of the highest in the world, a situation that has been exacerbated by the COVID-19 pandemic.

Climate change is already a measurable reality in South Africa, and along with other developing countries, South Africa is especially vulnerable to its impacts. Predicted impacts of climate change for South Africa include, among others, increases in the distribution and intensity of drought; reduced agricultural crop yields impacting on food security; potential species extinction; increased growth rates of invasive species; potentially catastrophic coral bleaching; and an increase in the areas affected by vector-borne diseases. It is also clearly stated in the South African Second National Communication to the UNFCCC (RSA 2011b) that, in all of these circumstances, it is the poor who would be worst affected. Specifically, projected impacts include:[3]

- **Water shortages:** South Africa is a water scarce country with a highly variable climate and has one of the lowest run-offs in the world. Official

2 The authors of this chapter are contributing to these programmes.

3 Information here is taken from the National Climate Change Response Strategy (RSA 2011a), and the Third National Communication submitted by the government to the UNFCCC (RSA 2018). This is just a brief summary of much more detailed information.

estimates suggest that South Africa will face shortages of between 2 and 13% of total water requirements by 2025. Other estimates that include climate change projections and other uncertainties calculate that these could increase to as much as 19–33% by 2025, and that South Africa will exceed limits of economically viable land-based water resources by 2050.

- **Agriculture and commercial forestry:** Climate change significantly impacts agriculture and commercial forestry. Agriculture is the largest consumer of water (through irrigation) and is vulnerable to changes in water availability, increased water pollution and soil erosion. Under-resourced, small-scale and subsistence farmers are particularly vulnerable to the impacts of climate change. Commercial forestry in the form of alien plantations reduces streamflow and so impacts on scarce water resources. It also reduces biodiversity.
- **Health and well-being:** There are several emerging and potential links between climate change and human health, particularly related to water scarcity and water quality as well as the geographical spread of vector and water-borne diseases, reduced air quality, and heat stress.
- **Biodiversity and ecosystems:** Climate change will compound the pressures on already stressed ecosystems that have resulted from the unsustainable use and inadequate management of many of South Africa's ecosystems, thus potentially reducing the quantity and quality of the services that ecosystems currently provide. These critical services underpin South Africa's socio-economic activities. Roughly 30% of endemic terrestrial species in South Africa may be at increasingly high risk of extinction by the latter half of this century if climate change is not mitigated.
- **Coastal areas:** Vulnerabilities of coastal areas have been identified as increased storm damage; damage to coastal infrastructure (including infrastructure such as breakwaters); threats to the erosion levels of shorelines; and changes in the salinity levels of estuaries, which will affect breeding grounds of many marine species. A significant proportion of South Africa's metropolitan areas, as well as numerous towns and smaller settlements, are situated along the coast, making them vulnerable to any dramatic sea-level rises.
- **Human Settlements (Urban, Rural, Coastal):** More than 60% of South Africa's population lives in urban areas. Urban areas are vulnerable to environmental health risks, and have a number of climate related challenges. Rural settlements in South Africa are characterised by inequalities and high levels of poverty, especially in former 'homeland' areas. This is also where most small-scale and homestead food production is practised, with roughly 1.3 million small-scale farm units, which are also home to 70% of the country's

poorest households. They too face several climate change challenges, especially increased vulnerability. Coastal settlements are also vulnerable to climate change, as they are at risk from sea-level rise. Coastal areas are home to about 40% of South Africans. The coast is generally exposed to moderate to strong wave action, with the coastline becoming increasingly vulnerable to storm surges, coastal erosion, sea-level rise and extreme weather events.

- **Energy and Greenhouse Gas emissions:** South Africa is a relatively significant contributor to global climate change with significant GHG emission levels from its energy-intensive, fossil-fuel-powered economy. South Africa therefore has significant mitigation challenges, in addition to adaptation challenges.
- **Temperature rise and general impacts:** Even under emission scenarios that are more conservative than current international emission trends, it has been predicted that by mid-century the South African coast will warm by around 1 to 2°C and the interior by around 2 to 3°C. By 2100, warming is projected to reach around 3 to 4°C along the coast, and 6 to 7°C in the interior. With such temperature increases, life as we know it will change radically: parts of the country will be much drier and increased evaporation will ensure an overall decrease in water availability. This will significantly affect human health, agriculture, and other water-intensive economic sectors such as the mining and electricity-generation sectors as well as the environment in general. Increased occurrence and severity of veld and forest fires, extreme weather events, and floods and droughts will also have significant impacts. Sea-level rise will impact the coast and coastal infrastructure. Mass extinctions of endemic plant and animal species will greatly reduce South Africa's biodiversity with consequent impacts on eco-system services (RSA 2011a).

The National Climate Change Response White Paper: Education implications and objectives

In 2011 the South African government released a National Climate Change Response White Paper (RSA 2011a). In terms of **adaptation**, the National Climate Change response includes a risk-based process to identify and prioritise short- and medium-term adaptation interventions to be addressed in sector plans (RSA DEA 2019). The National Climate Change Adaptation Strategy (RSA DEA 2019) outlines objectives for building climate resilience and adaptation capacity, promotion of climate change adaptation responses into development objectives, policy, planning and implementation, and ensuring that resources and systems are in place to enable implementation of climate change responses. Objective 3 is particularly significant for climate change education as it points to the need to 'Improve understanding of climate change impacts and capacity to respond to these impacts'. Sectors identified as being in need of immediate attention are water, agriculture and forestry, health, biodiversity, and human settlements. The NCCR White Paper (RSA 2011a) also notes that resilience to climate variability and climate change related extreme weather events will be the basis for South Africa's future approach to disaster management and region-wide approaches will be used where appropriate. South Africa's approach to **mitigation** articulates the country's contribution to the international effort to curb global emissions (RSA 2011a).

The NCCR White Paper for South Africa (RSA 2011a) identifies priorities for adaptation and mitigation as follows:

ADAPTATION	MITIGATION
Main thematic areas: • Water • Agriculture and Commercial Forestry • Health • Biodiversity and Ecosystems • Human Settlements (Urban, Rural, Coastal) • Disaster Risk Reduction and Management	Main thematic areas: • Benchmark National GHC Emissions • Carbon Budget approach • Sectoral mitigation • Lower carbon development strategies • GHG Emissions Inventory
CROSS-CUTTING ISSUES	
• Job creation • Mainstreaming climate resilient development (**including into education and training systems**) • Resource mobilisation • Monitoring and evaluation	

The NCCR White Paper (RSA 2011a) was informed by the development of long-term Mitigation and Adaptation Scenarios which provide a longer-term view on climate change adaptation and mitigation. These set out the longer-term strategic direction for climate change response, and also point to particular education and training systems demands. From a mitigation point of view, there is a need to develop education and training programmes that orient South Africans to carbon budgeting, environmental design and engineering, low carbon technologies, energy efficiency, ecological economics, and sustainable production and consumption (RSA 2018). From an adaptation point of view there is a need to develop education that builds capacity for ecological infrastructure management, rehabilitation and stewardship, adaptive capacity, risk reduction and management, early warning and vulnerability reduction, climate change governance, and health and well-being promotion. Sustainable agriculture, resilience-building and vulnerability reduction are key approaches to develop in agricultural education, while ecosystem-based approaches and restoration of ecological integrity, along with stewardship, are some of the approaches to reducing biodiversity risk (RSA 2018). Mainstreaming climate change into secondary and tertiary education curricula is also identified as a key action in the National Climate Change Adaptation Strategy (RSA DEA 2019).

Besides these specific implications for climate change education that are embedded in the actual thematic areas for climate change adaptation and mitigation, the South African Climate Change Response Strategy (RSA 2011a, Section 11.2) **includes**

a strategic goal of improving climate change education in South Africa. It states that '*Climate change is a relatively new issue that has cross-disciplinary and cross-sectoral implications in South Africa. Understanding the concept as well as the options to mitigate it and adapt to it is fundamental to future development pathways and the wellbeing of South African society.*' In this chapter we point to 'different understandings' of the concept that are circulating in the South African curriculum context, and propose a 'way forward' to strengthen alignment of the diversity of conceptual frameworks shaping both climate change education, and national policy.

The South African Climate Change Response White Paper Strategy (RSA 2011a) further suggests that to address the educational aspects of climate change '*systematic interventions*' are required to empower and capacitate people. The South African government states:

> *We need to mainstream climate change knowledge into education and training curricula.* ***Climate change education should be part of the broader framework of education for sustainable development,*** *and should equip South African citizens to re-orient society towards social, economic and ecological sustainability.* (RSA 2011a: 44)

This chapter considers how this is/or is not being done, and what might be done to strengthen further development and implementation of climate change education in a South African context.

While these policy commitments exist for climate change education, the Third National Communication to the UNFCC indicates that South Africa lacks a *systemic* approach to climate change education, and that approaches to climate change education are fragmented and lack conceptual coherence (RSA 2018). The implementation of Climate Change Education (CCE) currently tends to be left to the willing and able. There is acknowledgement that a strategic home and driver for CCE needs to be found and there are recommendations that strategic discussions need to happen at higher levels of government across different departments such as Department of Environment, Forestry and Fisheries, Department of Basic Education, Department of Higher Education and Training, Department of Agriculture and Land Affairs, and the Department of Public Works and Department of Water and Sanitation, among others (RSA 2018). Coherent and co-ordinated cross-sectoral response structures are needed that are inclusive of all government departments with a role to play in climate-compatible development. At this point, a question to be asked is when and how the education and training imperatives in the National Climate Change Response Strategy and the National Climate Change Adaptation Strategy will be internalised, assimilated and responded to by the educational policy-making community in ways that bring about wider policy synergy in the national development landscape, as projected and anticipated in the National Climate Response Strategy.

In this regard, it is instructive to note that the United Nations Development Programme and the United Nations Framework Convention on Climate Change

National Determined Commitment Outlook Report (UNDP & UNFCC 2019) takes stock of global climate ambitions and highlights that 'Climate action is inseparable from sustainable development', making the point that:

> Governments increasingly recognize that action to address climate change is inseparable from delivering the Sustainable Development Goals … [climate change is] … disrupting national economies and affecting lives, with a disproportionate impact on the poor, and prioritizing adaptation to climate is increasingly seen as critical for resilient sustainable development. (UNDP & UNFCC 2019)

With this in mind, it is helpful also to link Climate Change Education in South Africa to the SDGs, especially SDG 13 on climate action, which has a target on climate change education and empowerment, and SDG 4 on quality education, which has a target on integrating education for sustainable development into education and training systems as a key feature of quality education. These discourses, outlined above from the South African National Climate Change Response White Paper (RSA 2011a) the long-term mitigation scenarios, and the National Climate Change Adaption Strategy (RSA DEA 2019), which have gone through important consultation processes, highlight a strong link between climate change literacy and climate science principles, as well as discourses of adaptation, mitigation, resilience, vulnerability reduction and sustainable development. These need to be considered in their full scope and implications (i.e. one cannot consider adaptation discourse without considering implications for sustainable agriculture) when integrating climate change into the schooling sector in South Africa.

An understanding of both climate science and earth systems (i.e. foundational concepts and knowledge), as well as action-orientated responses to climate change (adaptation, mitigation, resilience building, vulnerability reduction, sustainable practices, etc.) need to be included in a coherent manner within and across a national curriculum that seeks to address climate change. As indicated in the Fundisa for Change programme and across the chapters of this book, curriculum innovation is not just about knowledge, however; it is also about pedagogy and transformative learning, values and ethics and the promotion of environmental health and well-being, social justice for current and future generations, as well as a new ethic of care and relational foundation for human-environment interactions in the world.

Climate change knowledge in the national curriculum

The section above has considered the policy context and some of the discourses emerging from climate change policy in South Africa. We now consider the Curriculum and Assessment Policy Statement (CAPS) (RSA DBE 2011c) and how it approaches climate change (or not). The CAPS curriculum, building on earlier versions of the curriculum (see Schudel, Lotz-Sisitka, Songqwaru and Tshiningayamwe, Chapter 1) emphasises the need for 'knowledge and skills that are meaningful to learners' lives' by including both local and global contexts (see also Schudel and Lotz-Sisitka, Chapter 2). The knowledge, skills and values component should enable the learners to fully participate in their society. Issues of inclusivity, human rights, environmental and social justice are key drivers of curriculum structure and processes, as has been indicated elsewhere in this publication (see Schudel and Lotz-Sisitka, Chapter 2). Problem solving, critical thinking and creativity are some of the goals of the education agenda. The South African CAPS (Grade R–12) is based on the following principles:

- *Active and critical learning:* encouraging an active and critical approach to learning, rather than that of rote and uncritical learning of given truths.
- *High knowledge and high skills:* the minimum standards of knowledge and skills to be achieved at each grade are specified and set as high, achievable standards in all subjects.
- *Progression:* content and context of each grade shows progression from simple to complex.
- *Human rights, inclusivity, environmental and social justice:* infusing the principles and practices of social and environmental justice and human rights as defined in the Constitution of the Republic of South Africa. The CAPS curriculum is sensitive to issues of diversity, such as poverty, inequality, race, gender, language, age, disability and other factors.
- *Valuing indigenous knowledge systems:* acknowledging the rich history and heritage of this country as important contributors to nurturing the values contained in the Constitution.
- *Credibility and efficiency:* providing an education that is comparable in quality, breadth and depth to that of any other country.

While all of the above is valid, and although CAPS pays heed to these principles, they are yet to be fully realised, as can be seen from the analysis that follows. When it comes to climate change knowledge in the curriculum we find that most climate change related content, values, skills and competences development is found in the following CAPS subjects: Natural Sciences/Life Sciences, Life Skills/Life Orientation, Social Sciences, Geography and Agricultural Science, Agricultural Management Practices, and the Marine Sciences (a new subject).

Appendix A offers a brief summary of this subject content from the CAPS (RSA DBE 2011c) and demonstrates that in the Natural Sciences curriculum, climate and climate change related content is covered mainly in the 'Planet Earth and Beyond' strand. Climate and climate related concepts are covered under 'Systems and Control' in Technology. Therefore the main purpose is to produce learners who are knowledgeable of their environment and can innovate to live responsibly in it. Climate change education is also embedded within the 'Environment Studies' strand. The Further Education and Training (FET) Life Sciences curriculum seeks to develop awareness of what it means to be a responsible citizen in terms of environment and lifestyle choices and deal with environmental impact, although climate change is not identified as a specific environmental impact.

The Life Skills and Life Orientation curriculum has content ranging from weather observations in Grade 1 to environmental rights and responsibilities and waste and pollution management. In the senior phases, the focus shifts to environmental health concerns and problem-solving skills in the context of community, local and global environmental concerns, of which climate change may be one (though not specified as such). There is some emphasis on disaster risk management, as well as personal views, lifestyles and the impacts of one's actions in life.

The Social Sciences and Geography curriculum carries content on renewable and non-renewable resources, water concerns and catchment management, climatology, and resources management. It also includes a focus on industrial development and sustainable industries, but this is generally poorly specified from a climate change impact perspective, and there are inconsistencies and contradictions in the way in which sustainable development, industrialisation and growth are represented in the curriculum. There is, however, some emphasis on development of a commitment to sustainable development, and it is only in Further Education and Training (FET) Geography that there is any in-depth study of climate science and climate related content, focusing on atmospheric dynamics such as the greenhouse effect, global warming and the impact of climate change on Africa's environment and people. Skills relate to weather monitoring and use of GIS technologies for climatology and meteorology, oceanography and Africa's weather and climate conditions, including issues such as droughts and desertification, regional risk and energy management. Thus, unless a learner specialises in FET Geography, they are not likely to engage in any significant depth with climate change foundational and applied knowledge (cf. Appendix A).

The Economic and Management Sciences curriculum contains inconsistencies and contradictions in poorly framed recommendations for green economy development that are in contradiction to the overriding narrative based on promotion of fossil-based industrial development, and the Agricultural curriculum likewise is characterised by similar contradictions.

The Agricultural Science Grade 10 curriculum has content on climate change and global warming, impacts of climate change and global warming on agriculture, short-term and long-term weather predictions and cyclic patterns of rainfall in South Africa, and agricultural adaptation measures to overcome climate change. However, there is no concept progression in Grades 11 and 12. While this content is included, it is also contradictory to other content in the curriculum that supports monocultural and high-demand irrigation technologies.

Coherence, progression and orientation

The curriculum seeks to address scientific as well as social justice related issues associated with environment and sustainability as this relates to the history of South

Africa, and to support learner empowerment, for example, via problem-solving approaches and environmental impact assessment studies. However, as can be seen from the above there are inconsistencies and a lack of clear progression in the way that climate change education is dealt with in the curriculum, with a bias towards cognitive forms of engagement with climate change issues and little emphasis on social learning and/or social-emotional engagements with climate change related concerns. This is a weakness identified more broadly by McKenzie (2020) in international approaches to climate change education. Unesco (2021) has also recently recommended integration of cognitive with socio-emotional and action-orientated (behavioural) education approaches in responding to SDG 13 on climate change action – an approach that overall is missing or absent from the South African CAPS curriculum when it comes to climate change education.

One of the issues associated with the 'topic' approach to including climate change in the CAPS curriculum is that it does not allow for approaches that reflect contemporary climate change sciences, which include approaches to science that (a) involve understanding of earth systems, (b) predictive sciences, and (c) inter- and transdisciplinary sciences that are transformation and action/response orientated. The South African curriculum deals in a patchy way with a above, but fails to deal adequately with b and c; thus it neglects both to prepare learners adequately with coherent foundational knowledge (provided by a and b), and with applied knowledge and capacity (provided by c).

As a result of this lack or absence, it is even more difficult to realise a social-ecological orientation to climate change education, which is the more mainstream orientation to climate sciences. This in turn affects possibilities for development of resilience-orientated approaches to climate change education. The main approach that teachers can use are approaches that integrate some 'patchy' aspects of climate change knowledge into specific subjects. There are also inconsistencies between the content being promoted in the curriculum and the national climate change adaptation, mitigation and resilience priorities outlined above, in other words, there is a mismatch between education-sector curriculum policy and national climate change response policy, with the result that, as noted above, some of the content is also contradictory within subjects.

This is not to suggest that the curriculum should only promote climate change policy content, but rather that it should provide a substantive foundation for engaging with national climate change priorities and policy directions. For example, it is interesting to note that climate change adaptation or mitigation is sporadically dealt with (see below) and that much of the other curriculum content is largely inconsistent with, or contradictory to, these orientations, and fails to develop a clear and systemic conceptual framework for a social-ecological systemic approach to dealing with climate change. It also fails to adopt a strong 'transformative approach' to dealing with climate change in South Africa, which is being argued for in the Global Change Social Sciences National Research Plan, for example (DSI/NRF 2020) and in the international literature on climate change education (e.g. Macintyre et al. 2019; McKenzie 2020; Unesco 2021).

Dealing with a patchwork approach to climate change education

From the brief analysis discussed above we can observe a somewhat 'atomistic' and 'fragmented' overall approach to climate change education in the South African curriculum context. This is due to the fact that different aspects of climate change education are to be found in sections of topics in different subjects of the Curriculum and Assessment Policy Grades R–12, as outlined above and shown in more detail in Appendix A. These 'atomised' sections or topics cover aspects of climate science, earth system science, climate change causes, impact on development, mitigation and adaptation – but without developing any clear, broad and/or holistic framework for interpreting these 'fragments' or atomistic aspects of climate change education. Mitigation, where it is present at all, focuses on the reduction of greenhouse gases. Teaching of climate and weather takes place in relation to adaptation of plants and wildlife. Other aspects such as climate, vegetation, human settlement lifestyles, and natural resources are all taught, but not related to each other; nor is climate change knowledge related to sustainable use of natural resources such as air and water or carbon footprint. Effects of climate on agriculture and food supply are mentioned, but this is not related to adaptation responses. The role of science and technology in food production is discussed but not in relation to climate change. Conservation or preservation and careful management of natural resources is mentioned in parts, but not related to diverse climatic regions, contexts or differences. The relationship between resources and economic development is mentioned but this is not linked to mitigation and concepts of low carbon future or climate-compatible development. The impact of overexploitation of resources on the environment and economy as well as issues of sustainable waste management are all found in the curriculum, but they lack a coherent related purpose and framework of understanding that can allow learners to 'join the dots' or make the links. The importance of developing systems thinking competence and other key competencies for sustainability is not developed.

Besides this atomistic and fragmented approach, there is no clear 'progression pathway' for such knowledge, and there is little guidance on how to develop agency for climate action as recommended by Unesco (2021). Issues such as climate risks and natural disasters, population growth, and diversity are explored at primary school level but it is not clear what the foundations of such knowledge is/should be, or how knowledge progression 'builds' over time in relation to concepts such as the relation between climate risks, natural disasters and/or population growth. The curriculum could be said to include a 'basket of relevant topics' but lacks a clear conceptual framework for adequate interpretation of such topics, and for the knowledge progression pathway that learners are to follow in growing their understanding of these 'new topics' and concepts that are found in the curriculum. This also has implications for how learners engage critically with the complexities and realities of climate science/climate change. There is, further, a need to ensure that the curriculum equips learners with a sense of agency – and urgency – to take action, and with the capabilities to develop responsiveness towards the real-life challenges of climate change, while also developing hope for the future (Unesco 2021).

It is not surprising therefore that the 'basket of topics' shows a somewhat confused mix of approaches to climate change education and/or education for sustainable development. Some topics reflect a socio-ecological risk approach through illustrating how issues are potentially hazardous to human existence, while others reflect sustainable development response approaches. Mitigation and adaptation are key, but topics that deal with these issues tend to reduce these important conceptual areas to the generation of greenhouse gases, and individualised action responses or fragmented aspects of the wider coherence of mitigation and adaptation responses. Tackling of development issues promotes a futures-orientated approach but does not develop a clear perspective on the meaning of climate-compatible development. Thus, while it seems that the curriculum has a lot of 'scope' and 'interest' in climate change education within an environment/education for sustainable development paradigm, there is a lot more that needs to be done to ensure curriculum coherence when it comes to the manner in which the issues are incorporated into the curriculum.

Conclusion: Moving forward

The current 'status quo' of environment/sustainability/climate change knowledge in the national curriculum would appear to require high-quality educational research that seeks to understand climate change knowledge production in the field of production; and a critical analysis of how this is being/should be recontextualised into official pedagogic discourse, into other fields of curriculum recontextualisation (i.e. teacher education and textbooks) and into the field of curriculum reproduction itself (i.e. at classroom level). A study by Nsubuga (2009) showed that without a clear conceptual framework for natural resource management education at national level (adequately derived from the field of knowledge production) poor-quality recontextualisation processes occurred in official pedagogic discourse (the curriculum); and in ongoing recontextualisations at teacher education, textbook, district level support, and at classroom practice level. As climate change knowledge is relatively new to most education systems, it includes many different facets (see also Schudel and Lotz-Sisitka, Chapter 2). Thus research into climate change education with the pedagogic device is vitally important to ensure a coherent approach to mainstreaming of climate change knowledge and its relationship to other forms of environment and sustainability knowledge.

Additionally, there is an urgency to work on appropriate support systems for teachers who ultimately need to have a wider perspective and understanding of these issues than is represented in the 'fragmented' topics of the curriculum, with many recommendations in this direction emerging from across the chapters of this book (see Schudel and Lotz-Sisitka, Chapter 2; Shumba, Mandikonza and Lotz-Sisitka, Chapter 12; Mkhabela and Schudel, Chapter 13).

In working towards a more coherent and foundational framework for climate change education in South Africa, we propose that scientific knowledge of earth systems and their risks and functioning, while necessary, is an inadequate framework for CCE on its own. Price (2021) has also noted that much of climate change education is troubled by 'slippages' in discourse that fail to develop adequately clear understandings of climate change challenges and politics. We propose that in addition to strengthening the quality of climate science knowledge (and its certainties and uncertainties), there is need to give coherent attention to emergent multi-, inter- and transdisciplinary concepts such as risk, social-ecological systems change, adaptation and mitigation, as well as seasonal variability and societal transformations towards more sustainable futures within climate change education. Additionally, there is a need to develop pedagogical praxis for development of intergenerational understandings, values, learners' agency for change, and reflexive co-learning competencies situated within proactive, socially just and transformative climate-compatible development orientation, without producing dualisms, contradictions or inconsistencies for learners in and through the curriculum. Also crucial is to foreground more strongly ethics and justice, action and agency, in addition to science and knowledge (see Figure 1 below) via transformative learning approaches that involve individual learners in classrooms, whole school environments and communities.

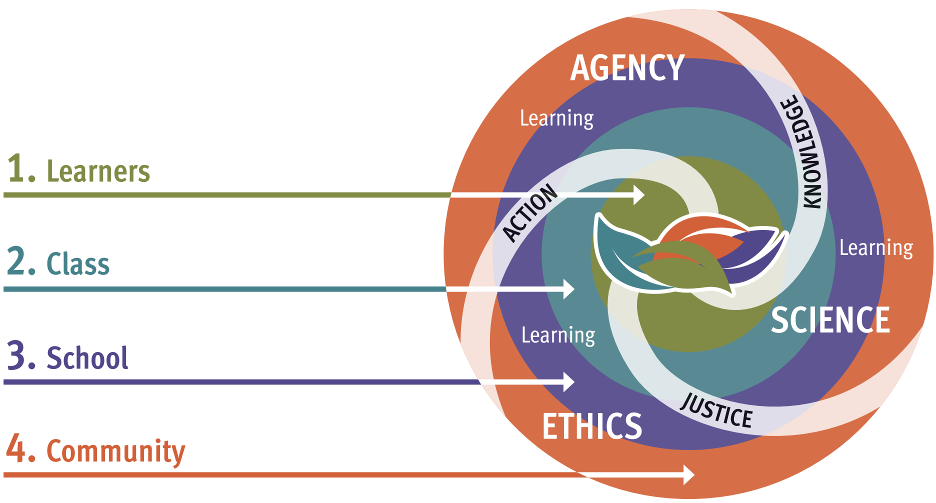

Figure 1. Adapted diagram offering a coherent framework for teaching climate change, and for conceptualising climate change education (adapted from Flynn, n.d. by Lotz-Sisitka 2021)

The ethical aspects need to be integral to both knowledge and pedagogy, and are at the heart of agency development, since motive drives agency; thus ethical praxis is central to self-directed and collective motive and agency development for responding to climate change and to the need for deep-seated transformations in society. As indicated in the curriculum principles, ethics are embedded, but not well grounded with regard to the way in which climate change education is currently being conceptualised in the South African CAPS curriculum. This clearly needs to be given more attention moving forward. There is also a need to consider the processes of ethics-led learning

(O'Donoghue et al. 2020) as expansive learning processes that draw on both foundational and systemic approaches to knowledge, and that develop transformative agency for change. Here pedagogical approaches that strengthen and develop active learning (see Section B of this book) and assessment processes that strengthen the assessment of ESD more holistically (see Shumba, Mandikonza and Lotz-Sisitka, Chapter 12; Mkhabela and Schudel, Chapter 13) are necessary. As pointed out above, the knowledge dimensions of climate change education are themselves complex and therefore require a more robust way of thinking about knowledge in the curriculum.

Ultimately, there is need to develop understanding(s) and pedagogical praxis for development of intergenerational understandings, values, learners' agency for change, and reflexive co-learning competences situated within proactive, socially just and transformative climate-compatible development orientation, without producing dualisms, contradictions or inconsistencies for learners. In a recent review, the lead author of this paper defined Climate Change Education as follows:

> … *an ethics-led transformative, transgressive social learning and agency process that builds regenerative cultures and activity for the future; informed by, but not limited to, science. Knowledge, Justice, Action should not be separated out in climate change education. This could form the foundation for how we approach CCE and then apply it to adaptation, mitigation, resilience building, disaster risk reduction and other areas of applied climate change responsiveness, and to different disciplines and inter-disciplinary contexts.* (Lotz-Sisitka 2021)

The above definition may offer a way forward or at the least a strong starting point for developing a more coherent framework for climate change education in South Africa that can respond to the problems identified in this chapter. Based on this review, and the works that the chapter is grounded in, it is clear that there is a need for a multi-stakeholder approach to conceptualising climate change education in the South African curriculum in a way that addresses the problems of inconsistency and 'patchiness'. The Department of Basic Education, who hold responsibility for curriculum development, should work with teacher educators, who are important mediators and recontextualisers in the higher education system, and with Fundisa for Change partners such as SANBI and the Department of Environmental Affairs, Forestry and Fisheries to better map out a meaningful foundational framework and progression pathway for climate change education in South Africa's curriculum. This needs to be done within and across the different curriculum areas within a whole systems approach that more adequately reflects the principles of the CAPS curriculum itself, and through this, provides better orientation in dealing with climate change education in teacher education settings.

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Appendix A (Tables based on the CAPS curriculum) (RSA DBE 2011c)

Science and Technology

Climate and climate change content: Natural Sciences and Technology (Grades 4–9)

Phase	Grade	Climate Science and Climate related content
Intermediate	4	'Planet Earth' covers content relevant for climate science knowledge. The Sun and Life.
	5	No visible evidence of climate science or climate change education
	6	Renewable ways to generate electricity is a concept under 'Mains Electricity'. 'Movement of the Earth and Planets' provides the scientific background useful for understanding Earth System Science.
Senior	7	The topics of the 'Biosphere covering atmospheric gases; Properties of materials; Heat energy; and Relationship of the sun to the earth' cover climate change science.
	8	'Earth as a system' and 'The Atmosphere' constitute climate science.
	9	Alternative sources of energy are covered under 'Energy and the national electricity grid'. Spheres of the Earth, including atmosphere; hydrosphere and lithosphere, are climate science concepts that are covered under the topic 'The Earth as a system'.

Climate and climate change content: Life Sciences FET (Grades 10–12)

Phase	Grade	Climate Science and Climate related content
FET	10	Strand 3 covers 'Biosphere and Ecosystems'. This topic enables learners to develop an understanding of constituents of the biosphere and how these components are connected into global systems. In this section the concept of environment is defined holistically. Energy and nutrient flow are discussed to the level of trophic levels. Nutrients cycles are developed here: water, carbon, oxygen and nitrogen. Changes in climate comprise a short section under 'History of Life on Earth', aimed particularly at explaining the Ice Ages. Impact of humans on biodiversity and the natural environment are discussed under fossil formation.
	11	Most of the climate change and climate related concepts are covered in this Grade and particularly in strand 3, 'Environment Studies: Human Impact on the Environment'. The atmosphere and climate change, including the greenhouse effect are covered in this section. Sub-topics of the section on 'Water' relate to climate change.
	12	Darwin's theory of evolution by Natural Selection is a climate change related concept.

Life Skills and Life Orientation

Climate and climate change content: Life Skills Curriculum (Grades R–3)

Phase	Grade	Climate Science and Climate related content
Foundational	R	Learners learn to notice the daily weather conditions, to describe the weather perceived and link weather patterns with the seasons of the year. Issues of a clean environment are introduced at this stage.
	1	Learners are taught to observe weather conditions and record observations using tools and symbols.
	2	What we need to live includes protection from the sun. The Seasons link clothes, food, plant and animal growth.
	3	Rights and responsibilities include the environment. Waste Management (re-use, recycle, reduce). Pollution and effects of pollution on the environment.

Climate and climate change content: Life Orientation Intermediate Phase (Grades 4–6)

Phase	Grade	Climate Science and Climate related content
Intermediate	4	concern for the environment – use of recyclable materials during design.
	5	concern for the environment – use of recyclable materials during design.
	6	concern for the environment – use of recyclable materials during design.

Climate and climate change content: Life Orientation (Grades 7–12)

Phase	Grade	Climate Science and Climate related content
Senior	7	Environmental Health is a sub-topic under **Health, social and environmental responsibility** but is limited to: – Community and individual projects and strategies to prevent and deal with environmental health problems. – Problem-solving skills: an action plan to address an environmental health problem and formulate environmentally sound choices and actions.
	8	Under **Health, social and environmental responsibility**, a section involving understanding of application of laws and policies to protect the health of the environment as well as honouring Earth Day.
	9	Under **Health, social and environmental responsibility**, the contributions of community-based and non-profit organisations to social and environmental health and sustainable development are dealt with.
FET	10	Under **Health, social and environmental responsibility**: Contemporary social and environmental issues that impact negatively on local and global communities are included – *even though climate change is not mentioned.* Under Social and Environmental Responsibility: Strategies to stop negative impact of contemporary social and environmental issues on local and global communities: knowledge and skills to take appropriate action are emphasised.

Phase	Grade	Climate Science and Climate related content
FET	11	**Social and Environmental Responsibility:** Environmental factors and disasters that cause ill-health, accidents, crises and disasters: – Impact of environmental degradation on society and the Earth: soil erosion; air and water pollution; waste dumps; radiation; floods; fires; loss of open space/ lack of infrastructure. Social and Environmental Responsibility: Climate change: causes, impact on development, mitigation and adaptation *(also covers Disaster Risk Reduction)*. – Community responsibility to provide environments and services that promote safe and healthy living. – Responsibilities of various levels of government: laws, regulations, rules and community services. – Educational and intervention programmes and impact studies. – Dealing with factors that cause ill-health on a personal level: attitudes, safety and first-aid skills and coping with disasters.
	12	**Social and Environmental Responsibility:** A personal mission statement based on: Personal views, values, belief system, religion, ideologies, lifestyle (physical and emotional well-being), environmental responsibility, goals for studies and career choices. – Impact of vision on: One's actions in life; one's immediate community; and society at large.

Social Sciences and Geography

Climate and climate change content: (Grades 7–9)

Grade	Climate Science and Climate related content
7	**Natural resources:** Renewable and non-renewable resources; How resources are used and abused – includes water, soil, air, wildlife, fish; Concept of conservation; Reasons for conservation and the protection of resources. **Water in South Africa:** Water needs of people and the environment; Water supply and demand in South Africa; Concept of a catchment area; Role and management of catchment areas and rivers; Disappearing wetlands and why conservation is necessary – case study.
8	**The Earth's revolution around the sun:** Seasonal temperature changes; Seasonal changes in lengths of day and night; Seasonal temperature changes (among others). **Climatology: Climate around the world** including: Elements of climate – temperature, pressure, humidity, winds and precipitation; Kinds of climate: Tropical, subtropical, temperate, desert, semi-desert, continental, polar, Mediterranean, tundra and high mountain (alpine); links between climate regions and factors that influence temperature and rainfall.
9	**Development issues:** **Resources and development:** The impact of development on the world's natural resources; Sustainable use of resources for development. **Industrial growth:** The concept of industrial growth; The impact of industrial growth; Multinational corporations; Sustainable industries. **Community development:** Development as community participation; Positive community projects.

Climate and climate change content: FET Geography (Grades 10–12)

Grade	Climate Science and Climate related content
10	**Field work** for developing Geographical techniques necessary to understand weather information as well as to handle weather information: Using maps and other graphical representations: atlases, synoptic weather maps, temperature graphs; Collecting and recording data using a variety of techniques: using weather instruments, collecting weather information from the media; Processing, collating, interpreting and representing field work findings: line graphs, bar graphs, maps, diagrams and synoptic weather maps. **The Atmosphere: Composition and Structure of the Atmosphere:** troposphere, stratosphere, mesosphere and thermosphere; the ozone layer; causes and effects of ozone depletion; and ways to reduce ozone depletion. **Heating of the Atmosphere** including: processes associated with the heating of the atmosphere, the Greenhouse Effect – impact on people and the environment; global warming as well as the impact of climate and climate change on Africa's environment and people – deserts, droughts, floods and rising sea levels. **Moisture in the Atmosphere** including: water in the atmosphere in different forms, such as water vapour and liquid; processes associated with evaporation, condensation and precipitation; the concepts of dew point, condensation level, humidity, relative humidity – factors affecting relative humidity. **Reading and Interpreting Synoptic Weather Maps:** weather elements: temperature, dew-point temperature, cloud cover, wind direction, wind speed and atmospheric pressure; weather conditions: rain, drizzle, thunderstorms, hail and snow, as illustrated on station models; and reading and interpreting a selection of synoptic weather maps.
11	**Geographical Information Systems (GIS)** including the application of GIS to climatology and meteorology, as well as oceanography, using satellite images. **The Atmosphere** with the following subtitles: **The Earth's Energy Balance:** the unequal heating of the atmosphere – latitudinal and seasonal; significance of Earth's axis and revolution around the Sun; and transfer of energy and energy balance – role of ocean currents and winds. **Global Air Circulation:** global air circulation and how it is related to world pressure belts; forms and causes of the different global air masses. **Africa's Weather and Climate:** Africa's climate regions; subsidence and convergence – link to rainfall; the role of oceans in climate control in Africa; El Niño and La Niña processes and their effects on Africa's climate; and reading and interpreting synoptic weather maps. **Droughts and Desertification:** areas at risk: regional and local scales; causes of droughts; causes of desertification; effects of droughts and desertification on people and the environment, such as differences in vulnerability; management strategies – case studies. **Resources and Sustainability** relating to: **Using Resources:** development of the concept of sustainability in relation to resource use. **Conventional Energy Sources and their Impact on the Environment:** Forms of energy production in South Africa, their advantages and disadvantages as well as their impact in the long term. **Non-conventional Energy Sources:** the range of sources and how they are of growing importance, their effects and the South African Economy and the Environment. **Energy Management in South Africa:** South Africa's changing energy needs; energy management, towards greener economies and sustainable lifestyles; responsibilities of governments, businesses.

Grade	Climate Science and Climate related content
12	**Mapping Techniques** are revised including: the use of maps and other graphical representations: synoptic weather maps and temperature graphs. **Climate and Weather: Mid-latitude Cyclones,** their general characteristics and nature. **Tropical Cyclones:** their origin, nature and general characteristics. Impacts on human life and the environment. **Subtropical Anticyclones and Associated Weather Conditions:** nature of subtropical anticyclones, general characteristics and causes. **Valley Climates:** the nature of micro-climates and indicators. **Urban Climates:** urban and rural climate as micro-climates, pollution domes, their causes and effects. **Agriculture:** including factors that favour and hinder agriculture in South Africa, such as climate, soil, land ownership and trade.

CHAPTER 7

An Analysis of Environment and Sustainability Content Coverage in the Grade 12 Curriculum

Sikhulile Bonginkosi Msezane

Introduction

Kyburz-Graber (2013) stated that environmental education (EE) was integrated into the curricula of many countries towards the end of the 1960s as a response to the growing fears about degradation of the environment. This movement is still in process as indicated by the international goal to integrate the principles, values and practices of sustainable development into all aspects of education and learning (Unesco 2019). The South African education sector has experienced several shifts in the curriculum since 1994, thus affecting the coverage, teaching and examination of environmental content in the Further Education and Training (FET) phase (Grades 10–12). Environmental content coverage in the curriculum is important for developing the capacity of South Africa's future leaders to respond to issues such as pollution, climate change, deforestation, desertification and loss of biodiversity in the country. Hence, this chapter investigates the coverage of environmental content in subject policy documents and the Grade 12 examinations written annually between 2012 and 2015. The start of this period coincides with the 2012 implementation of the latest South African curriculum – the Curriculum Assessment Policy Statement (CAPS).

Integrating environment in education systems and curricula

Environmental education has been encouraged through both informal means, geared towards the public, and formal means, such as its integration in curricula from primary up to tertiary level (Hill et al. 2006). Kyburz-Graber (2013) states that EE, as part of a demand for new education systems, was launched in many countries towards the latter part of the 20th century as a response to the growing evidence of human degradation of the environment. Sitarz (1994) notes that the increase in the world's population and unsustainable pathways of development, production and consumption, particularly in the industrialised countries, has stimulated economic growth and worsened negative environmental impacts. The nations of the world now recognise that the industrialisation and over-exploitation of the Earth's resources have degraded the environment and generated unmanageable amounts of waste and pollution. In line with the global scenario, South Africa, too, has experienced environmental degradation (South Africa DEA 2017).

In June 2000 the South African government recognised the importance of EE in the education system, implementing a policy to ensure that EE would become prominent in all learning areas in both the General Education and Training, and Further Education and Training bands (Irwin & Lotz-Sisitka 2014). Environment as a phase organiser became a tool to explore EE issues in the curriculum. In the changeover to a new curriculum – the National Curriculum Statement (NCS) for the FET band – environmental content became an integral part of all learning areas. This was underpinned by a principle of human rights, inclusivity, and environmental and social justice. Thus, there was a change from a cross-curricular phase organiser in Curriculum 2005 to a strong focus on environmental justice integral to all subjects in NCS (South Africa DBE 2011). The ongoing implementation challenges resulted in a review in 2009 (South Africa DBE 2011).

In 2011, the new Curriculum Assessment Policy Statement (CAPS) retained the principle of social and environmental justice and human rights, with the prescribed aim of producing learners that are able to use science and technology effectively and critically, while showing responsibility towards both the environment and the health of others (South Africa DBE 2011). The CAPS presents variability in environment and sustainable development concepts in all subjects. The aim of the study that informed this chapter was to explore the extent and breadth of the coverage of environmental content in the different subjects in the curriculum.

Research design

The study used both qualitative and quantitative descriptors and the method was a content analysis of documents. Content analysis concentrates on **word** and **phrase counts** as well as **numerical** measures of textual expressions (Given 2012b). Documents enter the social field as instructions, obligations, contracts and policies. These documents also have enduring effects in the present and the future, and are thus helpful in contextualising research within its subject or field (Given 2012a). They are significant as both the curriculum and trends in examination content will affect where teachers focus their teaching. They also influence the acquisition of knowledge and skills regarding environmental challenges with which students will move into their post-schooling professional and academic lives.

The study reviewed environmental content coverage in the syllabi for all eleven core subjects for Grade 12: Economics, Life Sciences, Geography, Agricultural Sciences, Physical Sciences, Business Studies, History, Accounting, Mathematics, Mathematical Literacy and English First Additional Language. The former seven subjects had identifiable environmental content. This content was analysed according to generic environmental content mentioned in the description of the purpose and specific aims of the subject (see Appendix A). The curricula were further analysed in terms of the extent of environmental content in the final year examinations for 2012–2015 (Appendix B).

The analysis of environmental content was conducted according to the following questions:

- How many of the subjects make explicit reference to environmental concerns when they describe the role and rationale of the subject?
- How many of the subjects prescribe explicit environmental topics and what is this topic content (see Appendix A for results of this analysis)?
- What is the total number of environmental topics in each subject?
- How much time is allocated for environmental topics (weeks) in each subject and how does this compare to other topics (percentage)?
- What is the coverage of environmental topics in examinations (measured as marks allocated to environmental content questions in relation to total marks) (see Appendix B for the results of this analysis)?

Discussion of findings

The introduction to this chapter described the generic CAPS principle and aim regarding the expected critical and holistic approach to environmental concerns. Table 1 shows only the subjects that explicitly prescribe content that would provide opportunity for this principle and aim to be exercised. The review of the CAPS syllabi revealed that only seven subjects out of the eleven have environmental content in the programme of teaching and learning. These subjects are Life Sciences, Geography, Agricultural Sciences, Physical Sciences, Business Studies, Economics and History. The policy documents show that Geography has the highest number of environmental content topics relative to the other subjects analysed. Life Sciences has only one topic, but it is an extensive topic, as indicated by the time allocation for this topic. Life Sciences has 9% of total time allocated to environmental content, which is the highest time allocation of all subjects. With time allocations of between 7% and 9%, Life Sciences, Geography, Economics and Physical Sciences appear to demonstrate the greatest commitment to environment and sustainability. Business Studies and Agricultural

Sciences have allocated 4% and 3% respectively. In History there is one small reference to environmental content in one of the topics, but the coverage is minimal and has insufficient time allocation to be counted as significant.

Table 1. Analysis of environmental content in CAPS documents in Grade 12

CAPS POLICY DOCUMENTS							
	Life Sciences	Geography	Agricultural Sciences	Physical Sciences	Business Studies	Economics	History
Total number of topics	12	31	41	52	15	20	6
Total number of environmental topics	1	3	1	2	1	2	1
Tuition time allocation for all the topics in the exams (weeks)	28	27	29	29	25	26	26
Time allocation for environmental topics (weeks)	2.5	2	1	2	1	2	Not specific
Percentage time allocation of environ-mental topics (%)	9	7	3	7	4	8	N/A

(Source: the author)

As mentioned above, the environmentally focused general principle and aim for all subjects does not specify content but is significant in terms of how to approach environmental concerns, as well as the type of competencies we expect to emerge from environmental learning. Environmental learning could either be guided by environmental content specified as topics in some subjects, or be included in classroom teaching or in textbooks as contextual cases or problem-solving contexts for other subjects. This might be the strategy for introducing environmental content in the four subjects that did not specifically name environmental topics as part of their syllabi (Accounting, Mathematics, Mathematical Literacy and English First Additional Language). However, the scope of the study did not include any analysis of classroom teaching or textbooks, thus we are not able to know the extent to which environmental topics might be included in these subjects. For the seven subjects listed in Table 1 that do explicitly include environmental content, more detail is provided below (see also Appendix A).

In **Physical Sciences**, the subject definition specifies inclusion of environmental content where investigation is based on physical and chemical phenomena. This is done through scientific inquiry, and application of scientific models, theories and laws in order to explain and predict events in the physical environment. The purpose of the subject is given as follows:

> *The purpose of Physical Sciences is to make learners aware of their environment and to equip learners with investigating skills relating to physical and chemical phenomena, for example, lightning and solubility.* (South Africa DBE 2011)

Notable environmental content mentioned in the Physical Sciences policy is the topic of 'oxidation numbers' that is applied to the fertiliser industry to evaluate the effect of the use of inorganic fertilisers on humans and the environment.

In **Business Studies**, the definition of the subject included a mention of an environmental focus, in that the subject encompasses business principles, theory and practice that underpins the development of entrepreneurial initiatives, sustainable enterprises and economic growth. Environmental content appeared in the overview of topics to be taught per term and in the annual teaching plan. This environmental focus highlighted issues such as protection and sustainability of the environment, and impacts on human health and the environment by businesses.

The **Economics** subject definition and specific purpose mentioned issues of sustainable development but made no mention of the ecological dimensions of environment, such as abiotic and biotic factors. In this subject, the environmental topics of environmental sustainability, basic economic problems in tourism, and economic redress can be found. Approached from an economic perspective, this subject content highlights the importance of critically reviewing the promotion and violation of human rights and environmental rights, the state of the environment, measures to ensure sustainability, and adherence to major international agreements.

In **History**, an environmental focus is mentioned in the purpose of the subject as described in the introductory History chapter. This chapter explains that History encourages civic responsibility and responsible leadership, including addressing current, social and environmental concerns. There is one topic in the curriculum, 'a new world order', in which 'environmental movements' are listed as part of the content; however, this content is minimal and has insufficient time allocation to be counted as significant.

The definition of **Life Sciences** is given as the scientific study of living things from molecular level to their interactions with one another and their environments. By studying Life Sciences, learners are expected to develop an understanding of the ways in which humans have impacted negatively on the environment and organisms. Further, learners are expected to develop an awareness of what it means to be a responsible citizen in terms of their impacts on the environment and the lifestyle choices that they make. The CAPS elaborated that **environmental studies** should be studied as a discipline or specialisation. The subject is organised into four knowledge strands, and Environmental Studies is one of these. This shows that environmental studies in this subject has significant coverage. The content described in Environmental Studies that covers Human Impacts (Current Crises), is dealt with in Grade 11, but this topic is only examined in the National Senior Certificate examination at the end of Grade 12. This content in Life Sciences helps learners to understand the contribution of Science to social justice and societal development, as well as the need for using scientific knowledge responsibly in the interest of society, the environment and ourselves.

In **Geography**, the main aim is making and justifying informed decisions and judgements about social and environmental issues. The subject is defined as the study of human and physical environments. The curriculum states that Geography can be explored by applying a conceptual framework that embraces one of the four big ideas, which is 'Human and Environment Interaction'. Environmental topics in this subject are environmental impact, human-environment interaction, and environment quality. These topics include content such as climate and weather, drainage systems, rural and urban settlements.

In **Agricultural Sciences**, the environmental content topics are based on sustainable natural resource utilisation, ecology and agro-ecology. Learners are expected to develop an awareness of the management and care of the environment, natural resources and the humane treatment of animals through the application of science and related technology. Learners are also expected to become informed and responsible citizens in the production of agricultural commodities, caring for the environment, and addressing social justice issues such as equal protection from environmental harm. Agricultural Sciences content also covers better cultivation methods to sustain natural resources; impact of organic and inorganic fertilisers on the environment; environmental factors to be considered when selecting the general locality for greenhouses; and water quality and sustainable use of water in agriculture.

In summary: all of the above subjects stipulate the general principle of taking cognisance of human rights, inclusivity where **environment** provides both opportunities for and challenges to **inclusion**, and environmental and social justice. All subjects also aim for learners to be able to use science and technology effectively and critically while showing responsibility towards the environment and the health of others. The content analysis findings showed that subjects such as Physical Sciences, Business Studies, Agricultural Sciences and Economics have a specific aim and purpose that mentions the importance of environmental awareness in the subjects. However, some subjects such as Life Sciences and Geography have no subject-specific aim or purpose that highlights the importance of environmental content in their policies. Despite this lack, these subjects still include some reference to environmental content in their definitions and descriptions. For instance, Life Sciences has environmental studies integrated as a discipline or specialisation, while Physical Sciences, Economics and Geography have specific definitions formulated around environmental themes.

Coverage of environmental content in examinations

There was a further narrowing in the range of the subjects eligible for analysis in this part of the research because only **four** subjects examined environmental content in the Grade 12 final examinations. The environmental content coverage in the curriculum versus the examination content of these four subjects is shown in Appendix B. In **Business Studies** and **History**, there was no coverage of environmental content in the summative assessments. Thus, the minimal environmental coverage in the syllabi for these two subjects (4% of the curriculum in Business Studies and only one topic on 'a new world order' in History) was further undermined by the lack of environmental reference in the examination content of these subjects.

Another subject eliminated for further analysis was **Physical Sciences** which, as stated above, was identified as one of the four subjects with the highest environmental coverage in the curriculum. With 7% of content in the curriculum of this subject dedicated to environmental content, it is particularly puzzling that there was no coverage of this topic at all in the examinations. The other notable inconsistency, for the opposite reason, was in regard to **Agricultural Sciences**. This subject had less time allocated to environmental content in the curriculum than Physical Sciences, yet allocated 2.5% of the marks to testing environmental content knowledge in the examination (see Appendix B).

In **Economics**, none of the environmental content in the examinations required learners to write on recent international environmental agreements as stipulated in the subject policy. In terms of percentage topic coverage between policy (8%) and examination (10.8%), there was greater emphasis on environmental content in the latter, thus indicating that examiners take the environmental content of the policy document seriously. Similarly, in **Geography**, the percentage of topic coverage in policy (7%) and examination (12%) indicated the importance with which examiners view environmental content in the curriculum. The study found that the significant difference between policy and examination in Geography is the result of some Grade 10 and 11 environmental content being included in the Grade 12 exit level examinations. This included Grade 10 content such as water resources and population distribution and identity, and Grade 11 topics of resources and sustainability, development issues and challenges, and drought and desertification. In **Life Sciences**, there was a closer alignment of the policy (9%) and examination (8.8%) content as seen in Appendix B. The alignment in Life Sciences can be attributed to the specific description of environmental content to be taught in the classroom that is stipulated in the CAPS policy, as well as the actual marks to be allocated for environmental content in the examinations. Lastly, in **Agricultural Sciences**, there was close alignment between CAPS policy projections (3%) and content coverage of environmental content in the examinations (2.5%).

Conclusion

Teachers are likely to be influenced by the extent of environmental topic coverage in documents such as the curriculum and examinations. If the policy implementers and examiners do not align what is in the policy with practice, it is likely that teachers will tend to concentrate on teaching and revising topics that have a wider coverage in the final-year exit level examinations; this is due to the agential/operational effects of the documents.

The findings show that English First Additional Language, Mathematics, Mathematical Literacy, and Accounting do not explicitly define environmental content in their syllabi. Environmental content coverage in these subjects would depend on the chosen texts and examples introduced by textbooks and teachers in classrooms. The findings further show that Geography, Life Sciences and Economics have significant environmental content coverage ranging from 7% to 12% with up to 5% difference between curriculum and examination. The chapter suggests that this significant coverage should require teachers to concentrate on teaching and revising environmental content in these subjects. Agricultural Sciences has 3% environmental content coverage and slightly less in the examination. Physical Science, Business Studies and History do have prescribed environmental content but this is not tested in the examination. In addition one can note that environmental focus in some subject definitions and purpose is evident, while in other subjects, while it is not specifically outlined, the general aims of the curriculum and purpose include an emphasis on environment.

The chapter recommends that during the next curriculum review, policymakers for all subjects replicate what Life Sciences has done in terms of stipulating the exact percentage of environmental content to be taught. This must then be written into the policy documents both for curriculum and practice (examinations). The chapter further suggests that all subjects are worth revisiting in the next national curriculum review to assess whether environment and sustainability is given the coherent and sufficient coverage it requires, in view of the important foundational role of this knowledge in guiding the young scholars, citizens and professionals who will be influencing human-environment relationships in the present and future.

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Appendix A: Environmental topics and content in CAPS

SUBJECTS	GENERIC ENVIRON-MENTAL CONTENT	ENVIRONMENTAL IMPACT TOPICS	CONTENT
PHYSICAL SCIENCES	• Definition, specific aims and purpose of physical sciences is only concentrated on understanding how the physical environment works	• Oxidation numbers and application of oxidation numbers • The fertiliser industry (Nitrogen, Phosphorus, Potassium)	• Evaluate the use of inorganic fertilisers on humans and the environment • Search for and present information on environmental issues related to the use of plastics • Describe, using half equations and the equation for the overall cell reaction, the layout of the particular cell using a schematic diagram, and potential risks to the environment such as electrolytic processes used in industries • Evaluate the impact of inorganic fertilisers on humans and the environment
BUSINESS STUDIES	• No mention of environmental content in the purpose of the policy	• Human rights, inclusivity and environmental issues	• Create business opportunities, creatively solve problems and take risks, respecting the rights of others and environmental sustainability • Environmental issues (protection of the environment and human health by business)
ECONOMICS	• The definition and purpose of the study unpacks issues of sustainable development that includes societal, economic, environmental and political	• Tourism & Economic redress (environmental sustainability) • Basic economic problem: environmental sustainability	• Promotion or violation of human rights and the environment (human rights and the environment) • Analysis of environmental sustainability, investigation of recent international agreements in this regard, for example, the Rio de Janeiro and Johannesburg summits • The state of the environment • Measures to ensure sustainability • Major international agreements (Rio de Janeiro and Johannesburg summits)
HISTORY	• Only one reference to environment can be found in the topic of 'A new world order' – and that is the focus on environmental movements	• A new world order	• Responses to globalisation, heralding an age of economic insecurity and environmental movements

SUBJECTS	GENERIC ENVIRON-MENTAL CONTENT	ENVIRONMENTAL IMPACT TOPICS	CONTENT
LIFE SCIENCES	• **Environmental studies** is studied as a discipline or specialisation of the subject • The subject is organised in strands, with Environmental Studies as Knowledge Strand No. 3 of the curriculum • Includes a deep appreciation of the unique diversity of past and present biomes in Southern Africa and the importance of conservation • Gives an awareness of what it means to be a responsible citizen in terms of the environment and of lifestyle choices that are made	• Human impact on • environment. Revision of current crises learned in Grade 11 • In Grade 12, three of the four Knowledge Strands are addressed and serve to ensure progression. The content described in Environmental Studies: Human Impacts (Current Crises), dealt with in Grade 11 in order to lessen the pressure in Grade 12, but this Knowledge Strand will only be examined in the National Senior Certificate examination at the end of Grade 12	• The development of scientific knowledge, understanding scientific knowledge and how it can be used to answer questions about the nature of the living world around us. It can prepare learners for economic activity and self-expression and lay the basis for further studies in science. Prepares learners for active participation in a democratic society that values human rights and promotes acting responsibly towards the environment • It also helps learners to understand the contribution of science to social justice and societal development as well as the need for using scientific knowledge responsibly in the interest of ourselves, society and the environment • Biosphere to ecosystems, biodiversity, population ecology, current crises for human survival
GEOGRAPHY	• Definition mentions that the subject is the study of human and physical environments • Specific aim of the subject is that learners should be guided in making informed decisions and judgements about social and environmental issues • Geography can be explored by applying a conceptual framework that embraces one of the big four ideas, that is, human and environment interaction	• Impact of tropical cyclones on human activities and the environment • Strategies that help to prepare for and manage the effects of tropical cyclones • Case studies that show how selected urban areas in South Africa are managing urban challenges and handling environmental, economic and social justice concerns • Physical, economic, social, political and cultural environments	• Water in the world, the world's oceans, water management in South Africa, floods, drainage systems in South Africa, fluvial processes, catchment and river management • Environmental impact, social impact, interdependence • Human-environment interaction, • Environmental quality

SUBJECTS	GENERIC ENVIRON-MENTAL CONTENT	ENVIRONMENTAL IMPACT TOPICS	CONTENT
AGRICULTUR-AL SCIENCES	• The purpose of the subject is to teach learners to develop an awareness of the management and care of the environment, natural resources and the humane treatment of animals through application of science and related technology	• Sustainable natural resource utilisation, ecology and agro-ecology	• Better cultivation methods to sustain natural resources • Impact of organic and inorganic fertilisers on the environment • Environmental factors to be considered when selecting the general locality of greenhouses • Water-use quality and sustainable use of water in agriculture

Appendix B: Environmental content coverage in the curriculum (policy) in relation to environmental content in examinations

SUBJECTS	ENVIRONMENTAL TOPICS AND CONTENT/ CONCEPT IN CURRICULUM	ENVIRONMENTAL CONTENT IN THE CAPS EXAMINATIONS (2012–2015)
ECONOMICS Tourism & Economic Redress: (Environmental sustainability) Basic economic problem: (Environmental sustainability)	• Promotion or violation of human rights and the environment (human rights and the environment) • Analysis of environmental sustainability, investigation of recent international agreements in this regard, for example, Rio de Janeiro and Johannesburg summits • The state of the environment • Measures to ensure sustainability **AVERAGE COVERAGE: 8%**	**2012:** Gas emissions and climate change (global warming), biodiversity loss, conservation of natural resources, pollution and environmental sustainability **2013:** Mineral resources depletion, depletion of ozone layer, recycling, green tax, acid water, water pollution, environmental sustainability, climate change, air pollution **2014:** Environmental sustainability, conservation, depletion of natural resources (coal, oil, gas), non-renewable resources, land and water pollution **2015:** Climate change, depletion of natural resources, green tax, carbon emission, water pollution, sustainability, land degradation **AVERAGE % COVERAGE: 10.8%**

SUBJECTS	ENVIRONMENTAL TOPICS AND CONTENT/ CONCEPT IN CURRICULUM	ENVIRONMENTAL CONTENT IN THE CAPS EXAMINATIONS (2012–2015)
LIFE SCIENCES Human impact on environment: current crises	• The development of scientific knowledge and understanding how scientific knowledge can be used to answer questions about the nature of the living world around us. It can prepare learners for economic activity and self-expression. It lays the basis for further studies in science and prepares learners for active participation in a democratic society that values human rights and promotes acting responsibly towards the environment • It also helps learners to understand the contribution of science to social justice and societal development as well as the need for using scientific knowledge responsibly in the interests of ourselves, society and the environment • Biosphere to ecosystems, biodiversity, population ecology, current crises for human survival **AVERAGE % COVERAGE: 9%**	**2012:** Threats to biodiversity, culling of elephants that are damaging the Kruger National Park and current crises for human survival **2013:** Carbon monoxide emissions, spillage of toxic minerals such as copper and invasion of alien plants in the environment **2014:** Global warming, negative effects on crops **2015:** Illegal killing of wildlife, excessive fertilisation of soil and food wastage **AVERAGE % COVERAGE: 8.8%**
GEOGRAPHY Environmental impact on development and energy management Human-environmental interaction and social impact Environmental quality and quality of life	• Water in the world, the world's oceans, floods, drainage systems in South Africa, fluvial processes, catchment and river management **AVERAGE % COVERAGE: 7%**	**2012:** Impact of climate change, loss of biodiversity, land degradation, drought, river pollution and air pollution **2013:** Health hazards caused by mines, poverty, the negative impact of human activities on wildlife, food security **2014:** Effects of Berg winds on veld fires, negative effects of overpopulation in urban areas **2015:** Water pollution in the Vaal River, environmental impact of cyclones, high levels of pollution on the outskirts of towns, soil erosion, overstocking **AVERAGE % COVERAGE: 12%**
AGRICULTURAL SCIENCES Sustainable natural resource utilisation, plant studies, ecology and agro-ecology	• Better cultivation methods to sustain natural resources • Impact of organic and inorganic fertilisers on the environment • Environmental factors to be considered when selecting the general locality of greenhouses • Water-use quality and sustainable use of water in agriculture **AVERAGE % COVERAGE: 3%**	**2012:** Threats of climate change (heat stress in pigs), adverse environmental conditions **2013:** Effects of high temperatures on animals **2014:** Farm management **2015:** Greenhouse effect, risk to environment of genetically modified plants **AVERAGE % COVERAGE: 2.5%**

SECTION B

Transformative pedagogies for environment and sustainability learning

CHAPTER 8

Theorising Active Learning – A Historical Analysis

Ingrid Schudel

Introduction

There is no definitive or consensual Education for Sustainable Development (ESD) pedagogy but there is a suite of techniques which, if examined, will reveal similar features and principles. For example, in its ESD sourcebook, Unesco (2012) highlights pedagogies featuring question-orientated, analytical, critical and decisive skills, as well as relational pedagogies with features such as learner-centredness and participation. In its later Roadmap for Implementing the Global Action Programme for Education for Sustainable Development, Unesco calls for pedagogies that support the designing of 'teaching and learning in an interactive, learner-centred way that enables exploratory, action-oriented and transformative learning' (Unesco 2014: 12). An international collaborative group – ESD Expert-Net – highlighted the 'active' element of ESD arguing that 'action' or 'doing' elements of learning have traditionally been neglected, and that if ESD practice is to address local and global challenges 'a strong action component' is needed (Hoffmann & Rajeswari n.d.: 9). The notion of 'active learning' has been of central interest in the Fundisa for Change project. This chapter describes its trajectory of development and use in South African ESD by outlining core features and principles for active learning. This is with a view to positioning the further chapters in this section of the book in relation to national and international research that has influenced the approach of Fundisa for Change. The chapter also serves to inform international interests in active learning.

The term 'active learning' is used, but not explicitly elaborated, in formal South African curriculum documentation. In official South African policy discourse, the first post-apartheid reference to active learning in education can be found in the 1995 White Paper on Education and Training which called for 'environmental education involving an interdisciplinary and active approach to learning' (South Africa DoE 1995: 11). The same notion has been incorporated into the three iterations of post-apartheid curricula up to the current South African Curriculum and Assessment Policy Statement (CAPS), which calls for 'encouraging an active and critical approach to learning, rather than rote and uncritical learning of given truths' (South Africa DBE 2011: 3). However, none of these policy documents have elaborated on what active learning means, and what teaching and learning processes might support it. Therefore, at the level of educational practice, much is left up to interpretation by curriculum implementers and teacher training institutions.

At issue in this chapter is a deeper theorising and understanding of active learning. This is achieved through two processes. The first is elaboration of the three emergent core features of active learning, as introduced above, through reference to influential national and international educational and ESD literature in South Africa since 1994. Second, the chapter seeks to elaborate further on active learning by drawing on a critical realist dialectic, which sees 'active and reflexive engagement within the world in which we seek to achieve the unity of theory and practice *in practice*' (Bhaskar 1993) as the culmination of dialectical thinking, and where agency is elaborated as 'embodied intentional causal absenting' (Bhaskar 1993).

A key influence in the implementation of active learning processes in South Africa was an active learning framework developed by O'Donoghue (2001) which played a significant role in supporting teachers through the design of environmentally focused learning units. The artist's rendition of active learning reproduced in Figure 1 below evokes the complexity of how the idea was taken up by ESD practitioners at the time.

Figure 1. Artist Richard Kilpert's rendition of active learning (2000)

O'Donoghue's framework (elaborated in the next section) structures information-based enquiry, action and reporting/reflection activities around a central environmental focus (problem, risk or concern). The use of this framework in teacher professional development programmes dates back to the National Environmental Education Programme for General Education and Training (NEEP-GET). This was piloted in South Africa in 2000 (Schudel et al. 2000) in the Eco-Schools programme, where it was used for guiding lesson planning (Rosenberg 2000) and in teacher education courses developed, for example, by Rhodes University in the Schools and Sustainability Course (Schudel et al. 2008a). Modifications of the same framework have been used in the national Fundisa for Change environmental education programme for teachers and teacher educators (O'Donoghue 2013; O'Donoghue 2019). The 2019 version is also discussed in the section that follows.

The active learning framework is designed as a structure for guiding learning programmes but can be used in many different ways depending on how its users see and understand its purpose, and how they experience its implementation in the field. This chapter first describes the earliest and latest (2019) framework versions in detail, followed by a clarification and critique of implicit and espoused theories, intentions and assumptions associated with the notion of active learning. This is achieved by a document review across numerous research reports which provide insight into how ESD research, both internationally and in South Africa, has influenced the development and interpretation of the notion. This part of the chapter results in the elaboration of three core features of active learning as a situated, action-orientated and reflexively deliberative pedagogy. In the final section of the chapter, a number of principles relevant to each of the core features is lifted from the analysis to suggest ways for strengthening the capacity of active learning processes to enable transformative learning in ESD.

An evolving active learning pedagogy

O'Donoghue indicated that active learning emerged at a time in South Africa when concern for 'local enquiry, problem solving and action learning' were recognised as important pedagogical processes (O'Donoghue 2007: 150). This was a time when environmental educators were recognising that environmental education was more than simply transmitting information about problems, or experiences, to raise awareness of the value of nature. Exploring human-environment relationships and alternative practices in the context of learners' own lives was necessary to help them deal with the everyday reality of environmental risks and concerns (O'Donoghue 2007). The importance of tackling concerns in everyday contexts is also evident in Janse van Rensburg's Guidelines for Learning Area Working Groups produced for the NEEP-GET to guide South African curriculum development. Here she called for 'active learning, critical thinking, involvement in real issues and encounters in the learners' immediate environment' (Janse van Rensburg 2001: 30).

This section provides an overview of the structure of the active learning framework as proposed by O'Donoghue (2001: 8) (see Figure 2). O'Donoghue's open process framework suggests the identification of an environmental focus (which may be a problem, concern or risk) and then draws attention to four different types of activities that can be used to structure environmental learning programmes around this focus. These are listed below and elaborated through my own understanding and experience of their implementation in the Schools and Sustainability Course:

- **Information-seeking activities:** Learners find out what is already known about the environmental focus (informal research). They identify what else they need to find out (know) and uncover that information (with help from the teacher), through the use of information resources and 'expert' knowledge from institutions and individuals in the local community. Types of information might include foundational environmental knowledge of ecological principles and systems; scientific (natural science or social science) information about an issue or practice; a technological design to support a particular practice; or information on an ethical standpoint regarding a particular issue.
- **Enquiry encounters:** Learners investigate the focus further (through investigations in local surroundings gathering qualitative and quantitative data through methods such as interviews, audits, surveys, observations and field studies) in order to explore how the environmental issue, risk or concern is being experienced in their community. In the course, this was used to help 'learners to monitor, analyse, and evaluate [a] situation, resource or activity, and then plan to take appropriate action' (Schudel et al. 2008b: 2).
- **Action taking:** Learners act to make 'a conscious and informed response' to an issue/concern/risk raised in the course or '[try] out ways of doing things differently' (O'Donoghue et al. 2007: 141). Schudel et al. (2008c) explained that action does not necessarily have to be a practical hands-on activity, but can also involve planning for action, or lobbying for authorities to take action.
- **Reporting:** Learners reflect on the other dimensions of the framework. The act of reporting brings opportunities for critical reflection, especially around O'Donoghue's suggested 'steering question' of 'What do we now know and what have we achieved towards sustaining alternatives?' (2001: 10).

O'Donoghue (2001: 7) saw his proposed framework as supporting 'open-ended processes of active learning' and suggested that educators could take any one of the dimensions as a starting point and superimpose appropriate methods within the different dimensions of the framework to create a 'multi-skilled and multi-perspective approach to environmental risks and concerns'. For example, activities initiated by O'Donoghue (2011) in the Environmental Learning Research Centre, suggest possibilities for starting with an **action** of making sour-dough bread, followed with

information about how the souring process breaks down gluten (thus addressing the problem of gluten allergies), followed by an **enquiry** regarding the ingredients, costs and taste of homemade versus shop-bought bread, and **reporting** on the differences between the two types of bread.

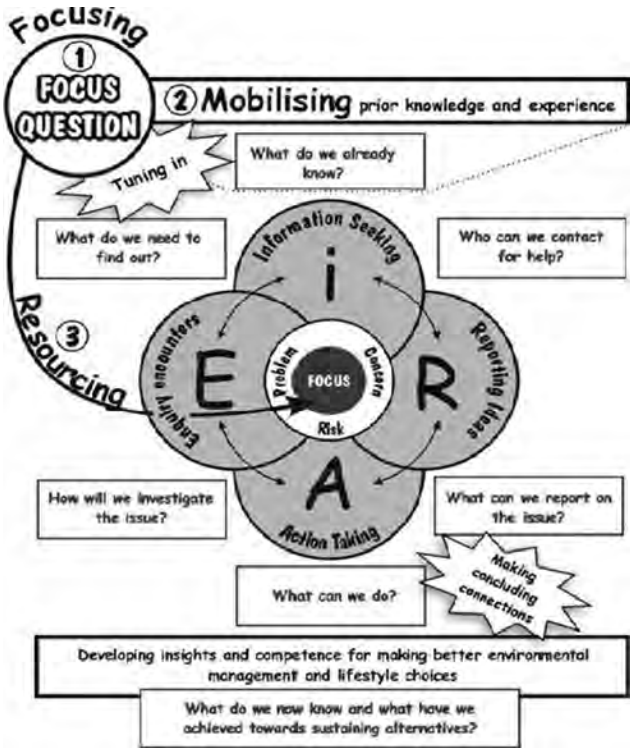

Figure 2. Active learning framework (O'Donoghue 2001)

O'Donoghue (2001) drew on Fien's (1993) concepts of education *about*, *through* and *for* the environment to inform the active learning framework. Fien described education *about* the environment as 'knowledge about natural systems and processes and the ecological and political factors that influence decisions about how people use the environment' (1993: 15). This concept clearly links with the 'information' dimension of the active learning framework. Education *through* the environment has the purpose of adding 'reality, relevance and practical experience' to learning (1993: 15), and this has links to the experiential nature of the 'enquiry encounters' dimension of active learning, the 'mobilising of prior knowledge' which is important to the 'information' dimension, and the hands-on and minds-on nature of responding to, or action-taking in, a real context. Fien (1993: 16) describes education *for* the environment as a 'counter-hegemonic process' and having 'an overt agenda of values education and social change'. Possibilities for this counter-hegemonic stance are opened up by O'Donoghue's (2001: 7) call for 'critical action', for trying out ways of doing things differently (see action-taking dimension above), and for making explicit the transformational possibilities embedded in the framework.

In 2019 O'Donoghue revised this framework for active learning for the Fundisa for Change programme where it was used as a core text for the training of South African curriculum advisors and teachers. The basic skeleton of the revised framework is presented in Figure 3, and elaborated in O'Donoghue, Misser and Snow-McLeod's chapter later on in this book (Chapter 10). For the purposes of this chapter, I will work with this 'skeleton' in order to highlight its similarities to the 2001 framework, and also to point out key changes made in response to the current South African curriculum needs.

First, one can see that the core interests in information (now in an embodied notion of 'knowledge'), inquiry, action and reporting (synthesis) are still evident. Similar to the 2011 framework's interest in making better environmental management and lifestyle choices, the current framework insists on application and innovation. How this new framework differs significantly as a response to the current South African needs, is in specifically highlighting the importance of subject-discipline knowledge in Quadrant 1. The framework also emphasises assessment more strongly by focusing on what learners ought to achieve through the active learning process. The New Bloom's Taxonomy, as revised by Krathwohl (2002) is evident in the framework, which highlights lower order (knowing and remembering), medium order (understanding and applying), and higher order (analysis, evaluation and innovation) cognitive skills. Innovation is particularly important for environmental learning, which is aimed at transforming the world, and this links to Krathwohl's cognitive level of 'create' which he described as 'putting elements together to form a novel, coherent whole or make an original product' (2002: 215). The historical significance of these moves will be highlighted in the discussion of active learning below.

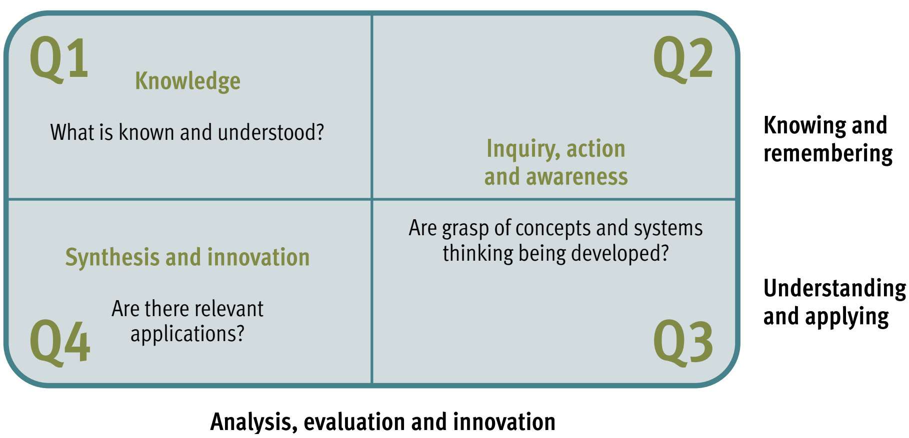

Figure 3. Mediating and assessing active learning (O'Donoghue 2019)

Methodology

The study represents part of a more extensive doctoral study on active learning (Schudel 2013). This chapter was established through a historical document review of research reports, project guidelines and course materials of the four national South African programmes that have contributed to the conceptualisation, and guided implementation of, active learning in the country since 1994. These programmes are: the Learning for Sustainability Course; the NEEP-GET Programme; the Eco-Schools Programme; and the Schools and Sustainability Course (see Schudel, Lotz-Sisitka, Songqwaru and Tshiningayamwe, Chapter 1 for insight into the role of some of these programmes). These are all programmes in which leading implementers of Fundisa for Change have participated, and which provide experience from which South African environmental educators are able to draw. Appendix A presents a log of the documents included in the review. The final document in the list is the doctoral study mentioned above. While this document has not been referred to directly in this chapter, a number of references to a critical realist dialectic, which were developed in the doctoral thesis, have been brought forward to deepen understandings of active learning in this chapter. Three core features of active learning emerged from the review. This shows that in South Africa, active learning has emerged as a situated, action-orientated, and reflexively deliberative pedagogy. In the next section, key pointers pertinent to this conceptualisation of active learning have been presented and elaborated on, with reference to literature that helps to position the pedagogical choices made iteratively across the four programmes.

The pedagogical underpinnings of active learning in South African ESD research

Active learning as situated

Reflecting on the NEEP-GET programme, Lotz-Sisitka and O'Donoghue argued that in the South Africa of the time, 'current patterns of practice in participatory education favour individualised meaning-making approaches that are disembedded from the realities of everyday life' (2008: 124). Participation as a pedagogical argument has been driven by post-apartheid South Africa's democratic ideals, and constructivist pedagogies and literature suggest that this concept requires situated grounding. Lotz-Sisitka and O'Donoghue (2008) noted that participation can become 'increasingly tenuous and self-referential' (p. 111). This, they argued, was evident in curriculum processes emphasising 'cooperative activity, solidarity, and apparent movement [which] have created an illusion of change' (p. 112). The critique they presented in this paper is followed by illustrative cases of ESD processes which are more grounded in socio-cultural and historical contexts. Their argument for such pedagogy emerged from a previous paper where they illustrated how 'situating in southern African socio-cultural context and history involves the interplay of real stories in context and the stories of what participants experience, do and know (situating story activities) in the contexts of intergenerational and everyday interactions' (O'Donoghue & Lotz-Sisitka 2006: 13).

Furthermore, ungrounded participatory processes can result in utopianist or reified applications of environmental learning (Jickling 1992; Lotz-Sisitka 2008). It then becomes necessary to examine the shaping influences and practical adequacy of normative frameworks (Lotz-Sisitka & Schudel 2006). Smyth (1995) raised a concern that the complexity of the issues often results in over-simplification of, and hasty judgements about, environmental issues – thus giving rise to solutions reflecting idealistic responses to negativity. This idealism results in learners having to deal with 'real contradictions in the world' (Norrie 2000: 60), but without the power to change them.

In order to gain insight into this dilemma, dialectical critical realism can offer some insight and ontological grounding by using Bhaskar's notion of concrete utopianism, to enable 'thinking about how a situation of the world could be otherwise, with a change in the use of a given set of resources or with a different way of acting subject to certain constraints' (Bhaskar 1993: 22). Concrete utopianism can be a useful concept that ensures that generalised, idealistic and unrealistic ideas are not imposed inappropriately on specific contexts. Furthermore, linked to the active learning interest in innovation, Bhaskar describes concrete utopianism as playing a 'role of creative fantasy … that yields at once hope **and** possibility' (1993: 209).

The grounding of situated understanding in intergenerational learning, as noted in the first paragraph of this section, has received much attention in South African ESD debates. For example Maqwelane – a participant in the Schools and Sustainability Course – examined how indigenous knowledge of wild vegetables (*imifino*) was integrated into the primary school curriculum by inviting wise grandmothers (*gogo*s) to share their knowledge about the health and ecologically friendly benefits of *imifino* with younger learners (Maqwelane 2011). The close connection between intergenerational knowledge and indigenous knowledge is significant here and is also a response to the concern about individualised meaning-making mentioned above. Knowledgeable and experienced generations are a significant dynamo in mobilising 'unique [African] histories of knowledge practices that have sustained its peoples over many generations of living in, and creating, habitable landscapes' (O'Donoghue et al. 2019).

The focus on 'local experience' and the 'everyday' link closely and often overlap with the vision of including more intergenerational and indigenous knowledge in curricula. For example, the Eastern Cape Province NEEP-GET project modelled environmental learning practices using issues and risks identified in photographs of local context and newspaper articles. These local examples were used in an issues-based approach to environmental learning in which issues and risks in context were the main emphasis (NEEP-GET 2005). This issues-based approach resonated well with the requirement for competency in 'knowledge and understanding of local environmental issues and risks' which became one of the key competencies for teacher education highlighted by the NEEP-GET (Lotz-Sisitka & Raven 2001). The issues-based approach has been expanded in South African ESD discourse to include a 'practice' element, as illustrated by further research in the NEEP-GET which noted an interest in 'practice-based discourse strongly focused on local, real issues' (Ramsarup 2005). This shift in practice as described by Taylor (2009) is not only about highlighting generalised problems in the world but about understanding the 'problem in context' (O'Donoghue 2014: 10).

Despite the above-mentioned interest in local and everyday experiences, learning does not and cannot be limited to knowledge of everyday contexts. We need to understand the fluidity of the notion of 'local': are we talking locally rural, or locally urban, locally indigenous, locally provincial, locally South African, locally African, or locally global south, for example? How local is 'local'? Even within a national programme in a country as diverse as South Africa, 'local plants' can be very different in different places. Also important to acknowledge is that we are all global citizens, so contextualised materials need to present global understandings with activities for developing embedded, not disconnected, local understandings. As stated in the 'Eco-Schools Handbook', 'most environmental issues have both a local and a global dimension' (Eco-Schools Programme South Africa 2009: 18).

For example, in their 'Handprint: Action Towards Sustainability' series, O'Donoghue and Fox (2009) illustrated an iterative relationship between knowledge and practice through the use of case studies of local learning (knowledge construction in communities of practice) and change (the trying out of sustainability practices) in real contexts. This allowed them to develop a series of resource books 'around locally relevant knowledge resources and practical learning activities' (p. 1) which are situated in the context of global environmental change. For example, one of the books on carbon sequestration supported the planting of an indigenous succulent – 'spekboom'. This plant has a high capacity to absorb carbon – thus enabling the regeneration of indigenous biomes at a local level while responding to the global climate change concern.

Finally, because the notion of situatedness plays into the next core feature of active learning – its action-orientated nature – another important insight into situatedness can be added from dialectical critical realism: that is, the notion of absence which brings additional opportunity to the language of possibility described above. Sayer (2000: 12) explained that a critical realist ontology 'makes it possible to understand how we could be or become many things which currently we are not'. Even in cases where potential powers of societal structures and mechanisms are exercised, tendencies exerted by other structures and mechanisms may counteract or reinforce these powers.

Thus, the work of dialectical realism becomes consistent with the transformative intent of ESD as we need a process of 'absenting absence' (Bhaskar 1993: 176). By negating absence (also a part of concrete utopianism as described above) Bhaskar stresses that we need to 'pinpoint the real, but non-actualised possibilities inherent in a situation, thus inspiring grounded hope to inform emancipatory praxis' (1998: 215).

Active learning as action-orientated

An important historical influence on the notion of active learning in South Africa has been the action competence approach – a concept originating among Danish authors working in the health sector and introduced to South African educators through Danish involvement in national environmental education programmes, such as the Learning for Sustainability Project and the NEEP-GET in the late 1990s (Janse van Rensburg 2001; O'Donoghue 2007). Action competence has helped with giving meaning to the notion of active learning in that the 'action-orientation' of active learning in the field of environmental learning can create misunderstandings if the change-orientated element becomes displaced. For example, research in the NEEP-GET reported that 'there appeared to be some confusion between notions of action and activities, reflected for example in collecting leaves or making objects as forms of "action taking"' (Raven et al. 2005: 48). Jensen and Schnack (1997: 165) described competence as 'being able, and willing, to be a qualified participant' while action they saw as distinct from activity in that action is 'conscious, considered and targeted' at an environmental issue. Action-taking thus differs from activity in that it involves a conscious and informed response to an issue, problem or something that has been learned. An activity is simply a task done for the sake of doing or learning something. Environmental 'action' moves us towards environmental improvement and an improved quality of life.

An action competence approach is consistent with education *for* the environment as described in the section above, and is illustrative of the transformative intent behind the active learning framework. Another way of emphasising the transformational intent of social learning is 'a shift or switch to a new way of being and seeing' (Wals 2009). With this transformative intent, it is possible to conceive of the active learning framework being used in a behaviourist way that, ironically, might be counter to its intention as an alternative to authoritarian and top-down or instrumentalist approaches to environmental learning (O'Donoghue 2007). This possibility is backed by previous research in the Schools and Sustainability Course, where Hoffmann noted that: 'It seems that behaviourist assumptions and intentions can easily be camouflaged within techniques borrowed from popular contemporary theories such as the active learning framework' (2005). This implies that the active learning framework, with an intention for positive and empowering change, could paradoxically be re-interpreted to endorse oppressive and top-down relationships, for example, mandated litter clean-ups or other regimented activities in schools.

As with situated learning, education *for* the environment also needs to take care not to over-individualise the need for change. While individual behaviour changes can make a difference in the world, Jensen and Schnack (1997) insist that environmental problems are not only solved by decisions made by individuals but by addressing systemic structures of society. Similarly, Wals calls for a 'systemic and reflexive way of thinking and acting with the realisation that our world is one of continuous change and ever-present uncertainty' (2007a: 37). Critical realism stretches this notion even further by insisting that an understanding of agency requires an understanding of the relationship between these structures in society and the agents acting in it. Bhaskar uses the notions of 'positions (places, functions, rules, tasks, duties, rights, etc.) … and practices (activities, etc.) as a system of mediating concepts representing a "point of contact" between human agency and social structures' (Bhaskar 1979: 51). This means that instead of focusing either on the individual or on societal structures, the critical point of intervention in environmental change is the relationship between structure and agency.

Education *for* the environment also requires cognisance of power relations among the deliberators. Education *for* the environment has helped to place, and keep, the political dimension of issues on the environmental education agenda, thus illuminating the socially critical agenda of ESD and helping to give life to the field in the face of conservative influences (Jickling & Spork 1998). A pertinent question is whose knowledge dominates in the active learning process of 'sharing', 'reporting' and 'mediation' (O'Donoghue 2001). Reflection on democratic processes can be of use here. In its handbook, the national Eco-Schools Programme explained the intention that 'as a democratic and participatory programme, pupils and staff experience active citizenship in school which encourages them to take ongoing, important roles in improving both their school and home environment' (Eco-Schools Programme South Africa 2009: 2). Wals and Jickling (2009: 80) make a distinction between 'shallow' democracy which is 'superficial, obligatory, detached, cosmetic, and strategic', and 'deep' democracy that is 'real, intrinsic, involved, genuine, and meaningful'. Wals argues for co-creation and co-ownership of 'contextual solutions' with the understanding that 'forcing consensus on how people should live their lives is undesirable from a deep democracy perspective' (2007b: 43).

In South Africa, co-engagement was supported, in particular, through an Eco-Schools process that led to the development of eco-committees in schools, which encouraged 'community involvement' along with 'whole school development and democratic management'. Eco-committee members were involved in whole school audits at the beginning of each year, and in reviews at the end of a co-engaged policy development and implementation process (Rosenberg 2009: 22). Whole school development 'integrates the formal curriculum, social/organisational aspects, institutional practices, evaluation and community links' (Shallcross & Wals 2004: 1).

Jickling and Spork argue that: 'If we are serious about education, we should, in the first place, put aside our most promising visions for the future. Moreover, if we really want to open students' minds to alternative world views, it makes little sense to steer them, however gently, towards a particular vision' (Jickling & Spork 1998: 342). This highlights the importance of transformation not being imposed by an outsider or presented as a pre-determined doctrine, thus 'militating against the evolutionary tendencies of environmental thought' (p. 323). The deep democracy perspective is a reaction against actions being driven by 'outside' concerns, that is, an imposed, decontextualised, 'outsider' view of what we should do.

Active learning as reflexively deliberative

O'Donoghue described the broadening of environmental learning processes in South Africa, from a narrow focus on communicating environmental 'messages' and raising awareness about environmental problems, to a process of 'deliberative co-engagement in the challenges and risks of the day' (O'Donoghue 2007: 148). In the early developments of the active learning framework, deliberation is implied through the series of 'steering questions' in Figure 2:

- What do we already know?
- What do we need to find out?
- Who can we go to for help?
- How will we investigate the issue?
- What can we do?
- What can we report on the issue?

The first three steering questions clearly have a dependence on foundational knowledge which can be either prior knowledge (what do we already know?) or new knowledge (what do we need to find out and who can we go to for help?). Fien's reference to education *about* environment is clearly an objective here. The new knowledge described can be sourced from many different places, as suggested by Wals's argument that problem solving needs to involve 'the integration of multiple perspectives, the co-designing of viable alternatives, the utilisation of diversity, and the simultaneous development of a whole range of sustainability related competences' (2009: 385).

In South Africa, this multi-perspective vision of ESD was very different to the authoritarian pedagogy associated with apartheid South Africa, in which rote learning dominated and learners were seen as passive receptors of knowledge (Janse van Rensburg 2000). Therefore, a distinction between passive and active learning became significant in South Africa. For an understanding of active learning, it is important to make a distinction between active learning in the Piagetian sense of learners 'actively constructing their own development, through their interactions with the environment' (Capel et al. 1995: 219) and activity-based learning in which the cognitive meaning-making process can easily be sidelined through an over-emphasis on hands-on practical action. Rosenberg, O'Donoghue and Olvitt (2013) drew attention to this possibility of sidelining meaning-making when noting that those involved in projects and practical actions (methods under the banner of 'learning-by-doing') may be so absorbed in the practical activity that they neglect to reflect on what they are learning. This point is also made by Vinjevold and Taylor in their concern that:

> *Learning must involve cognitive and affective activity and not merely movement and speech. Thus … if not carefully structured and guided by the teacher, [educational activity] succeeds only in passing the time without engaging the cognitive faculties of participants, and thus results in little or no learning.* (1999: 65)

In essence, the distinction being made here is between hands-on/minds-on learning as opposed to simply hands-on learning.

Important across all national projects has been the role of disciplinary knowledge in understanding everyday problems without falling into the trap of over-emphasising everyday knowledge at the expense of formal school knowledge. This is consistent with concerns about education quality raised in South Africa, regarding how important it is that 'the two-way relationship between everyday and school knowledge provides important pedagogical tools for inducting learners into the art of formal discourse, and for the practical application of formal knowledge to problems in the real world' (Taylor 1999: 113). Thus, there is an important role to be played by subject-specific knowledge in deepening and grounding the understanding of environmental issues within the situated learning processes described previously.

Examples of discipline exploration developed by the NEEP-GET at the time of an outcomes-based focused curriculum include a description of the role of each subject in contributing to environmental understanding:

- Life Sciences was described as important for 'ecosystem and biodiversity studies, and to develop a good understanding of the threats to biodiversity, and why biodiversity is an important dimension of ecosystem maintenance' (South Africa DoE & NEEP-GET 2004: 14).
- Economic and Management Sciences was described as preparing learners to 'adapt to, and participate in an economically complex society, which includes the sometimes conflicting aims of promoting productivity, social justice and environmental sustainability' (p. 18).

The NEEP-GET developed extensive explorations for all curriculum disciplines and the above extracts are illustrative of the role played by the NEEP-GET in highlighting the important explanatory power of the different disciplines. Acknowledgement of this discipline-based explanatory power was not explicit in the active learning framework at the time, but the 2019 framework now highlights the role of CAPS knowledge in Quadrant 1 (O'Donoghue 2019: 7).

In a further example of discipline-based work, in the Schools and Sustainability Course, teachers explored their specific disciplinary areas for opportunities for developing enquiry-based activities in order to gain understandings of environmental challenges they had identified in an earlier contextual profile of their school and community. Teachers were introduced to a variety of qualitative and quantitative ideas for hands-on enquiries, as well as tools for supporting these enquiries, and then encouraged to find or develop their own enquiry tools to suit the focus of their lesson plans. Different methods used in different disciplines included quantitative audits (for example, water use), ecological studies, observations, mapping, descriptive essays, surveys using interviews, and surveys using questionnaires (Schudel et al. 2008b). This emphasis on methods in disciplines highlights how the disciplines provide skills and procedures (procedural knowledge) to gather information about phenomena in addition to the content and concepts that describe and explain these phenomena (propositional knowledge). These two types of knowledge are based on the understanding that a subject 'is composed of two epistemic domains, the "know how" or procedural knowledge' or the 'know that' or propositional domain (Muller 2014: 263).

When reflecting on the deliberative nature of environmental learning it is also important to acknowledge that deliberations may often be value-based. Thus, not only are they 'minds-on' but also have an affective component. Olvitt describes value-based deliberations as ethico-moral and elaborates by explaining that our deliberations are 'moral in terms of our practical and often private deliberations about our conduct in a world characterised by injustice, risk and uncertainty, and ethical in terms of the theories and patterns of thinking in society that influence how we distinguish right from wrong' (2017: 12). Deliberation is a process whereby people 'recognize, evaluate and, when needed, potentially transcend or break with existing social norms, group thinking and personal biases' (Wals 2007b: 39).

Concurrent with the interest in democratic and constructivist educational processes in South Africa has been an interest in South African ESD pedagogy in social learning. Wals describes social learning as 'learning by mirroring one's own ideas, views, values and perspectives with those of others' (2009: 385). A particular challenge with social learning is that the integration of perspectives is often not viable due to oppressive power relationships. Pedagogies embracing strong constructivism can lead to a relativist 'anything goes' outcome in environmental deliberations. From a critical realist perspective, Price explained that this 'leads to the inability to act, since how can we act if we cannot choose between better or worse?' (Price 2007: 107). For example, the concept of sustainability is also open to relativist interpretations leading to an 'ambiguity that, somewhat paradoxically, provides the focus for discourse about a variety of issues within the contemporary problematique, while undeniably also providing fuel for those who would procrastinate in their resolve to seek sustainability' (Bawden 2004: 21). Instead, we can conceive of a weak (non-relativist) constructivism (Brown 2009; Lotz-Sisitka 2008) in which views of reality can be constructed in the minds of learners, but remain open to critique, and still need to stand up to tests of truth and normative judgements. This critique is dependent on philosophically embracing the importance of 'judgemental rationality' which ushers in the question of ethics, thus enabling the possibility for 'explanatory critique of consciousness (and being), entailing judgements of value and action' (Bhaskar 1994: 71).

Of course, normative judgements are themselves constructed so that we are called to examine the shaping influences and practical adequacy of prescribed normative frameworks – as suggested by Lotz-Sisitka and Schudel (2006). The authors drew on Sayer's concern that normative arguments pose the danger of 'empty moralizing [and] of assuming that whatever is agreed to be good, will therefore come into being' (Sayer 2000: 178). Sayer argued that a critical realist argument would need to 'think about the feasibility of desirable alternatives in terms of how the recommended social processes would work, asking counterfactual questions, conducting thought experiments and scrutinising critical standpoints (p. 178). This highlights the importance of deliberation in ESD processes.

A further comment on deliberation is that it is seen in the context of sustainability practices as discussed in a previous section. O'Donoghue called for 'practice-based deliberations that might allow the better mediation of choices that are more reality congruent and socially responsible' (2007: 153). This aspect of deliberation links to Fien's education *through* the environment as described in section two of this chapter and is consistent with Uzzell's (1999: 404) call for 'authentic learning' so that actions developed in school are not 'surrogate or fantasy actions' but authentic and close to the reality learners might find themselves in after school. In this way deliberations are not taking place in a whirl of ideas but are reflecting off tangible practices and dilemmas. Similarly we can note that ethico-moral deliberation does not happen in a whirl of emotions but in relation to the cognitive skills highlighted above. This is important because 'lack of knowledge reduces our capacity for effective moral agency' (Parker 2010).

The descriptions of reflexive deliberation in this section can thus be summed up as deliberations between and amongst the cognitive, affective and practical dimensions of learning. It is these deliberations that enable a reflexive approach to ESD driven by 'dissonance created by introducing new knowledge, alternative values and ways of looking at the world [to] become a stimulating force for learning, creativity and change' (Parker 2010: 39). Reflexivity links to the emphasis on assessment and higher order cognitive thinking levels (analysis, evaluation and innovation), introduced in the reworked active learning framework as discussed in a previous section above. In the reflexively deliberative work of environmental learning (see Chapter 12 for the challenges with reflexive approaches to learning) it is the 'making sense' of different perspectives (analysis), the comparisons across cases and contexts (evaluation), and the identification of new ways of being and seeing (innovation) that engage these higher order thinking skills.

Principles for active learning

This chapter has presented the active learning framework as an open-ended framework for structuring environmental learning, through including activities where learners work with environmental information, conduct enquiries in their local environment, consider appropriate actions towards sustainable living, and reflect critically on the process. The chapter has reviewed guideline documents as well as research and evaluation reports across four historically significant national programmes that have influenced the development and implementation of active learning in South Africa. It has elaborated on these using influential educational and ESD research literature in the country, in particular drawing on a critical realist dialectic to extend conceptions of active learning. The historical research as well as the elaborations with dialectical critical realism helped to set the scene for the emerging conceptions of active learning in the Fundisa for Change programme, which followed the four South African ESD programmes highlighted in this study. The critical realist dialectic has strengthened perceptions of agency (embodied intentional causal absenting – see introduction to this chapter) in active learning by contributing to:

- the groundedness of a situated approach to active learning,

- an understanding of structure/agency relations in the emancipatory agenda of an action-orientated approach to active learning, and
- a need for judgemental rationality in a reflexively deliberative approach to active learning.

The chapter has identified and described three core features of active learning, following this, this chapter now proposes core principles for strengthening active learning in national and international ESD processes.

Principles for active learning as situated pedagogy. Active learning should:

- Situate problem solving and sustainability practices in socio-cultural and historical context.
- Situate sustainability practices and problem solving in intergenerational and indigenous knowledge.
- Situate global and generalised environmental issues and risks in local contexts.
- Explore non-actualised possibilities as intervention points for change.
- Search for concrete utopian visions for change in context that yield visions for both hope and possibility.

Principles for active learning as action-orientated pedagogy. Active learning should:

- Be conscious, considered and targeted at an environmental issue.
- Search for opportunities for positive and empowering change.
- Address environmental problems and sustainability practices from both an individual and a systemic perspective, with focus on positions and practices for understanding relationality between these.
- Ensure co-creation and co-ownership of solutions in context with deference to deep democracy.

Principles for active learning as reflexively deliberative. Active learning should:

- Strengthen deliberations in relation to propositional and procedural knowledge of discipline knowledge.
- Employ counterfactual questions and thought experiments, and scrutinise critical standpoints in finding resolutions that stand up to tests of truth and normative judgements.
- Employ reflexive engagement within and between the cognitive, affective and practical dimensions of knowledge.

It is hoped that the histories and new insights into active learning offered by dialectical critical realism in this chapter will inform and guide national and international perceptions and practices in ESD.

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Appendix A: Document log for historical review of active learning

Programme/ Course	Document name	Author(s)	Pub. date	Type of document	Further information
Learning for Sustainability Course	The Learning for Sustainability project: An overview of the conceptual framework.	Janse van Rensburg	2000	Research Report	This document summarised the conceptual rationale for the Learning for Sustainability Course.
NEEP-GET Programme	Environment in the NCS: Guidelines for learning area working groups writing learning outcomes for the NEEP	Janse van Rensburg	2001	Guideline Document	A guideline document for project partners to help them develop an understanding of how to work with the environmental focus that had been integrated into the curriculum.
NEEP-GET Programme	Active learning through OBE: An interdepartmental support for the piloting of environmental learning in Grades 4-8	Schudel, Dambuza, Lotz-Sisitka, Magonare, O'Donoghue & Solomon	2000	Guideline Document	This book was developed to help pilot active learning in the context of Curriculum 2005.
NEEP-GET Programme	Active Learning in OBE: Environmental Learning in SA Schools	Lotz-Sisitka & Raven	2001	Evaluation Report	NEEP: This was an evaluation report developed for the GET Pilot Project: August 2000 to February 2001.
NEEP-GET Programme	Formative Monitoring and Evaluation Final Report: Storyline of a project in context: NEEP-GET in the Eastern Cape	Raven, Timmermans, Lotz-Sisitka & Nduna	2005	Evaluation Report	This was part of the monitoring and evaluation of the post-pilot NEEP-GET programme: 2001–2004.
NEEP-GET Programme	A critical dialogues monograph: Building capacity for environmental learning in South Africa's education system	NEEP-GET	2005	Research Report	This research report analysed dialogues among key partners in the NEEP-GET programme.
Eco-Schools Programme	Eco-Schools South Africa: Handbook	Eco-Schools	2009	Guideline Document	This document outlined the programme and gave guidelines and suggestions for certification.
Eco-Schools Programme	Methods and processes to support change-orientated learning	Rosenburg, O'Donoghue & Olvitt	2013 (reprint)	Guideline Document	This document was developed for use among Eco-Schools partners and was reprinted for Fundisa for Change.

Programme/ Course	Document name	Author(s)	Pub. date	Type of document	Further information
Eco-Schools Programme	Evaluation of the Eco-Schools South Africa programme	Rosenburg	2009	Evaluation Report	This was an extensive evaluation report of the national EcoSchools programme.
Schools and Sustainability Course	Course Orientation, Unit 2 and Unit 3	Schudel, Hoffmann, Wigley & Conde	2007	Course Materials	These materials were developed for the courses run nationally around South Africa, and redeveloped each year. These were the materials for the Eastern Cape tranche of the course.
Schools and Sustainability Course	Examining emergent active learning processes as transformative praxis: The case of the Schools and Sustainability professional development programme	Schudel	2013	Doctoral Thesis	This was the last study conducted of the Schools and Sustainability course, and it included a meta-analysis of all previous Schools and Sustainability materials and evaluation reports.

CHAPTER 9

An Examination of the Nexus between Environmental Knowledge and Environmental Learning Processes

Christina Chitsiga and Ingrid Schudel

Introducing the study

Previous chapters in this book have discussed the complexity of environmental content (see Schudel and Lotz-Sisitka, Chapter 2; Isaacs and Olvitt, Chapter 4) and Chapter 8 (Schudel) has highlighted the significance and key elements of active and critical approaches to learning. The primary purpose of this chapter is to draw these two approaches together; that is, to explore the nexus of environmental content and environmental learning processes.

Environmental content faces challenges in many curricula internationally as, according to Grossman (1995, in Cutter-Mackenzie & Smith 2003), teachers tend to teach well that which they know, and are not confident when it comes to teaching content with which they are not familiar. Findings from environmental education research have shown that unfamiliarity is a problem in South Africa as teachers lack environmental and sustainability content knowledge due to the fact that this content is new (Lotz-Sisitka 2011; Fundisa for Change Programme 2013). Lotz-Sisitka (2009) reports cases in which teachers' recourse has been to rely on memories linked to prior curricula or lifeworld experiences to drive the learning processes of environmental content in the curriculum, with minimal reference to the curriculum framework, structure, content or assessment methods and standard. Thus, according to Lotz-Sisitka (2009*)* teaching practices are not providing adequate access to knowledge in the contemporary world as framed by curricula. This appears to be filtering through to learner achievement; for example, findings from a South African National Diagnostic Matric Exam for 2013 report showed a lack of content understanding in most of the subjects that have a focus on environmental content, such as Life Sciences and Geography (Mandikonza & Lotz-Sisitka 2016).

However, even familiarity and confidence with environmental content is not sufficient to improve education for sustainable development (ESD). Concurrent with the need for understanding the complex content, is establishing pedagogies that support the designing of 'teaching and learning in an interactive, learner-centered way that enables exploratory, action-oriented and transformative learning' (Unesco 2014: 12). Spork (1992) and Fien (1993) both note an emphasis in literature on how the teaching approaches of teachers can affect the way in which content (environmental content in the case of this study) is understood by learners, as education is seen as a continuous interpretation of the curriculum by teachers (Stables 2004).

Exploring the nexus between environmental content and environmental learning processes has been informed by the concept of pedagogical content knowledge (PCK). In terms of PCK thinking, an educator's knowledge needs to go 'beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching and ways of representing and formulating the subject that make it comprehensible to others' (McEwan & Bull 1991: 324). An interest in PCK is explicit in the South African context, with the South African Minimum Requirements for Teachers specifying the development of 'specialised pedagogical content knowledge, which includes knowing how to represent the concepts, methods and rules of a discipline in order to create appropriate learning opportunities for diverse learners' (South Africa DHET 2011: 10). Employing PCK in this study meant exploring an interest in how complex environmental content plays out when active and critical approaches to learning are mobilised through typical ways of representing and formulating subject matter in the field of ESD.

The research explored this nexus through an empirical study of teacher mediation strategies in two Life Sciences classrooms in South Africa. For full understanding of these teachers' practices, there was also a need to acknowledge that expected outcomes do not always play out in classroom practice. Thus, the second purpose of the chapter is to develop an understanding of the enabling and constraining factors that influence the emergence of active and critical approaches in classroom practice.

Ultimately, the study sought to explore possible strategies to inform and strengthen classroom practices, particularly in the teaching of the environmental content in the curriculum. The study examined the teacher-mediating strategies through the following research question:

> How are active and critical learning pedagogical strategies enabled and constrained at the nexus of environmental content and environmental learning processes in Grade 11 Life Sciences classrooms?

From the research question the following goals were derived:

- To explore the nexus of teachers' content knowledge and teaching strategies with respect to environmental learning in the Grade 11 Life Sciences.
- To establish the architectural factors (cultural-discursive, material-economic and socio-political) that enabled and constrained the teachers' implementation of active and critical teaching strategies.

Constructing a framework for reviewing environmental content and pedagogical knowledge

Given that the nature of environmental content is contested and ideological, socio-historical, tangible and demonstrable, and transformational, this research sought to explore how typical ESD pedagogies engage such knowledge foundations. To achieve the first research goal, the study used four pedagogical sensitising constructs from the field of environmental education for viewing mediation of environmental knowledge construction in Life Science classrooms. These pedagogical sensitising constructs: deliberation, situating story, proximity experience and practical reasoning, were drawn from Lotz-Sisitka and O'Donoghue's (2006) open process learning framework for environmental learning. This framework described teaching strategies which promoted active and critical approaches to learning. These sensitising constructs, as well as their relational process, are presented in Figure 1.

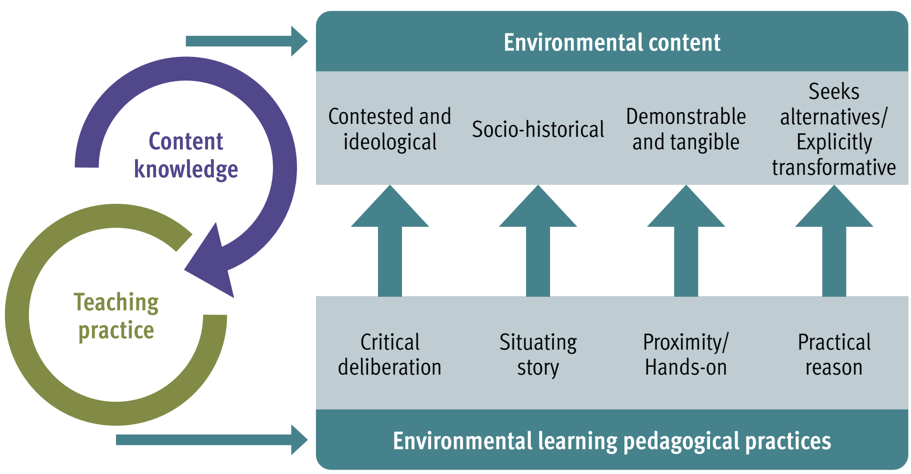

Figure 1. The representation of environmental pedagogies in relation to the nature of environmental content (elaborating on Lotz-Sisitka & O'Donoghue 2006)

The four pedagogical sensitising constructs are outlined in the bottom part of the diagram, while the top part considers the environmental content that feeds into each.

This is in an attempt to explore the nexus of teachers' content knowledge and teaching practice (that is the mediation of learning). Thus, the diagram has four nexus points:

- The **contested nature** of environmental knowledge meeting pedagogies requiring **critical deliberation** in classrooms. Here, **ideological** positions regarding environmental content are discussed and weighed up with value-based consideration of possible inequalities, compromises and trade-offs.
- **Demonstrable and tangible** knowledge meeting pedagogies requiring **hands-on proximity encounters**.
- **Socio-historical** context of environmental knowledge. This includes contextual knowledge of how formal Life Sciences content came to be. It also includes everyday, intergenerational and indigenous knowledges. This is where the evolution of knowledge meets pedagogies requiring **situating stories**.
- **Transformative** knowledge illustrating alternatives meeting pedagogies requiring **practical reasoning**. That is as a process of know-how, where there is an iterative relationship between change-orientated content knowledge and sustainability practices in a process of what Lotz-Sisitka and O'Donoghue (2006) term 'reasonable practice'. With practical reasoning, reflection about action itself directly moves people to act, thus developing reflective thinking as environmental content is being mediated. Practical reasoning, according to Jickling et al. (2006), is a process of self-validation allowing students to re-evaluate and re-imagine their lives.

Reviewing the enablements and constraints of classroom implementation of ESD

The study is framed by *practice theory* as proposed by Schatzki (2005) and *the theory of practice architectures* (Kemmis & Heikkinen 2011) which elaborated on practice theory. Practices architectures were first articulated by Kemmis and Grootenboer (2008) who argued that practices are shaped not solely by intentional action and practice knowledge of participants but also by circumstances and conditions 'external' to them, due to: pre-existing cultural-discursive (concerned with the language of teaching and learning or language of the environmental field); material-economic (concerned with resources of teaching and learning); and social-political arrangements (concerned with policy guiding teaching and learning as well as organisational rules and regulations in teaching and learning institutions). These architectural arrangements shape the content and conduct of a practice that is comprised of the distinctive sayings, doings and relatings that occur in a particular kind of practice. The theory of practice architectures, developed from practice theory by Schatzki (2005) and Kemmis and Grootenboer (2008) helped to give insight into Goal 2 of the study.

Research methodology

Data generation process

Two Grade 11 Life Science teachers (colleagues of the first author) were respondents for this study. The teachers chose to remain anonymous in the reporting of this study. However, for purposes of contextualising the study, we note here that the teachers, who were teaching in the same district as the first author, were from two coastal schools within the Ndlambe (Port Alfred) area of the Sarah Baartman district in the Eastern Cape province of South Africa.

The study's qualitative orientation enabled engagement with teachers in context-enabling first-hand encounters and in-depth analysis and understanding. A case-study approach enabled empirical inquiry, investigating a phenomenon within a real-life context (Baxter & Jack 2008). This approach required continuous engagement between the researcher and the research participants.

Various data generation techniques were used in this study. Semi-structured interviews with each teacher elicited data about their contexts, practices (sayings, doings and relatings about their mediating practices), as well as the architectures influencing these practices. Questions were specifically designed to elicit information in relation to the pedagogical sensitising constructs of interest to the study.

Four lesson observations per teacher were conducted during the four-week duration of the environmental content coverage as set out in the Life Sciences curriculum. Lesson observations enabled generation of first-hand data and accounts of teacher approaches to mediating ESD. They also provided evidence of the practice architectures in each one of the schools in the research study.

Lesson observations were video recorded with Iris Connect technology which enables researcher and teacher participants to log on to a website and retrieve the saved lesson. This made possible the retrieval of data missed during the observations and enabled lesson recall with teachers during stimulated-recall interviews (Patton 2000). Such interviews assist in retrieving of memories, as well as enabling participants to explain their decision-making (Slough 2001; Mackey & Gass 2005; Sime 2006). This strategy, together with the context-sensitive lens of practice architectures, added to the rigour of case-study research thus ensuring that the researchers did not impose naïve or context-blind interpretations onto teacher practice. Discussions with teachers during stimulated interviews were voice recorded for detailed recording of data.

Data analysis

The analytical tool (presented in Table 1) placed sensitising constructs from the Lotz-Sisitka and O'Donoghue (2006) open process framework for environmental learning, in a matrix against the theory of practice (Schatzki 2005) and the theory of practice architectures (Kemmis & Heikkinen 2011).

Table 1. Analytical framework combining practice theory and an open process framework for environmental learning

		Analytical Dimensions		
		SAYINGS What does the teacher say in his/her teaching practice to support …	DOINGS What does the teacher do in his/her teaching practice to strengthen …	RELATINGS How do teachers relate to students and curriculum content during …
Pedagogical sensitising constructs (Conceptual framework)	CRITICAL DELIBERATION	of contested and ideologically based knowledge		
	SITUATING STORY	with knowledge construction in socio-historical context		
	PROXIMITY EXPERIENCE	where demonstrable and tangible knowledge is linked to specific place		
	PRACTICAL REASON	exploring knowledge of alternative (sustainability) practices		
		Practice architectures (enabling and constraining) affecting interaction via cultural-discursive, material-economic and socio-political arrangements.		

Research findings and discussion

Case Study 1

In her first lesson, Teacher 1 encouraged **critical deliberation**. She discussed the curriculum focus of water availability, under the topic of 'human impact', thus: 'The resources of South Africa are actually in short supply. And if the economy grows as they expect and the population grows as they expect, the demand for water will not be sustainable.' In the observation of the first teacher's lesson, her discussions focused on economic and industrial practices; poor practices and management; and ecological disturbances and geographical factors, which are suggested in the CAPS curriculum under human impact. She introduced similar factors when discussing water quality (listed under the same CAPS topic) thus: 'In this case most of the water is actually polluted by humans by industrial influence, domestic and commercial usage, by mine drainage and so that is quite bad and we should look into how to fix that.' This discussion illustrates the explicitly ideological nature of environmental content, with specific human practices being labelled as 'bad' and with a call for change emerging from this. In addition, through encouraging debate on ideological standpoints, she added to the discussion on water availability: 'Is water equally available? Let us discuss this idea.' Significantly, this political concern about unequal access to water is one of the few dimensions regarding water not raised by the CAPS curriculum. Yet equal access to water is a critical concern in South Africa, as illustrated by statistics that report that 'although 45% of the population has water access in their dwelling this ranges from 0.07% to 100% at ward level, with a high level of inequality' (Cole et al. 2018: 37).

Discussions about human impact are inherently critical but abstractions can make it difficult to fully understand the complexities and develop the skills of 'weighing up' and discussing 'trade-offs' – thus limiting the depth of critical engagement. **Situating stories** with specific cases in a specific place and time and with due consideration for socio-historical underpinnings can therefore operate to strengthen critical deliberation. For example, in the stimulated recall interview, the teacher described how,

> I tried to include examples of things that the learners and their parents do that directly interfere with the environment, such as cutting down trees, dumping rubbish in undesignated grounds and how they dispose waste. The re-use of water particularly turned out to be quite a hot debated topic.

She showed the learners a **situating story** – a video of polluted water and its effect on a community in another province, which she said helped learners relate to pollution in their own town. To quote the educator: 'This town has had water issues being talked about a lot so it would only be good to bring learners to that reality that this happens in their context and perhaps they can then learn from this.' Situating her lessons in local context, she discussed the town's high salt-content levels in the water. She also discussed climate change and made links to the recent floods experienced in the town. Illustrating how that situating story had resonated with the learners, she reported their own example that they had offered: 'They mentioned that people, especially in the informal settlements, live off the fish that they catch in the river. If you keep water in a reservoir there is not enough water in the stream and it will affect the fish. If there is a flood it will affect them as they may not be able to catch fish, this will force them to move elsewhere, where they can make a living. And you will always find people living next to water supply.'

She illustrated that the inclusion of local issues in her teaching was not a 'once-off' activity, implying a good grasp of local potential that could be included in the topic of 'human impact' in the CAPS:

> A lot of examples are … from what happens in our direct environment where learners live, such as garbage and water pollution. Even the issue of abalone poaching and alien plants around their homes.

While a **hands-on proximity experience** was not directly observed in this study, the teacher indicated that she planned on 'doing a water quality expedition on the [local river] and this would also develop their scientific skills.' The Life Sciences curriculum includes a section where water-quality tests and knowledge of the effects of pollution of water are required. To prepare learners for the excursion, the teacher used audio-visual material which enabled learners to make the link between what they had learnt earlier in a section on micro-organisms and the water quality section they were currently engaged with. **Proximity experience** was clearly not an approach that was foreign to this teacher who asked learners in class: 'Remember when we went to a recently cleared area of the school and looked at all the possible effects the cutting down of trees may have had on the process of photosynthesis and the environment?'

Practical reasoning is the fourth sensitising construct. In the section above, we argued that a situating story is an important aspect of critical deliberation. Building on this, processes such as reimagining, re-evaluating and the search for alternatives that are reasonable to institute in practice are also critical for teaching strategies trying to develop practical reason. Lotz-Sisitka and O'Donoghue argue that: 'Young learners are quick to work out how one way is better than another but are seldom much good at the critical analysis of prevailing orientation without any experience of alternatives' (2006: 12).

The first teacher showed an interest in seeking alternatives with her comment that: 'Through teaching others about the environmental issues, we can have a cleaner and safer environment. I am actually honoured to be part of teaching learners who preserve and protect our environment.' However, in the observed lessons there was no evidence of a search for alternatives, notwithstanding that these may have been included in further lessons not observed in the course of this research.

Case Study 2

Teacher 2 supported **critical deliberation** processes by pushing for understanding of the science behind environmental issues. For example, during one of the presentations he asked: 'The factories release heat which gets trapped within the ozone layer. What is this referring to exactly and tell the class why is it bad? What is the reason behind this happening? Tell the class more.' This quote highlights two things: first, it is another example of the ideological nature of ESD. Yet an ideological standpoint on ecological impact (the problematic of global warming) is easier to critique than a complex social-ecological development problem (e.g. nuclear power or coal-driven power as a solution for remedying a country's electricity supply shortfall). The CAPS's focus on 'human impact' therefore does not lend itself to more critical engagement through asking learners, for example, to consider the question of whether addressing South Africa's electricity shortfall and access for all necessarily must impact negatively on the environment.

The quote also highlights one of the problems mentioned above of teachers' limited content understanding (Lotz-Sisitka 2011). Misconceptions among school-going and university students and teachers in training about the relationship between the ozone layer and climate change have long been documented and are still ongoing, as shown by the recent research by Gungordu, Yalcın-Celik and Kılıc (2017). While the teacher was not incorrect that the ozone layer traps heat (United Kingdom. Department of Environment Food and Rural Affairs n.d.), the relationship between ozone and heat is complex and it would be better to focus simply on how greenhouse gases in the troposphere (a different atmospheric layer to where the ozone is found) impact on climate change.

The teacher issued an invitation to the groups to criticise or add relevant information they deemed necessary to the presentations. In the stimulated recall interview, he mentioned that his choice of approach was informed from his own experiences, saying that if learners were not probed via verbal interaction or in written tasks they became passive. To support this, he said:

> Learners just sit and don't think through their answers or what the teacher would have asked. There is no considered thinking on their part, but this time I kept digging deeper into their responses asking why and how. The level at which they answered as well as the sort of questions asked, they showed deep thought and engagement with the content.

Teacher 2 supported **situated learning** in the homework task exploring case studies of climate change on the African continent, for example, a case study on how climate change is fuelling malaria in Kenya, or a worksheet on water-borne diseases affecting our South African context. This teacher also enriched the discussion through everyday examples to which the learners could relate. For example, he argued:

> You are what your surrounding is like. Hence what you do in the community around your house reflects on you especially where environmental issues are concerned. If you have an illegal dump outside your house, it is calling for all sorts of diseases and I make such links possible to learners.

While **proximity experience** was not observed in this research, a previous visit to the local beach area and river to study water pollution due to the presence of red tide was one of the references made by Teacher 2 to enhance proximity experience – although, notably, red tide is not a 'human impact' issue, but a seasonal fluctuation of algal blooms influenced by salinity, temperature and wind (see Figure 2). He acknowledged the need for learners to have a hands-on experience of learning. His beach and river visit encounter served this purpose as he noted that:

> We went to visit the beach and river and it made sense now when we spoke of water pollution and water quality as some of the effects of that red tide could be linked by the learners to this section. So it is that ability to give learners the closeness to experiences especially within their context that enables them to have a feel and make sense of this environmental content.

Learners were then able to incorporate this previous proximity experience into the discussion on 'human impact'.

As with Teacher 1, there was no evidence in the lessons observed of learners using practical reason to seek alternatives to the environmental issues presented in class.

Figure 2. Previous outdoor river expedition led by Teacher 2 to test for water quality as affected by a red tide (photograph cropped to protect learner identity)

Practice architectures as enabling and constraining teaching practice at the nexus of environmental content and environmental learning pedagogical practices

Critical deliberation of contested and ideological environmental content knowledge

Teacher 1 indicated her limited exposure to and training for the environmental content of the curriculum (discourse of the environmental field). Teacher 2 noted material-economic constraints in the form of lack of photocopying machines for district staff (subject advisors) to copy teaching and learning material and a lack of cars to travel to schools, thus restricting ongoing training seminars and curriculum coverage monitoring to enhance teacher readiness for CAPS.

This lack of preparedness meant a need for preparing and sourcing information from elsewhere in order for Teacher 1 to supplement her lecture-style teaching practice. She stated that despite the fact that she was still a beginner teacher in the field she was familiar with some of the content knowledge and that this, to a certain extent, enabled her to mediate.

As an additional constraining factor, Teacher 1 and her learners use English as their second language. However, most of the available learning and teaching materials were in English, limiting both Teacher 1 and her learners. This meant that she found it difficult to articulate the content in a way that learners could easily understand, and this hampered mediation.

She used internet-based video resources containing relevant material on environmental issues to supplement her teaching. She went on to support her use of audio-visual material through arguing that,

> Whenever I use internet-based materials I find it easier for the learners to relate and also to answer their questions. I get a feeling that it's learning together in a way, as we both watch the material and learn.

Teacher 2's lessons were more strongly reliant on learner-led research. He was concerned about his own 'limited knowledge in some content areas'. However, he appeared confident enough in the discourse to be able to 'guide them during their discussions so as to not make them lose track of what's to be discussed'. In fact he appeared so confident with some of the content that he commented: 'Most of my students know how I get carried away when I'm busy teaching any topic therefore I would say that they rather chose to join me on this journey, sharing and discussing ideas. This helped me also not to wander off the topic.' It appears that this teacher's confidence was borne from years of experience in an alternative discourse – Geography and Adult Education – rather than in training or experiences in Life Sciences teaching per se. This enabled him to use questioning strategies to evoke 'deeper reflective thought in the learners'.

Giving more power to learners in classrooms can support learning. However, Teacher 2 highlighted that the multicultural set up in the school meant that working together and learning from one another did not flow easily. This was the reason for his choice of group work as a teaching method – to provide more opportunity for such intercultural dialogue. A socio-political concern for keeping power in the hands of the teacher can have equally convincing argument. For example, Teacher 1 argued: 'Well, I make use of minimum group work as I find it difficult to control the class or judge just how much of the actual learning is happening as I'm not with all the groups at the same time.'

Situating story with knowledge construction in socio-historical context

A resourceful teacher, Teacher 1 supported situating stories by gathering 'information of our environment to include in the lessons. This means the topic is a bit more 'real' to learning such as the water quality issue in the town.' Teacher 2 added that the use of local context was one strategy that could be used more to develop deeper engagement with the environmental content as most issues were prevalent in the communities in which learners found themselves.

Being in a multicultural environment and a dual-medium (English/Afrikaans) school, Teacher 2 used both languages as a medium of instruction. While leading critical deliberation, being fluent in both languages meant that he was easily able to code-switch, thus making the content better understood. However, situating stories can often be presented as written case studies. In this case, lack of familiarity with a language can become a barrier when 'comprehension and ability to read through the case studies are essential'.

Proximity experiences exploring demonstrable and tangible knowledge

The CAPS suggests 'Practical observation of ONE example of human influence on the environment in the local area' (South Africa DoE 2012: 51), thus supporting proximity experience. However, resource constraints means it is not always possible to take learners on excursions, as noted by Teacher 2:

> There is also the issue of availability of resources, with not much extra teaching materials, transport to take learners for field trips and teachers or textbooks, that sort of thing, it then becomes difficult to fully and enjoyably make the learners excited about such topics.

He added:

> I also think there are too few or no excursions or fieldtrips which would otherwise bring a real feel to the learners and enable them to carry out observations and experiments in the environment. It is part of their skills development as well which the syllabus requires them to attain but is currently being limited.

Teacher 2 furthermore reported that his planning of lessons and adherence to some of the expectations of the curriculum, such as field trips, were dependent on approval of these trips by schools and the district office.

Practical reason drawing on transformative knowledge illustrating alternative sustainability practices

Teacher 1 noted that the socio-political architecture of the prescriptive curriculum helped her in controlling what she would teach and how she would mediate. According to her, the CAPS document (South Africa DoE 2012) 'directly influences the delivery of certain topics in schools. It gives strict guidelines as to the topics to be discussed.' Openings are made in the CAPS curriculum for seeking sustainability alternatives, with sub-topics such as reducing carbon footprint; water purification and recycling; control of alien plant invasion; inclusion of indigenous knowledge on natural heritage and its sustainable use; searching for alternatives to poaching; prevention in soil and water pollution; and rehabilitation being among the listed sub-topics.

Yet, despite the curriculum imperative, the lessons covered for this research did not provide evidence of this important aspect being taught. Teacher 1 noted a desire for more help with biodiversity, saying: 'I would have loved some help with the section on endemic plants, their role, threats to them and what role citizens can play in their preservation.'

The problem-orientated discourse of the observed lessons, which avoided a search for problem-solving alternatives, may not be surprising. That is because, even though sustainability practices are listed in the CAPS, the main topic of 'human impact' emphasises problems above alternatives, and this is exacerbated by 'cause and consequence' as the opening interest line in the description of the topic, which thereafter hierarchically governs all further sub-topics.

More insight into the lack of a search for solutions comes from Teacher 2's critical observation that, 'one has to have a full understanding or at least familiarisation with the environmental content, otherwise you will not fully be able to implement it or develop ways to help intervene.' By this he is signifying that the different dimensions of active and critical pedagogies are linked, and he presents a perception that the critical and contested nature of environmental issues needs to be mastered before one can adequately address transformative pedagogical practices.

However, Lotz-Sisitka and O'Donoghue argue an alternative perspective, that one does not necessarily have to begin with a problem, suggesting a 'shift in focus from problem-centred approaches that depict the environment awash with complex problems to a more practical engagement with and practising of better ways of doing things' (2006: 12).

Summary and conclusions

The first aspect of this study dealt with teachers' PCK. A substantive pedagogical framing from an environmental learning perspective enabled a detailed exploration of the opportunities afforded at the nexus of teachers' environmental content knowledge and teaching strategies (in response to Research Question 1). The findings from Question 1 are summarised below in conjunction with the second aspect of this study, which was Question 2's interest in practice architectures and what enabled and constrained the emergence of the pedagogical practices described in response to Question 1. From these summaries, suggestions for curriculum changes, support materials and training are made.

The cases reveal that **contested and ideological** environmental content can be misleading if environmental knowledge of topics such as climate change is not accurate. This highlights the importance of ongoing interventions in strengthening teacher environmental content knowledge. Ideologically, environmental knowledge is complex and while it is easy to label practices that negatively impact on the environment as 'bad', teacher training should include critical deliberations of social-ecological complexities around questions of social justice and sustainable development. Notably, teachers drew on their Geographical knowledge to strengthen their effectiveness in the human impact topic of the Life Sciences curriculum and it is suggested that Life Sciences may be able to draw on inquiry strategies in the Geography curriculum to deepen this particular topic within the Life Sciences. Strategies such as 'why', 'how' and 'when' questions were highlighted as important for critical deliberation.

In order to support **critical deliberation**, training and support materials could strengthen environmental content knowledge by:

a) building on teachers' capacity for filling gaps in their knowledge with internet-based teaching materials;
b) building on their visions of themselves as life-long learners when resources and training programmes do not meet their needs;
c) supporting and strengthening their interest in learner-led research and intercultural dialogue in a way that will enable quality products

from learners (e.g. through explicitly supporting critical thinking, inquiry and research strategies among learners);

d) and supporting their visions of themselves as critical thinkers who can guide learning in insecure knowledge contexts.

Teachers indicated an awareness of case studies relevant for supporting **situating stories**, particularly in the local context, as well as capacity for resourcing these case studies. Local case studies identified included abalone poaching, alien invasives around homes, and high salt water levels in local water supplies. Teachers should be encouraged to do more of this work, drawing on local news reports and local experts to gain insight into these topics. Teaching strategies to support situating stories rich with **socio-historical** context included 'comparative studies' and learner-led research and it is suggested that these strategies could be included in teacher training to support the human-impact topic. However, one difficulty identified with these contextualised situating stories is that by drawing on local newspapers and articles, you are not drawing on resources developed for the specific grade and group of learners with which you work, and the material is often exclusively in English, which, for second language learners, can make these cases difficult to follow. Thus teachers need to be supported in how to adapt and select case-study material that is accessible to second language learners.

Proximity experience was not demonstrated during this study but discussions of past activities and possible future activities provided insight for the study. This is a curriculum-driven need and deemed valuable and necessary by the teachers in this study. However, teaching resources as well as material-economic needs and logistical complexities were cited as reasons for limitations on this curriculum requirement. One teacher described field work where learners recorded local deforestation effects, illustrating a potential for developing **tangible and demonstrable knowledge** of human impact. However, not all field work was relevant to the specific topic at hand (red tide might be considered pollution, but is not an example of pollution caused by human impact). This suggests that teachers need field-work support material and suggestions of relevant studies to conduct which can be sufficiently generic to succeed in diverse South African contexts.

Evidence of **practical reason** and exploration of **alternative sustainability** practices was not well supported in the cases studies, despite teacher resourcefulness and creativity as described above. This could be because the curriculum makes suggestions for where alternative sustainability practices should be sought, but this is over-shadowed by a more dominant problem-orientated cause/effect representation of 'human impact' – as suggested even by the limitations in the title of this topic. Another suggestion made by one of the teachers was that limited knowledge of environmental complexity can limit understanding of appropriate responses. However, what emerges from this study is that a less linear and problem-orientated starting point for understanding human-environment relationships in the CAPS curriculum might enable a more transformative approach to support active and critical pedagogies in the Life Sciences.

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CHAPTER 10

Review of a Course-supported Design Research Intervention Process for the Inclusion of Education for Sustainable Development in School Subject Disciplines

Rob O'Donoghue, Shanu Misser and Janet Snow-Macleod

Introduction and approach: A co-engaged design research process of professional development

The study was informed by an expansion of the 'design research' reported by McKenny and Reeves (2012) and it developed as a collaborative design process similar to that described by Voogt, Laferriere, Breuleux, Itow, Hickey and McKenny (2015). Voogt et al. approached design research as a successive and developing process of formative work by participants working together to design and assess a learning programme. In our case the design work was undertaken within a course-supported process of ESD design innovation among participating teachers and subject advisors.

The collaborative Fundisa for Change professional development system had two intermeshed design dimensions: first, the design of the mediating Hand-Print CARE tools (a set of learning materials focusing on sustainability actions and ethics) for the course-supported Fundisa for Change process of professional development (see Schudel, Lotz-Sisitka, Songqwaru and Tshiningayamwe, Chapter 1); and alongside this, the co-engaged design research support materials for interventions undertaken by participants working in their subject disciplines. This chapter developed as a preliminary review of two course-supported design research intervention programmes on the inclusion of Indigenous Knowledge Heritage and ESD pedagogy in school subject disciplines. Subject advisors and teachers participating in a course-mediated professional development process were invited to design school-subject-based ESD programmes for knowledge acquisition and participatory learning in CAPS curriculum work with the Sustainable Development Goals (SDGs).

Propositions (evidence/data) informing this chapter were derived from Hand-Print CARE project records and significant moments of insight in participatory design and intervention processes during the two Fundisa for Change short courses on deliberative professional development. The iterative insights and models of process reported here developed around cumulative case evidence and innovative moments that emerged through an open-ended retroductive[1] process where abductive inferences (Danermark et al. 2002) informed the refinement of schematic models of process as mediating tools to inform the inclusion of ESD.

The chapter presents these formative models in schematic diagrams alongside illustrative case evidence that informed the design of Hand-Print CARE materials as start-up exemplars for use with mediating ESD design tools in school curriculum settings.

The two Fundisa for Change programmes from which insights were drawn developed around Indigenous Knowledge as intergenerational heritage for situating curriculum topics related to sustainability matters of concern in the southern African region. The work of the Science Subject Advisors in Gauteng became centred on climate change, and the Intermediate teachers in the KZN Midlands explored a variety of Life Skills topics related to biodiversity, waste and nutrition. An outcome of the Natural Sciences course-supported work was a Hand-Print CARE module on African Heritage and Climate Change, and the Intermediate Phase deliberative work touched on waste practices, nutrition and how to look after local animals and habitats in times of change.

An overview of Fundisa for Change as a co-engaged Education for Sustainable Development design process

The study informing this chapter might best be characterised as an iterative process of design research and deliberative course-based intervention that emerged from:

- Collaborative research to design formative tools for participating educators to mediate the inclusion of ESD in school subject disciplines (O'Donoghue et al. 2020)
- A course-based process of co-engaged design and intervention research to explore, clarify and work with successively refined tools for mediating ESD in school curriculum settings.

1 Retroductive inferences are insights derived through data that builds a picture over the passage of time and through reflection on past events.

The Fundisa for Change course invited participants to work together with formative tools for mediating new environmental **knowledge** in a school subject, while exploring interventions to improve their **teaching practices** and enhance the **assessment** of learning (Fundisa for Change 2013). A key attribute of Fundisa for Change as co-engaged design and intervention processes is a tacit recognition that educators working together can bring about transformation through ESD. This perspective carries through to participating teachers working in collaborative learning with their learners to produce knowledge-mediated change for human flourishing. In the Fundisa for Change courses, this is assumed to develop from a deepening grasp of the subject through the inclusion of new environmental knowledge, taking into account several sources of propositional and local knowledge, alongside enhanced ways of teaching with improved assessment of learning.

The co-engaged dimension of the Fundisa for Change collaborative process of professional development was consistent with a generative design research process of deliberative intervention as emergent and cumulative processes framing the course and this review. A design research process of mediated participant intervention was thus aligned with, and activated within, the Fundisa for Change professional development process.

The framing of the Fundisa for Change course progression for ESD

This chapter reports on emergent conceptual tools informing mediating models of process for the inclusion of ESD in school subject disciplines. The deliberative iterations of design-based intervention research as collaborative work with participating subject advisors and teachers enabled us to clarify and refine conceptual schema (tools). These were used for supporting teachers to undertake learning design work by planning ESD lesson sequences with their learners, using a course-mediated process (Figure 1) that involved the following:

- Reviewing the subject curriculum in context with associated ESD competencies.
- Working with the SDGs to co-define environment and sustainability concerns in relation to the subject and new environmental knowledge in the curriculum.
- Accessing learning materials and activities for inclusion in a subject-based ESD programme of teaching and learning.
- Planning learning progressions to mediate content acquisition and learner-led collaborative inquiry with collective/individual agency in problem-solving or action-taking.
- Developing an appropriate strategy for the continuous assessment of attainment, skills and competencies as well as fostering significant learning outcomes and change in material practices.

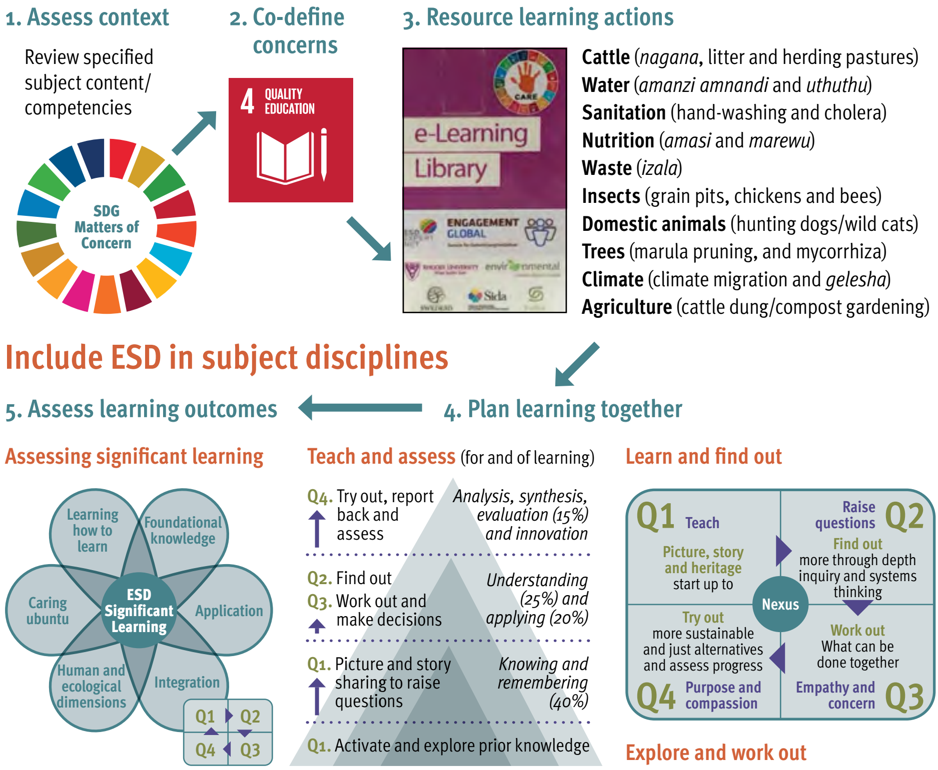

Figure 1. Course-supported design research tools and mediating schema for expanded lesson sequences and assessment planning

The mediating progression reflected in Figure 1 was developed by Lotz-Sisitka and Chikunda (2019) for a Unesco Sustainability Starts with Teachers (SST) programme that both drew on and informed the Hand-Print CARE collaboration. This course-based networked social learning progression framed the collaborative design-based action research processes of mediated participant-intervention undertaken with the subject advisors and teachers involved in the two Fundisa for Change programmes reviewed here.

The development and framing of Hand-Print CARE materials

Ten start-up Hand-Print CARE modules (available at https://sustainabilityteachers.org/resources) were made available to the participating teachers and subject advisors as exemplars around which to develop their own ideas based on key curriculum subject area topics with an environment and sustainability focus. All the learning support materials were available as open access digital files to be used as start-up materials for the inclusion of indigenous heritage and new environmental knowledge in Life Skills, Natural Sciences and other subject disciplines.

Open-ended and formative Hand-Print CARE tools for framing and mediating ESD learning progressions as locally relevant themes (LORET) (WWF 2012) (see Figure 2 below) were compiled using a four-quadrant planning template that included:

- start-up photographs and true stories,
- related inquiry and problem-solving tasks,
- clarifying change challenges,
- action-learning and assessment tasks.

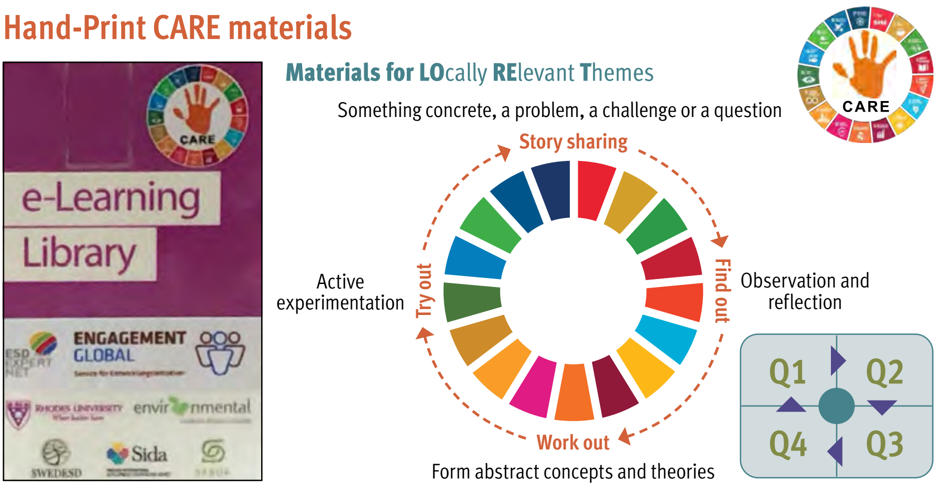

Figure 2. Including locally relevant themes in Hand-Print CARE teaching materials
Source: Adapted from WWF (2013)

The Hand-Print CARE materials were used as exemplars for situating and expanding teaching and assessment practices in a supportive course-mediated programme to include ESD in school subject disciplines.

The inclusion of indigenous knowledge

The participating teachers deliberated examples of intergenerational indigenous knowledge associated with the subject content they were currently teaching.

Teachers in the KZN Midlands, for example, deliberated how teaching about waste and school clean-ups was a continuous labour of teaching that 'bore little fruit'. The schools appeared to be locked into cycles of litter clean-ups without a transfer of knowledge to effect change in 'the littering behaviour of learners'. This problem was approached as a design process of formative intervention to enhance relevance in ESD with, for example, the inclusion of the Zulu Indigenous Knowledge practices of *Izalene* – composting.

1. *Deliberations revealed how teachers and supporting NGOs had been working on waste over many years where it was included in the curriculum and as part of an Eco-School process of whole school development, with some of the schools having been awarded 'Green Flags' for their innovative efforts. Despite this, the teachers were not happy with the ESD outcomes as the challenges of littering in the school environs persisted.*
2. *Work with the SDG Wheel revealed that waste and associated pollution and disease was a threat to community pride and health and that this was included as a Life Skills topic that many of the teachers regularly taught.*
3. *Working with the Past-Present-Future model of process after Chikamori, Tanimura and Ueno (2019) and using an IK-Today video on 'Dumping Rubbish', we looked into how the children are being taught out of their experience of the presence of waste as a punishable problem with an incomplete understanding (absence) of how past change has produced the littering challenges of the present day. The IK video opened up understanding of the waste problem of the present through a window on how things had changed out of the past.*
4. *To explore how to expand learning progressions we posed the question, 'Why was litter less of a problem for the Nguni in the past?' and began to design changed teaching progressions around start-up stories and pictures of 'Izala/Izaleni'.*

Note: The numbering of the above section corresponds with course activity progression in the above diagram. We did not initially take the process into the development of continuous assessment strategies as the litter question emerged early in the course. The deliberations prompted some teachers to work on improving their teaching of litter and waste through the addition of Nguni heritage so as to better understand the present problems of waste. Their teach-backs as the course progressed drew on the mediating tools for lesson planning but some found it difficult to expand their normal categories of lesson planning, using a four-quadrant approach. All of the work did, however, strongly affirm the relevance of heritage knowledge as a past for understanding the present conditions and for contemplating creative innovation for future sustainability.

The Gauteng subject advisor deliberations were centred on the inclusion of climate change in Science teaching. In a similar course-supported collaborative design research and intervention process, they also worked from the subject curriculum and developed course deliberations around the inclusion of heritage to enhance relevance and balance the interplay between intergenerational epistemic processes and the scientific knowledge on climate change in the curriculum.

1. *Working with curriculum documents, participants identified how the inclusion of climate change as new environmental knowledge was orientated towards learning the facts of the matter and doing something with the knowledge and insights acquired. The analysis revealed how the topic presented as abstract concepts and systemic knowledge to be acquired so that students could contemplate the changes in human material practices necessary to maintain future planetary conditions for all living things to thrive. Participants deliberated how the topic presented as abstract knowledge necessary to be acquired for students to make sense of climate change and make the necessary changes to avoid a fearful future. To moderate this reading of the topic as reified abstraction of a crisis produced by humanity, we resolved to work from indigenous knowledge and with a practical example of climate change in southern Africa.*
2. *The SDG wheel deepened our grasp of the impact and scope of climate change as a key matter of concern for teachers and learners to explore across the acquiring of a conceptual grasp and the reading of its implications in contexts of risk. Climate variation in the Eastern Cape was explored as an example and we resolved to work towards the development of a Hand-Print CARE exemplar on Climate Change.*
3. *With no start-up resources to work with, we started with the indigenous knowledge heritage of the amaXhosa of the Eastern Cape, where climate variation in cycles of drought shaped seasonal variation migrations to the further southern grasslands of what came to be known as The Zuurveld. Within the course we began to write up case evidence from the recent drought in Makhanda. This framed climate change extremes as complex systemic crisis events that encapsulate many interacting dimensions of the SDGs.*
4. *The Xhosa heritage practices of a season-end process of Gelesha ('cleaning fields and breaking the sod') and drought season climate migration provided a rich cultural tapestry for a start-up story for climate inquiry. It resonates with the explanatory scientific knowledge we now have about the impact of the elNino-laNina oscillations in the southern Pacific on climatic variation in southern Africa and elsewhere. The seasonal practices in times of severe drought also point to how increasing atmospheric carbon is producing regional warming that is having forcing effects on seasonal cycles in southern Africa. This deliberative work served to mute the reified abstractions presented in the subject content, closing the current chasm between concepts and actions to mitigate climate change at a global level. Both of these deliberative trajectories (past heritage practices and case-based explanatory insights) pointed to a need for abstract subject concepts to be used in an ESD process of illuminating the present through an understanding of the past, as proposed in the Transformative Model of ESD uncovered by Chikamori et al. (2019).*

5. *The participants had depth knowledge on the assessment conventions for continuous assessment both of and for learning, as well as the requirements for testing knowledge, understanding and higher order skills of synthesis, analysis and innovation. We thus spent more time on the question of significant learning. This produced a rich discussion on how the inclusion of heritage had enriched our own learning and how case-study work was essential for relevance.*

Note: The 5-day format of the Gauteng course did not allow the time for the co-development of a Hand-Print CARE module on Climate as a work-together/work-away process. The materials development work was thus done after the conclusion of the course and will be fed back to participants as an exemplar to be modified for their use in teacher training. A workshop kit has also been developed.

The above vignettes from each course process highlight the situating and additive role of heritage in ESD. They also illuminate ESD as individual and collective processes of becoming engaged in the matters of concern in the present that have been produced by material practices of the past. In uncovering these insights for effective subject teaching as ESD, each of the mediating tools developed in the Hand-Print CARE collaboration were explored, reviewed and refined as the participatory course unfolded. Key contours of the implicit design research process in the course are explored in the review of the course process and mediating tools that follow.

ESE/ESD methodological texts as a starting point

Participants worked with a Fundisa for Change methodology text (Rosenberg et al. 2013) that exemplified diverse methods commonly used in Environment and Sustainability Education (ESE), for example, 'problem-solving', 'role-play', 'projects and practical actions' and 'demonstrations and experiments'. The course narrative here was one of introducing ESE methods to be explored and applied to improve teaching practices.

A course task to explore a few of the discrete ESE methods provoked discussion, with some innovative suggestions. We then worked on the curriculum imperative for active learning as a way of characterising the learning transactions across the diverse methods explored by participants. Work with the 5Ts of Action Learning (Figure 3, O'Donoghue et al. 2018) opened up the range of learning interactions in differing subjects. We also explored how children today are more visual, using media and the internet as well as being exposed to more graphic animations.

The Fundisa for Change methods text on methodology was thus used as an introduction to discuss the methodological scope of current subject teaching practice and how this could be expanded beyond existing Teach-Task-Assess approaches for including ESD in subject disciplines.

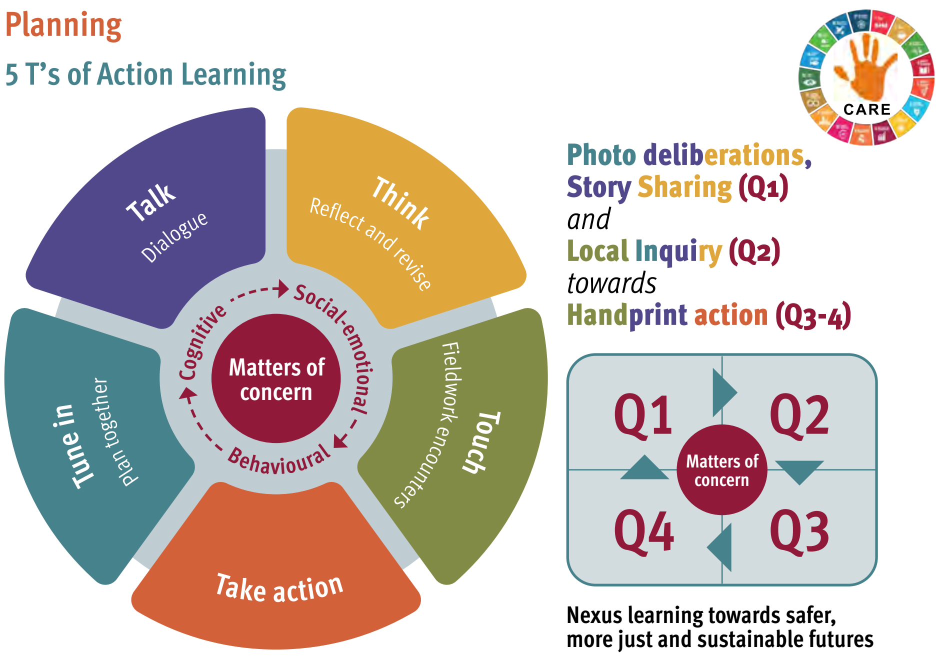

Figure 3. Relating the 5 Ts of action-learning with the 4-quadrant schema for expanded task sequences

Source: Adapted from 'How are ESD learning and training changing environments', Unesco (2018)

Teach-Task-Assess conventions as foundations for expansive learning pathways

The course structures were situated within a prevailing pedagogical conventional wisdom that classroom education involves ***teaching*** *subject knowledge through learning* ***tasks****, the outcomes of which are* ***assessed***. Here assessment commonly serves to determine if the learning of knowledge, values, attitudes and skills has produced desired competencies that reflect in the learner having acquired and developed valued knowings, beings and doings for success in schooling and daily living.

The formative rationale for a Fundisa for Change collaborative course of mediated participant intervention resonated with a Teach-Task-Assess start-up (Figure 4).

In opening with this mediating schema, we noted three processes supporting collective learning on the course:

1. Teachers were surprised that ESD was not presented as something new and extra to be infused into teaching practices but rather as situated in everyday teaching, common sense and local concerns.
2. There was a good correspondence between Hand-Print CARE and the Fundisa for Change inclusive approach.

3. The blank quadrant created a sense of there being something to add, as well as of this being possible without a rejection of what is currently seen as good teaching for the acquisition of subject knowledge and competencies.

In the opening interactions, participants explored the inclusion of knowledge acquisition for learner participation in knowledge construction and the development of personal and collective agency in change challenges.

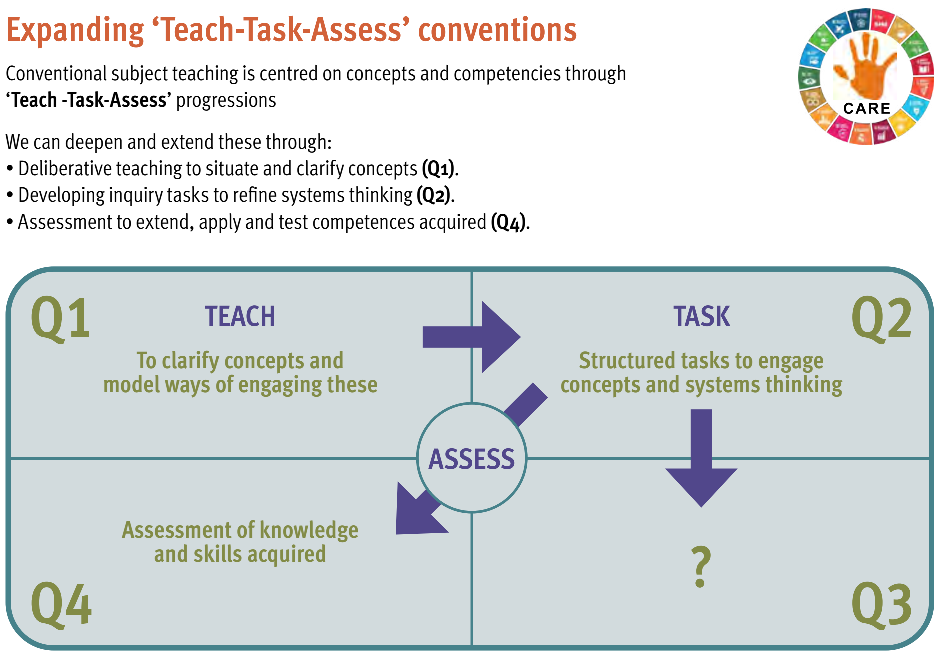

Figure 4. An initial mapping of Teach-Task-Assess conventions underpinning subject-discipline teaching

Figure 4 reflects the starting point for identifying the expansion needed for a balanced interplay of **knowledge acquisition** and how this opens up opportunities for deliberative processes of **participatory meaning-making and action** in learning transactions that are more learner-led and centred on local matters of concern.

This opening insight and start-up perspective on methodology shaped a collaborative learning and co-engaged research landscape for working together on ESD **as an expansion of a sound conventional wisdom** with a simple four-quadrant schema for lesson planning for **knowledge acquisition** and **participatory learning** in subject disciplines, as given in Figure 5.

Clarifying ESD as a process of methodological expansion

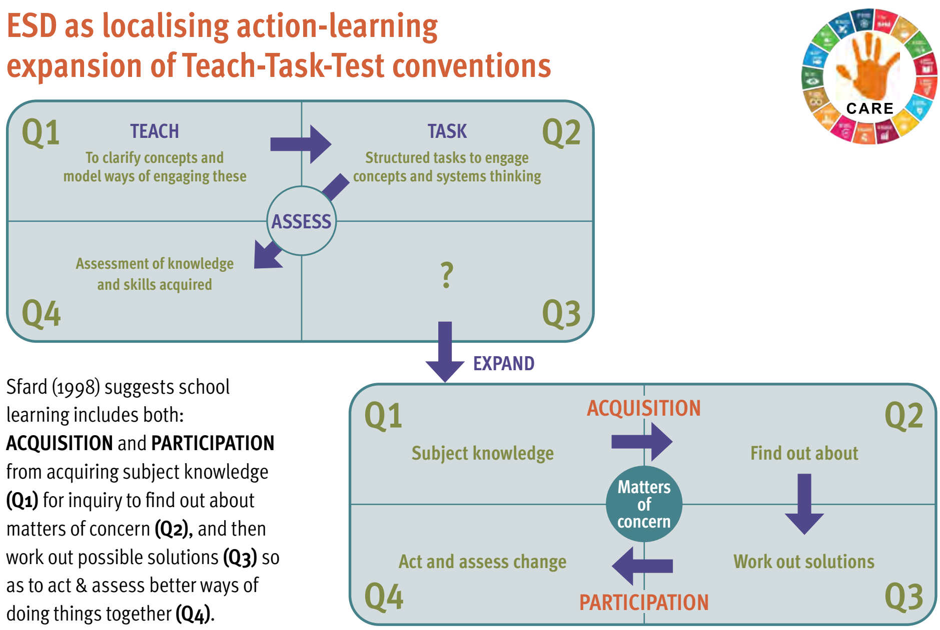

Figure 5. ESD as a methodological expansion
Source: Adapted from Edwards (2014)

Start-up Hand-Print CARE materials had been constituted to open up mediated and learner-led learning progressions informed by the Vygotskian task sequencing schema developed for teacher education by Anne Edwards (2014). The Edwards paper was introduced as a professional reading on the course and the four-quadrant model was applied in conjunction with the Sustainable Development Goals (Figure 6).

The implicit assumption underlying this notion of mediated knowledge acquisition and participatory meaning-making transactions associated with this, is that all learning is a process of expansion and that this develops from and in relation to what is known (knowledge heritage) and what is already being done (life experience).

This premise shaped the introduction of a Hand-Print CARE approach to ESD as deliberative expansions of conventional **Teach-Task-Assess** progressions commonly found in most school subject disciplines. We worked with this underlying conventional wisdom to deliberate how Edwards (2014) reports that this teaching progression found in conventional lesson planning can foster rote learning of facts in ways that mute agency in relation to the application of concepts (recontextualisation) and an associated higher order mastery. Participating teachers identified with the Teach-Task-Assess subject-teaching progression and used it as a referential benchmark around which they might improve their teaching and assessment practices through the Fundisa for Change participatory course.

In this way, each of the two Fundisa for Change programmes (Subject Advisors and Subject Teachers) were introduced to ESD with a focus on materials exemplifying intergenerational practices as indigenous heritage. Both were conducted with primary teachers.

Ethical purpose in subject teaching using the SDGs

Figure 6. SDGs as a basis for mediating learner competence to 'recognise and assess' sustainable development concerns
Source: Adapted from creative commons ELRC Rhodes University, South Africa

Through engaging with and deliberating local matters of concern activated in case story materials, the issues presented as locally authentic, taking the learners into inquiry tasks where they gathered evidence in the home and community contexts of daily life.

With the teachers, we deliberated problem solving as a methodology and worked with the SDGs to locate environment and sustainability problems as open-ended challenges in complex systems. We explored how the Fundisa for Change methods booklet presented ESD problem-solving as an open-ended process of 'action research and community problem solving' (Rosenberg et al. 2008: 28). Mini-SASS was used as an example and we deliberated how learners need to base their problem-solving inquiry work on true stories that can serve to mediate how to undertake a problem-solving inquiry. This resonated with the heritage work of Chikamori et al. (2019) where 'the past is a necessary mirror for understanding the present'.

We concluded that students cannot simply be presented with problems to solve but that we have to learn to work with 'start-up case materials' to frame problem-solving inquiry, and that this work can be deepened and activated using the 'SDG Wheel' (Figure 6). This deliberative work opened up climate change and the sciences as a focus for the Gauteng subject advisors. The KZN Midlands participants developed a wide range of focus areas based on their analysis of the curriculum.

Working with Edwards' (2014) expansion of conventional Teach-Task-Assess curriculum processes, the knowledge was modelled in an authentic story (Q1), shaping leading questions for an inquiry task (Q2). Here the inquiry and case narrative often shaped emerging empathy and concern, along with a need to resolve contradictions through a remodelling of better options (Q2–3) and a re-imagining of possibilities that could, in turn, be taken up into change challenges that were either enacted or narrated by the students (Q3-4). Start-up topic materials were provided for teachers to adapt for engaging their students in learning tasks to develop competences.

The inclusion of ESD competences and systems thinking

The introduction of ESD competencies was not an easy matter as these present as abstract propositions to be inscribed and developed in learning transactions. We thus used the four-quadrant model to deliberate how and where to include activities and tasks to develop and refine the competencies necessary for transitioning to future sustainability. This developed as a translation task that simplified and located the use of the Unesco ESD curriculum competencies within a teaching and learning progression, from subject knowledge acquisition to more learner-led activities to foster participative initiative and agency (see Figure 7).

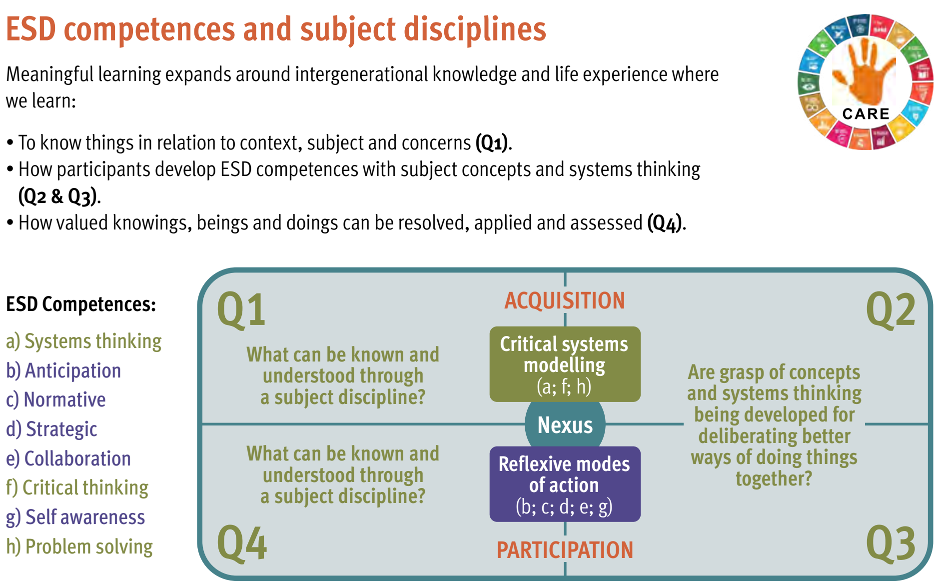

Figure 7. A schema for relating competencies to learning progressions and tasks
Source: Adapted from Unesco (2017: p. 10)

In the opening Hand-Print CARE materials an animated model of a simplified ecosystem was used as a starting point for the introduction of systems thinking at the level of knowledge acquisition for scientific subjects. The knowledge-led models of process worked with became grouped as competencies related to 'critical systems modelling' within which one might constitute the more agentive competences shaping reflexive modes of action. In this way, participants were able to begin to work with ESD competencies in lesson-planning sequences that transitioned from subject knowledge of social-ecological, economic and political systems to the generative competencies (reflexive modes of action) shaping the agency necessary to bring about individual and collaborative change.

A blended approach to ESD and continuous assessment for and of learning

As each course progressed it became apparent to us that the emerging schema for scaffolding ESD processes of Hand-Print CARE in subject disciplines needed to correspond with the prevailing curriculum specifications for the assessment of learning. We thus used a similar strategy of expansive innovation to that reflected in Figure 8, where the four-quadrant learning progressions schema is juxtaposed with the prevailing continuous assessment schema of the curriculum.

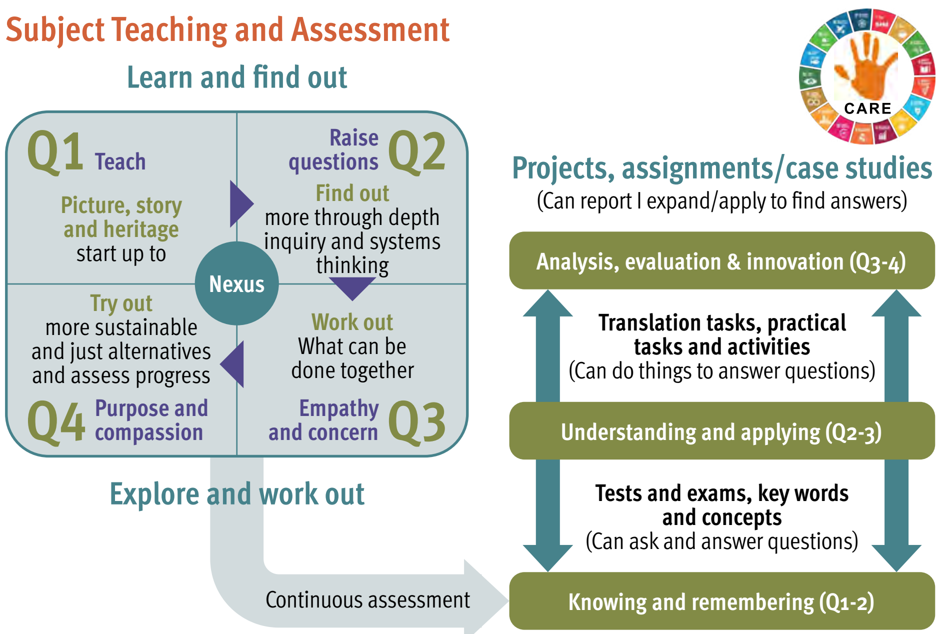

Figure 8. A template for contemplating continuous and summative assessment in CAPS subject disciplines

Using this approach, we aligned school subject ESD progressions with an existing model of continuous assessment using an updated but simplified model for conventional classroom assessment predicated on Bloom's Taxonomy.

In our deliberative work we noted that ESD is an evaluative process in itself, thus it requires an integrated process of continuous **assessment for and of learning.**[2] This meant there needed to be a balance between the students developing the competencies to assess matters of concern, if they were to develop the competence necessary for bringing about much-needed change in human material practices. Working from school exam performance records, we noted that most South African learners are not doing well at answering higher order examination questions. We thus approached ESD as a means of enhancing higher order competencies and related this to movement through quadrants of knowledge acquisition (Learning and Finding Out), into working things out with new understanding and going as far as to try out new ideas and assessing these. Within this blended process of continuous assessment for and of learning as a referent, we drew on the work of Shumba, Mandikonza and Lotz-Sisitka (Chapter 12), postulating that we would all want ESD to produce significant, higher order learning and the agency to bring about both personal and collaborative change.

An important expansion in conventional assessment was thus two-fold:

1. The inclusion of evaluative assessment of matters of concern as a competence for ESD.
2. The addition of a schema for assessing 'significant learning' after Shumba, Mandikonza and Lotz-Sisitka (Chapter 12).

The latter addition was included as an exploratory model of process for teachers to try out and assess in their subject-based ESD programmes.

Conclusion: Tentative insights on the inclusion of heritage and ESD competencies in school subjects

The course-supported design work with the Hand-Print CARE mediating tools accentuated the following outcomes:

- The inclusion of history and cultural heritage in locally relevant themes for co-engaged learning transactions.
- The importance of the acquisition of new environmental knowledge towards competence development for recognising concerns, assessing value, and initiating knowledge-informed actions for change.
- The way in which deliberative work with the SDGs served to broaden and deepen participant grasp of ESD concerns of local relevance.

2 This is a subtle expansion of existing conventions for the continuous assessment of learning in South African schools.

- How work to refine diverse forms of systems thinking interacted to produce higher order thinking and action ideas in course deliberations.
- Start-up true stories engaged learners in story-sharing that provided a gateway to locally relevant teaching.
- Deliberative learning transactions led to the identification of absences in past practices which emerged as contradictions in the present that needed to be resolved through ethics-led change.

Many of these insights were synthesised into an open process model for ESD in school subject teaching settings (Figure 8). This is reflected as a mapping of the key dimensions in a learning pathway for the inclusion of ESD in the teaching of new environmental knowledge with an integrating inclusion of other knowledge systems.

An integrated approach starts with the latter (plural epistemologies) by highlighting history and plural cultural perspectives and experiences as necessary foundations for learning-led change, as participants bring their knowledge into meaning-making deliberations.

Drawing on the simplified 'prediction loop' model differentiated in recent work in the cognitive sciences (Barrett 2017), it is possible to model how learning about abstract and complex concerns like climate change can develop in cyclical deliberative work with new knowledge that enables participants to predictively simulate propositions that are compared and resolved through both individual thought and collective deliberations that shape and inform this.

Here, the inclusion of the SDG wheel as a mediating tool was effective for opening the scope and depth of knowledge related to ESD matters of concern, such as climate change and biodiversity loss.

We also found that work with critical systems modelling and competencies emerged in collective modes of action as participants learned together to recognise concerns, assess value and act for future sustainability (Schreiber & Siege 2017). Learning in a deliberative environment and sustainability education is clearly an iterative and collaborative process of expansive learning and transformative action with enhanced capability to know, feel and do things differently, and these processes inform changed dispositions and material practices.

Finally, taking the integrated elements explored in this chapter into a model of process for ESD as an open learning pathway, a key conceptual underpinning of an emerging picture of ESD in school subject disciplines is a critical realist grasp of how the concerns of the present derive from a retroductive grasp of how the past has produced sustainability issues in the present, after Chikamori et al. (2019). The Transformative Model of ESD that these authors propose notes how generative processes of meaning-making can activate retroductive learning to open up future possibilities that can be clarified and worked towards within generative re-imaginings and 'back-casting' deliberations.

Overall, the Hand-Print CARE collaboration and the two Fundisa for Change courses accentuated a need for course-supported processes of co-engaged design work to clarify and initiate ESD in school subject disciplines. The design research served to refine the mediating tools, and the emerging exemplars provided starting points for ESD as a process of curriculum innovation in diverse subject disciplines.

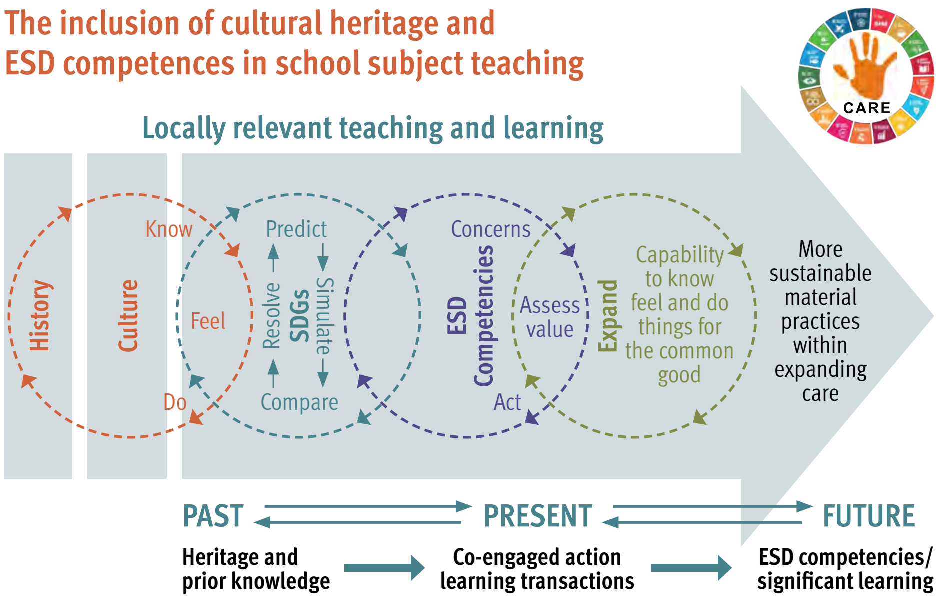

Figure 9. An open process model for a learning pathway integrating plural heritage knowledge, the SDGs and ESD competencies in locally relevant themes for teaching school subject disciplines

Source: Adapted from ESD Expert-Net (2018)

Acknowledgement

The collaborative design work as a co-engaged process of course-supported action research would not have generated the insights reported here without the open and honest reflections and on-course reporting of all the participants. Acknowledging thanks must thus go out to all involved in this exploratory work in which it is not possible to ascribe particular insights to individuals. We have tried to be true to an understanding that the inclusion of ESD is a collaborative endeavour with common mediating tools but wide contextual variation.

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CHAPTER 11

Assisting Learners to Take Up Agency in Problem-Solving Activities

Therese Lambrechts, Rob O'Donoghue and Ingrid Schudel

Introduction

The Centre for Renewable and Sustainable Energy Studies established the Schools Programme to provide professional development and learning materials to support school educators in the teaching of renewable energy topics (Van Niekerk 2008). Research undertaken in 2016 on the renewable energy learning material showed that while the learning material supported the development of factual and conceptual knowledge; opportunities for learner-led inquiry work, where learners are required to engage with open-ended problem-solving activities, needed to be included for higher order cognitive development (Lambrechts 2017). This study builds on the research done on the above-mentioned renewable energy learning material.

The study's argument is that in order to achieve sustainability, there is a need to facilitate learning processes where learners acquire sound knowledge and have opportunities to engage with this newly acquired knowledge that can lay a foundation for future changed patterns of energy use. It is therefore necessary that learners engage deeply with content knowledge in order to understand why it is important to make the changes.

One way for learners to develop their own curiosity, thus leading them to want to understand their own environmental impact, is to develop an awareness of how much energy they use on a daily basis, for example, through an energy audit in their homes or school. The aim of this study was to determine in what way the learning materials developed for the Grade 11 Physical Science audit encouraged learner-led inquiry work, where learners were required to engage with open-ended problem-solving activities.

This study used a learning task sequence framework (Edwards 2014) as an analytical tool to determine how gained knowledge motivated learners to take up agency, in this case through assessing and acknowledging their own energy use by performing an energy audit. As the name suggests, the framework is made up of sequences, where learning tasks are scaffolded and build on one another, enabling learners to become familiar with new content, ideas and concepts in such a way that they internalise the content and reach specific knowledge goals (Edwards 2014). The required outcome of the learning material developed for this study of ESD was that the learners would engage with the learning material to such an extent that they would understand the consequences of electricity use on various levels, take responsibility and get involved in managing their own energy use.

The research question underlying the way in which the study was developed and implemented was the following:

> Did the energy audit encourage learners to implement the acquired knowledge and show agency through skills necessary for a more open-ended problem-solving activity?

Renewable energy learning material in an ESD context

To date, the world economy has relied on fossil fuels as its main energy source. This has created a negative impact on the environment with regard to mining damage, resource depletion and climate change. The burning of fossil fuels has added certain gases to the atmosphere which are causing an increase in the greenhouse effect and resulting in changes in the climate (Boyle 2012). With climate change comes uncertainty and risk (Beck 1992) because of its complexity and its reliance on extensive time scales and predictive modelling. To add complexity to the uncertainty of climate change, the Planetary Boundaries 2.0 report notes that the boundaries of the earth's systems are interlinked, and there is uncertainty as to what will happen to one system if another system exceeds its boundary (Steffen 2015). Not only can renewable energy counteract climate change but it can also address the challenge of resource depletion (Boyle 2012).

South Africa's current energy supply is mainly derived from the burning of fossil fuels. South Africa is a relatively energy intensive country in Africa and relies on coal for its primary energy use. It is one of the largest emitters of greenhouse gases in Africa and one of the most carbon-emission-intensive countries in the world (South Africa DME 2003). South Africa's total energy demand is 51 GW of which 80% is generated from non-renewable energy sources. The dependence on coal alone is 72% (South Africa DOE 2018). It is therefore important that the focus within the country should be on increasing renewable energy, especially given that the solar power potential in South Africa is very high (South Africa DOE 2012). With more than 2 500 sunshine hours per year, South Africa has the perfect climate for generating solar energy – in fact, one of the best in the world (Gauche, Von Backstrom & Brent 2013). It is important that the South African public is educated on how renewable energy can help combat climate change. This is in line with some of the key objectives of the government's enabling framework, namely to raise public awareness on renewable energy and to educate the public on the benefits and opportunities of renewable energy and how it can counteract climate change (South African NDP 2012).

It is to this end that the renewable energy learning material was developed to support teaching of the topics of climate change and renewable energy which have recently become included in the CAPS curriculum (South Africa DBE 2011). One negative offshoot of this is that teachers at secondary school level have to teach topics with which they are not necessarily familiar (Lambrechts 2017). To mitigate this, a research-based set of learner and teacher support material for high school teachers on renewable energy was developed. This aimed to empower teachers to effectively facilitate learning about non-renewable and renewable energy; broaden the knowledge base of teachers around climate change and renewable energy; and provide them with appropriate subject materials to ensure effective implementation in classrooms.

Education for Sustainable Development

This study also responds to a challenge in ESD of how one should design learning material so that learners can understand and engage with the educational topic at hand (Russo & Lotz-Sisitka 2006). In the study, the topic of the learning material was the use of electricity through developing an energy audit as the tool of inquiry. For the energy audit to be designed in line with ESD goals, it was important that teachers communicated to learners an understanding of not only the impact that the use of fossil fuels currently has on our environment, but also the fact that we need to do something about it (Boyle 2012). As such, the renewable energy learning material was developed to teach learners to switch from non-renewable to renewable energy use and to provide in-depth, solid content in order that they could develop sound knowledge to understand why this switch is important (South Africa DBE 2011).

It is a challenge to design learning material in such a way that it is both specific to ESD processes and can meet the teacher and curriculum goals (Russo & Lotz-Sisitka 2006). O'Donoghue (2015) argued that learning topics on the environment, sustainability and usable energy need to be presented in such a way that learners will internalise concepts and deduce meaning that is relevant to the context of the curriculum, as well as in their daily and future skills and actions.

In the development of learning content for ESD, different learning opportunities are influenced by the design, adaptation and use of the material (Russo & Lotz-Sisitka 2006). Effective and successful use of learning materials also depends on the curriculum requirements; relevant subject content; teacher support in the use of the learning material; and appropriate language use (Russo & Lotz-Sisitka 2006; Glover 2006; Riet 2012; Van der Merwe 2011). Sound learning materials for ESD should not only benefit the learners' knowledge but also promote agency (NAAEE 2004).

This study focused on how teachers used the Physical Science energy audit within the Anne Edwards learning task sequence framework, and whether the audit could promote agency (Edwards 2014).

Vygotsky's influence in the development of the learning task sequence

Anne Edwards based her work on Vygotsky's view that learning is centered on externalisation and internalisation in order for a learner to develop his or her own learning processes. In other words, an internal reconstruction takes place where learners accept new information brought to them through external stimuli such as language or signs. This led Edwards to recognising the importance of the development of a learner's ability to take responsibility in the acquisition and use of knowledge (Edwards 2014; O'Donoghue 2015).

Vygotsky's theories of scaffolding, semiotic mediation and Zone of Proximal Development (ZPD) emphasise different processes that take place in learning acquisition (Daniels 2008). Edwards used these concepts in the framing of the four quadrants in her task sequencing framework for classroom learning. Here, scaffolding is a process through which learners are initially guided to develop concepts and skills that will enable them to complete the task required (Daniels 2008). O'Donoghue (2015) pointed out that the learning expands from acquisition, through participation in work with the teacher and texts, into learning activities that are more learner-led and reflexive. Smidt (2009) described the term 'scaffolding' as moving from the performance level to the potential level.

Daniels (2008) stated that the concept of Zone of Proximal Development (ZPD) was hypothesised by Vygotsky as a device for explaining the way in which social and participatory learning takes place as an expansive learning process. John-Steiner and Mahn (1996) described the ZPD in a learning process as the distance between the level of development where the learner performs alone and independently; and the potential level of development with assistance from an adult or a more capable peer. It could therefore be argued that the ZPD is a proposition which suggests the level of possibilities or potential for development of a learner in a mediated process of learning (John-Steiner & Mahn 1996). Two aspects of Vygotsky's notion of a ZPD are significant in the Edwards task sequence model: first, the development of a learner through the guidance of an adult teacher or in collaboration with more capable peers who understand the concepts being taught; and, second, the notion that in learning, instruction moves ahead of development (Daniels 2008).

Edwards used these Vygotskian concepts of scaffolding, semiotic mediation and ZPD in the framing of the four quadrants in her task sequencing model for classroom learning. She argued that if the sequencing was in a lesson, scaffolding would enable mediated learning to take place, whereby learners would make meaning and take control over their own learning processes (Edwards 2014). Here, the sequences of learning instruction would precede development but development could enable learners to take control of their own learning and use their knowledge effectively. The learner-led agency explored by Edwards and the reflexivity associated with this were key for ESD as critical processes of learner-led change (O'Donoghue 2015).

Learning task sequencing

The learning task sequence is developed as an open-ended progression of learning tasks differentiated into four quadrants. The task sequence design focuses on the actions taken by the teacher in these tasks and the learners' responses. It also allows for an examination of patterns of lesson planning and delivery. Its employment as an analytical tool enabled a mapping and review of how the materials reflect learning sequences, and how this in turn sheds light on learning outcomes (Edwards 2014).

The four quadrants focus on the following aspects:

In Quadrant One (Q1) knowledge is being displayed by the teacher or a capable learner in the selective use of the learning materials. Here the teacher or capable learner selects and works with the materials to model and instruct key concepts. This is achieved through the use of different mediation tools, for example, language, text and multimedia on a specific topic.

In Quadrant Two (Q2) more tightly structured tasks are given to the learner as activities by the teacher. These demand engagement with key concepts (substantive knowledge) and ways of enquiring (syntactic knowledge), for example, the energy audit or measuring electricity use in their school or homes.

In Quadrant Three (Q3) more open tasks are given, for example, investigations and research on energy consumption and the related effects, which enable learners to apply key concepts and ways of enquiring. Here tasks may be phrased as open-ended questions for learners to research. This is where participation and inquiry will take place and where the learners take that inquiry into contemplating future sustainability.

In Quadrant Four (Q4) knowledge is being displayed by the learner through summative assessment, for example, writing a test or presenting their findings on the energy audit (Edwards 2014). Edwards is careful to specify that her task sequencing model of process is open-ended in that teachers can start a learning sequence in any quadrant and move through in any order. For example, a learning challenge can open with an inquiry where learners use what they know to undertake and scaffold inquiry tasks into which a teacher might insert activities to clarify concepts and also mediate learning with direct inputs.

This implies that the learning task sequence allows for an analysis of the classroom learning process through a mapping out of processes of knowledge acquisition (internalisation, mostly found in Q1 and Q2) and use (externalisation, mostly found in Q3 and Q4) (O'Donoghue 2015). Key aspects of the tasks are the amount of structure provided and the amount of control that allows learners to take over their own learning and develop higher order thinking skills (Edwards 2014). Edwards further notes that the task sequencing can take place in any order and that the model is a demonstration of how learners can be developed and learning promoted. For example, as noted above, sometimes the teacher will start a sequence in Q3 and move back to Q1 or move from Q3 back to Q2 to clarify concepts. In short, the task sequencing is designed to enable a learner to discover or learn something. This applies not only with regard to the subject matter but also in developing the learners' own learning skills.

If the energy audit is going to be effective then the teachers need to be able to teach with it and set it as a project where learners can take the lead, and also test their own knowledge on the content. The mapping of this level of detail using the learning task sequence to probe lesson progressions enabled me to identify some of the learning sequences evident in the way in which teachers are teaching the energy audit, and to look for evidence of how learners are able to apply their new knowledge. Thus, the learning task sequencing work of Edwards enabled me to observe how the energy audit learning material was used in a classroom context, and how learning was facilitated by the teachers.

Energy audit activity

The energy audit assignment was provided to learners in the format of the scientific method. The objective was to investigate the amount of electrical energy that the school uses per month for six months.

Learners were expected to write a **literature review** where they had to investigate and provide a summary of definitions and formulas on electrical power; how to calculate power; how to calculate electrical energy; the unit in which electrical energy is measured; the cost of electrical energy in their area; and the formula and methods for calculating the cost of the electrical energy consumption of an institution or household. It was suggested that the **method** for how to do the investigation would take the form of work in groups. The responsibility for obtaining the information daily could then be shared among the group members so that every member had one task only. Monitoring their schools' total electrical energy consumption over six months required that the information be collected in more than one way. Therefore two methods from which they could choose were suggested for gathering data.

In Method 1 they had to do a survey of all electrical appliances used in the school and write down the power value (in kilowatts) for every appliance; study how long (in hours) each one of the electrical appliances was in use or turned on and record this information; obtain the average cost of electrical energy per kilowatt-hour (kWh) from the schools' electricity invoice; use the formula from the theoretical study to calculate the electrical energy consumption (in kilowatt-hours) and the total cost of electrical energy consumption per month (using the tariff for electrical energy consumption that could be obtained from the school's electricity invoice provided by the Municipality or Eskom).

Method 2 was based on the electricity meter readings. Learners had to read the electricity meter installed in the school building every afternoon after school from Monday to Friday and first thing Monday morning (to calculate weekend consumption).

This meter reading indicated the amount of electrical energy consumption (in kWh). They had to add up the daily/weekend meter readings (in kWh) to calculate monthly electrical energy consumption. However this method could only be used if the schools' meter was accessible.

The next step was to do the calculations and determine the **results**. Learners used a spreadsheet as template to record the daily data and did the required calculations to complete the database in full.

In the **data analysis** it was required that they draw a pie chart to compare the electrical energy consumption of the various appliances in the school (the spreadsheet could be used to draw the charts). They also had to draw a bar chart to compare the electrical energy consumption per month over a period of six months and discuss the charts obtained. They then had to compare the results in Method 1 to those of Method 2 and explain why the results might be different.

Finally they had to use all the information and graphs obtained from their investigation to formulate a complete and meaningful **conclusion**. They had to state clearly whether their hypothesis was confirmed or disproved and make meaningful suggestions about what could be done to save on electrical energy at the school. This had to be done very specifically and explained in full. They also had to make meaningful suggestions about what the school could do to generate its own electricity from a source that would be more environmentally friendly and possibly more cost-effective.

Prior to my intervention, I made the assumption that the learners knew the following concepts:

- Calculate electrical energy use
- Interpret an electricity bill

Research method

The learning material was workshopped in three different schools, in three sessions, with three teachers, to instruct them on how to use the material. This was followed by data generation from six classroom observations (Cohen et al. 2007); teacher accounts through questionnaires; emails and telephonic conversations; one focus group discussion with all the teachers; and two final presentations by the learners on how the materials were used (Creswell 2014).

Table 1 provides the profile, class size and socio-economic context of each school, and the activity timeframe in which the investigation took place. Please note that this was a pilot study, therefore the actual timeframe did not extend over six months, in accordance with the suggested timeframe.

The Vygotskian-based learning task sequence developed by Edwards was used as an analytical lens for mapping the learning tasks and task sequencing (Edwards 2014). Table 2 is a summary (created by the author) of key features of each quadrant in Edwards task sequencing framework. The table provides the framework of what the teacher or more expert learner is doing compared to other learners, and how this relates to facilitating the learning interactions and understanding the content topic. This table was used to analyse all the data from the study.

Table 1. Profiles of the three Physical Science classes investigated

Grade 11	Case 1	Case 2	Case 3
Profile	Girls	Boys and girls	Boys
Class size	25	18	4 Grade 11 Science Club learners
Socio-economic context	High income	Low income	Low income
Activity timeframe	2 weeks	4 weeks	4 weeks

Table 2. The Anne Edwards learning task sequence

<table>
<tr><th colspan="4">Knowledge is displayed</th></tr>
<tr><td colspan="2">Quadrant 4
Students display their understanding and knowledge through summative assessment.</td><td colspan="2">Quadrant 1
Knowledge is displayed by the teacher or expert learners as they model and instruct on key concepts.</td></tr>
<tr><td>What are the learners doing?
• Complete the summative assessment task
• Master the tool of uncertainty</td><td>What are the teachers / expert learners doing?
• Summative assessment of learning
• Give grades for the display of new-found understandings
• Jumping point for new cycle</td><td>What are the learners doing?
• Learners engage through meaning-making.
• Respond to teachers questions.</td><td>What are the teachers / expert learners doing?
• Introduction of key concepts and revisiting what is already known
• Help learners recognise a gap in their knowledge that can be filled
• Imitation (Vygotsky)
• Demonstrate knowledge
• Diagnose interpretation by the learners
• Introduce the learners to using the language and other forms of the knowledge displayed
• Courteous conversation that leads learners towards mastery of the knowledge that matters in a subject</td></tr>
<tr><td colspan="2">Quadrant 3
More open tasks that enable learners to apply key concepts and ways of enquiring. Task may be phrased as an open-ended question for learners to research.</td><td colspan="2">Quadrant 2
Tightly structured tasks that demand engagement with key concepts (substantive knowledge) and ways of enquiring (syntactic knowledge).</td></tr>
</table>

Knowledge is displayed			
What are the learners doing? • Open-ended, problem-solving activities • They take control of the knowledge they have just grasped and use it to solve problems • Students show agency	**What are the teachers / expert learners doing?** • Require high levels of teacher subject knowledge • Responding to student questions. Only intervening if learners are experiencing real difficulty	**What are the learners doing?** • Students show thinking skills and respond to the task demands, taking control and exploring what they can do • Students scope the tasks, allocate time, and identify needed resources • Students self-assess against criteria – referring to knowledge and strategies used	**What are the teachers / expert learners doing?** • Teachers' formative assessment of quadrant 1 indicates that learners are starting to make the connections between already known and new knowledge • Individual, paired or grouped tasks are given • Teacher gives actively formative feedback on both the use of knowledge and the organisation of learning.
ZPD takes place in Quadrant 2 and Quadrant 3. Semiotic mediation takes place through the use of different mediation tools, for example, language or readings. Quadrant 2 and Quadrant 3 are safe places, where mistakes can be made, misunderstandings revealed and risks taken. Here learners acquire and use, internalise and externalise; and substantive and syntactic knowledge is acquired and used. Learners develop higher order thinking skills and take control of their own learning through tasks given by the teacher.			

What the data revealed

The following data was obtained from observations, feedback from teachers, and the focus group discussion. The four quadrants are identified in the data.

Case 1

The teacher ran the activity as a tightly structured task by controlling the process and focusing on information and data that had to be gathered (**Quadrant 2**). She divided the class into groups that aligned with the different sections of the scientific method, deciding who was in which group (**Quadrant 2**). She focused the learners' attention on the fact that they had to plan the project carefully because while some steps could run simultaneously, others could only start after the information was gathered by another group (**Quadrant 2**). Learners adhered to the instructions and collected the information and data (**Quadrant 2**). The learners responded by working in their groups, dividing the tasks among themselves in each group (**Quadrant 2**).

The teacher gave a specific timeframe for the learners to adhere to for submitting draft results and the final presentation (**Quadrant 2**). The learners presented a draft outline to the teacher where they discussed difficulties they foresaw occurring (**Quadrant 2 and 3** – knowledgable teacher's response), for example, the learners struggled to take accurate electricity use readings, possibly because they did not have access to the electricity meter and therefore their calculations did not correlate with the electricity bill. Some appliances were overlooked (**Quadrant 1**). Certain concepts had to be clarified, such as how to calculate electrical energy (**Quadrant 1**). The teacher gave support where needed, showed high levels of subject knowledge and was able to respond knowledgeably to learners' questions (**Quadrant 3**).

The learners presented the final PowerPoint presentation according to the scientific method (**Quadrant 4**).

Table 3 provides a summary of the data obtained from Case 1 plotted in the Anne Edwards learning task sequence.

Table 3. Data summary of Case 1

Quadrant 4	Quadrant 1
Learners Presented a PowerPoint presentation	**Teacher** Clarified concepts by revisiting existing knowledge on how to calculate electricity and interpret an electricity bill **Learners** Struggled with conceptual knowledge
Quadrant 3	**Quadrant 2**
Teacher Gave support when asked and showed high levels of subject knowledge **Learners** Took control of the knowledge	**Teacher** Used the assignment as a tightly structured task **Learners** Showed thinking skills and responded to the task demands

Case 2

The teacher had to go away during the excecution of the energy audit and could only guide the learners to a limited extent before leaving (**Quadrant 3**). The learners divided themselves into groups according to the task demands and chose a class representative to communicate with the teacher (**Quadrant 3** – learners show agency). Conversations followed between the teacher and learners via email; the guidance from the teacher empowered the learners to excecute the task on their own (**Quadrant 3**).

As in the previous case, the learners struggled to take accurate electricity usage readings, as they did not have access to the electricity meter and therefore their calculations did not correlate with the electricity bill. Some appliances were overlooked, such as the school bell, and they also struggled with how to read and interpret the school electricity bill (**Quadrant 1**). Conversations followed between the learners themselves, and between the teacher and learners about their findings and interpretation thereof: how the task needed to be done, what the results meant, and how they should be interpreted (**Quadrant 3**, ZPD).

The teacher requested postponing my follow-up observation visit to have time to respond to the learners' questions. Learners worked mostly on their own to execute the task. They took control of the knowledge needed for the assignment, used it to solve the challenge and completed the assignment (**Quadrant 3**).

The learners developed and presented a PowerPoint presentation based on their research and findings (**Quadrant 3 & 4**). The way in which the learners took responsibility was a revelation for the teacher, in seeing how capably the learners executed the task. She commented that this was the first assignment where it had worked so well.

Table 4 provides a summary of the data obtained from Case 2 plotted in the Anne Edwards learning task sequence.

Table 4. Data summary of Case 2

Quadrant 4	Quadrant 1
Learners Did final presentation	**Teacher** Revisited existing knowledge by clarifying concepts such as how to calculate electricity and interpret an electricity bill **Learners** Struggled with conceptual knowledge
Quadrant 3	**Quadrant 2**
Teacher Responded knowledgably to learners' questions and only intervened when learners experienced real difficulty **Learners** Took control of the process and used the knowledge they had aquired to solve the challenge, showing agency	

Case 3

There was very little involvement by the teacher in this case and he was not available to guide and help the learners on the process that needed to be followed. Learners from the Science Club, comprising four highly motivated Grade 11 boys, did the task. The learners counted all the electrical appliances to be included in the audit but struggled to process the information (**Quadrant 3** – worked on their own). They were able to gather the information but could not understand the scientific process or how to present the results accordingly (**Quadrants 1 & 2** – lack of knowledge regarding how to calculate electricity [conceptual knowledge] and lack of guidance from the teacher).

Table 5 provides a summary of the data obtained from Case 3 plotted in the Anne Edwards learning task sequence.

Table 5. Data summary of Case 3

Quadrant 4	Quadrant 1
	Teacher Did not revisit conceptual knowledge **Learners** Struggled with conceptual knowledge
Quadrant 3	**Quadrant 2**
Teacher Uninvolved **Learners** The learners planned and tried to do the assignment on their own	**Teacher** Lack of guidance **Learners** Learners struggled to excecute the task at hand

Discussion

The Vygotskian-based (Daniels 2008) learning task sequencing work of Edwards enabled me to look at the learning processes that took place in three cases: that is, the teaching processes of the same learning content by three different teachers to three different classes. The aim was to investigate whether teachers could use the energy audit learning material to engage learners in Quadrant 3 learning activities of the Anne Edwards framework. A Quadrant 3 learning activity was defined as an open problem-solving activity where teachers show high levels of subject knowledge and intervene only when learners experience real difficulty. It is also an activity where learners take control of existing knowledge and use it to solve problems (Edwards 2014), in other words, engaging with their gained knowledge and showing internalisation. An unintended but important outcome of the study was seeing the effect that differing levels of teacher involvement had on the way that learners engaged with the content and took responsibility for their own learning.

In Case 1, the teacher conveyed the learning topic as a tightly structured Quadrant 2 task (Edwards 2014), and the learners responded to the task demands by taking control and exploring what they could do. In Case 2, the teacher used the topic as a more open-ended Quadrant 3 task which enabled learners to apply key concepts and ways of enquiring (Daniels 2008; Edwards 2014; O'Donoghue 2015). The teacher responded knowledgeably to learners' questions and only intervened when the learners were experiencing real difficulty. This resulted in the learners taking control and showing skills in performing the audit (Daniels 2008; Smidt 2009; O'Donoghue 2015). In Case 3, there was little involvement from the teacher and not enough knowledge in the group to take control of the task demands (John-Steiner & Mahn 1996; Edwards 2014). As a result, the required learning and development could not take place.

The intention of the audit was a Quadrant 3 learning task activity where learners take responsibility for their own learning and implement their knowledge and acquired skills to complete the task (Edwards 2014). It was therefore important to determine whether learners had been guided through a process of scaffolding where the desired concepts could be put into action. The evidence in all three cases showed that some concepts needed to be clarified, as was the case with how to calculate electrical energy, a Quadrant 1 process. The concept had to be revisited and learners helped to recognise and fill in their knowledge gap (Edwards 2014).

Two aspects of Vygotsky's notion of ZPD are significant in the Edwards task sequence model (Daniels 2008; Edwards 2014). These are, first, the development of a learner with the guidance of an adult teacher or in collaboration with more capable peers who understand the concepts being taught; and, second, the notion that in learning, instruction moves ahead of development (Daniels 2008; John-Steiner & Mahn 1996). Where there was minimal involvement from the teacher, as in Case 3, the learners did not receive the necessary guidance from the teacher, nor was there a capable peer who understood the concepts well enough to complete the task. Therefore, the required learning development could not take place effectively, because of the lack of instruction (O'Donoghue 2015). In Case 2, because the teacher was not present at school, the learners had to depend on one another to produce the desired results and access the availability of the teacher to clarify their uncertainties. This is an example of ZPD where the development of the learners took place with the guidance of a knowledgeable teacher and the collaboration with more capable peers who understood the concepts that were necessary to complete the task (John-Steiner & Mahn 1996; Daniels 2008; Smidt 2009; Edwards 2014; O'Donoghue 2015).

The audit itself proved to mediate learning in all four quadrants but particularly with regard to Quadrants 2 and 3 in the Anne Edwards learning task sequence. From the presentations of the learners in Cases 1 and 2, it was clear that the learners understood how their energy use patterns influenced the amount paid for electricity by the school, as well as the impact that energy use has on the environment. The solutions they gave to counteract the energy use, for example, informing learners more regularly on the schools electricity use or installing solar energy for the school, since the school's electricity needs are largely during daytime, were all feasible. In other words, the learners could display their understanding and knowledge, which also made it a Quadrant 4 activity.

The outcomes for Cases 1 and 2 were similar, in that both groups did the task according to the scientific method and both groups delivered a presentation on their findings with more or less the same outcome, struggles and recommendations. The main difference was that in Case 1 the teacher tightly controlled the learning activity; she divided the class into groups and allocated the next contact session when they would discuss their problems. The learners showed thinking skills and responded to the task demands, taking control and exploring what they could do as they scoped the task and self-assessed against criteria.

In Case 2 the learners scoped the task, allocated time, and identified the needed resources. They also self-assessed against criteria, but with the difference that *they* controlled the process, not the teacher – though they did ask her for help when they really got stuck. The result was that there were examples of ZPD and semiotic mediation where the expert learner took control and could help the class show agency (O'Donoghue

2015). By taking up control in relation to knowledge practices in the learning process the learners had the opportunity to show externalisation and internalisation of the knowledge acquired and the agency to deploy it in further learning actions (Daniels 2008; O'Donoghue 2015).

Conclusion

As can be seen from the evidence above, what emerged from this study is that the energy audit learning task had the potential to achieve the goal of open-ended, learner-led inquiry. The success of the activity appears to have been supported through mediation by the teacher across three quadrants, as in Case 1. In Case 2, the success of the activity was supported through mediation of the concepts and the problem-solving capacity of knowledgeable learners working proactively with the teacher (who had withdrawn from active mediation of the activity and played more of a support role in Quadrant 3). The difficulties arose when there was no proactive, knowledgeable teacher or more expert learner to mediate in Quadrant 3, as illustrated by Case 3.

The study recommends that for successful open-ended enquiries and agency in Quadrant 3, materials need activities to ensure that concepts are scaffolded through various processes of mediation and opportunities for externalisation and internalisation. This is achieved through teachers sharing knowledge with the learners (Quadrant 1) and through tightly structured tasks (Quadrant 2). Activities must also create the opportunity for learners to show that they have taken control of the knowledge and can use it to solve more open-ended problems. Teachers mediating the process need to be aware that support from a more knowledgeable person is still needed in Quadrant 3. They therefore cannot withdraw their support, but need to be prepared to intervene if learners are experiencing real difficulty.

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SECTION C

Assessing environmental learning

CHAPTER 12

Advancing Assessment Thinking in Education for Sustainable Development with a Focus on Significant Learning Processes

Overson Shumba, Caleb Mandikonza and Heila Lotz-Sisitka

Introduction

This position paper is developed in the context of the Fundisa [Teaching] for Change teacher education programme (www.fundisaforchange.co.za), as well as the Sustainability Starts with Teachers programmes for teacher education (www.sustainabilityteachers.org/course). Fundisa for Change is a South African programme while Sustainability Starts with Teachers is a Southern Africa Development Community (SADC) programme for teacher educators. Both these programmes seek to enhance transformative environments and sustainability education processes in teacher education. They have a strategic focus on situated and transformative learning approaches for learners to learn to 'know the world' and practice 'being in the world'. The real world provides the context for learning and assessment for learning, but not enough is known about assessment of such learning.

This leads us to the questions that Fundisa for Change and Sustainability Starts with Teachers projects and case studies need to suggest answers for:

i) What guiding conceptual and theoretical frameworks exist or can be developed for assessing knowledge, skills and competencies in

Education for Sustainable Development (ESD) processes? What is needed to contextualise them within the socio-cultural and teacher education contexts of southern Africa?

ii) What are some of the assessment approaches and strategies for knowledge, skills and competencies relevant to the southern African context?

This chapter explores issues regarding ESD and proposed higher order and significant learning outcomes. It considers assessment of learning outcomes through case studies situated in different southern African countries. The chapter illustrates the need for innovation in assessment and for positioning *assessment as a learning process* by adapting Fink's (2003) taxonomy of significant learning to the broader southern Africa context. The two chapters that follow illustrate the relevance of innovations and reflexive assessment practices in the South African context. The first, by Mkhabela and Schudel (Chapter 13), demonstrates how higher order thinking was connected to Wiek's competencies in ESD even though the teacher was not doing summative assessment using the competencies per se. The next chapter, by Mgoqi and Schudel (Chapter 14), demonstrates the connection between *assessment as learning* and the development of higher order learning skills.

The nomenclature of learning outcomes, skills and competencies is vast and can be confusing. In this chapter, we have drawn from the Unesco International Bureau of Education (IBE) *Glossary of Curriculum Terminology* that defines learning outcomes as the 'totality of information, knowledge, understanding, attitudes, values, skills, competencies or behaviours a learner has mastered upon the successful completion of an education programme' (2013: n.p.). Unesco IBE defines 'skill' as the ability to perform tasks and solve problems, while 'competence' is a combination of knowledge, skills and attitudes appropriate to the context, making it broader than 'skill'. Unesco IBE goes further to point out that competence indicates the ability to apply learning outcomes adequately in defined contexts including education, work, personal or professional settings. It elaborates that competencies entail the use of knowledge, technical skills, and interpersonal attributes such as communication and collaboration. It also notes that competencies can relate to knowledge, skills and attitudes within one specific subject or discipline (i.e. domain-specific), or they can be general/transversal because they have relevance to all domains/subjects. In this chapter, 'skills and competencies' are dealt with together to reflect their connectedness as well as the broader, significant learning and capacities that must be developed in curricula and real-life contexts. As can be seen from the discussion below, we include values and ethics in the conceptualisation of ESD competencies.

Education in the early part of the 21st century

While educating people in the early part of the 21st century is challenging, given contemporary conditions, it also carries with it exciting prospects. Current life is characterised by uncertainty and complexity, by economic, social and ecological challenges aggravated by the debilitating impacts of environmental and sustainability pressures, including climate change. This occurs even as rapid advances in digital and other technologies are driving what is being termed a 'fourth industrial revolution'. There is much talk of knowledge economies that are intended to replace resource- and service-based economies, with these advances occurring while poverty levels in some parts of the world are increasing and wealth gaps between rich and poor expand (as has become highly visible during the COVID-19 pandemic). With 'wicked' and complex problems such as these, one is often confronted with contradictory knowledge, or knowledge that is incomplete. The skills and competencies to resolve such problems are not easy to assemble, and may not even be available; moreover, contradictory values make the problems difficult to evaluate. Wicked problems such as climate change and poverty also intersect, and have real-life consequences that differ from place to place. They manifest as local matters of concern that influence people's lives everywhere and that require different sets of skills and competencies. Such problems characterise early 21st-century life and pose particular challenges for the types of skills and competencies developed in education systems, in that they may demand very different skillsets and competencies to those that were taught and assessed in earlier times. Consequently, they require shifts in the types of assessments used in association with these developing qualities.

In such a context, learning also has to take on new dimensions, becoming transformative, continuous and adaptive to the rapidly changing conditions and complexity of concerns, thus involving cognitive, social-emotional, action, and wider social learning dynamics (Unesco 2018; Wals 2007). The rapidly changing nature of reality also means that the skillsets people need to live in an ever-changing and unpredictable world have a shorter life (Thomas & Brown 2011). More intricate skillsets will be required that entail systems thinking and development of mindsets that allow us to reflexively learn our way to a better future and more sustainable lifestyle (Wals 2007). In this sense, Siarova, Sternadel and Masidlauskaite observed that the skills we need have evolved to become 'transversal and multi-dimensional in nature' (2017: 7). Given these ever-changing societal contexts and the demands for new skillsets, a different culture of learning must emerge. Thomas and Brown (2011) posited that in the new culture of learning,

> the point is to embrace what we don't know, come up with better questions about it, and continue asking those questions in order to learn more and more, both incrementally and exponentially. The goal is for each of us to take the world in and make it part of ourselves. In doing so, it turns out, we can re-create it. (2011: 38)

This background sets the scene for this positioning chapter, which focuses on the new dynamics of learning and assessment. It examines the international context and thinking around assessment *for* learning ever more complex skills and competencies in ESD. Unesco (2018) explained that ESD is a type of multi-dimensional, inter-disciplinary and multi-modal education that seeks to address complex intersecting environmental, societal and economic concerns. Therefore, the concern is for assessment of the development and learning of new skills and competencies in the present, and for continued learning in the future (Siarova et al. 2017; Ibáñez et al. 2010). In this regard, we cast our eyes firmly on the formative functions of assessment (Mattheos et al. 2009; Price et al. 2011). We pose questions, propose a framework, and raise issues for research, innovation and concerns with regard to recontextualising the discourse on assessment in the southern African ESD context, where Fundisa for Change is becoming an escalating demand.

A focus on skills and competencies

One of the main shifts in educational thinking is towards emphasis on the multi-dimensional nature of learning, involving cognition, social-emotional engagement, normative commitments, and action orientations (Unesco 2017). These can be summarised as acquisition of skills and competencies (including psycho-social, cognitive and action aspects) for realising human well-being through effective functioning and contributing to improved quality of life for self, others and the society. Attempting to capture this multi-dimensionality, many educational reforms, especially in primary and secondary education, point to outcomes as the main intention of education. These are captured in discourses about 'outcomes-based' education, implying that the outcomes are pre-determined and, consequently, shape the way that learning programmes are structured. This is problematic, given the administrative burden on teachers in specifying learning outcomes (Jansen 1998) and the difficulties experienced by teachers in implementing these approaches (Chisholm 2002; Lotz-Sisitka 2000, 2002). It can also give rise to a somewhat popularist and reactionary orientation that produces a dualism between knowledge and competence, thus leading to a loss of key elements such as knowledge progression in key subjects (Jansen 1998; Schudel 2012). Despite such problematic experiences with outcomes-based education, these discourses still offer useful insights into how assessment can be framed, especially if the full scope of knowledge, skills, values and competencies is to be included in such assessments.

The engagement with learning outcomes and competencies, from three southern African case studies, is discussed below in order to gain insight into assessment challenges in this region. First, in the national curriculum of Zambia, for example, it is stated:

> The approach (outcome based education) seeks to link education to real life experiences as it gives learners skills to access, criticize, analyse and practically apply knowledge. Learners are given practical experiences during the teaching and learning processes that help them gain life skills. (Curriculum Development Centre 2013)

Second, the Curriculum Framework for Primary and Secondary School in Zimbabwe advocates for a competence-based approach to education (Ministry of Primary and Secondary Education 2015). This approach foregrounds the development of competencies, outcomes of the learning process that are enduring and relevant for life and work contexts. These discourses function as a call for transformed forms of education that are envisioned to enable school leavers to function more adeptly and reflexively in society in the face of ever-increasing emerging and growing challenges to the society.

The third case, South Africa, shows that these discourses, as mentioned above, are not unproblematic. Experience in South Africa has shown that superficial interpretations and poor quality engagement with outcomes-based education (OBE) can lead to further disenfranchisement of learners. There is therefore a need to give attention to the quality of engagement with these discourses, including from the perspective of knowledge, skills, values and assessment thereof.

In South Africa, the outcomes-based curriculum was discontinued to focus more directly on knowledge progression in order to provide a stronger balance between knowledge and skills. The curriculum has become more content driven rather than outcomes based. Noteworthy is the fact that the 'aims' in the Curriculum and Assessment Policy Statement (CAPS) can be traced back to the 'outcomes' of the discarded OBE curriculum and that the CAPS principles demand higher order skills and competencies for their realisation, for example, social transformation, active and critical learning, high knowledge and skills, human rights, inclusivity, environmental and social justice, and valuing indigenous knowledge systems (South Africa DBE 2011).

Consequently, the Minimum Requirements for Teacher Education Qualifications in South Africa underline both knowledge and practice, and propose knowledge of, as well as competence for, designing situational learning during teacher development programmes (South Africa DHET 2015). Furthermore, the South African National Curriculum and Assessment Policy Statement for Grades R–12 advocates that children acquire and apply knowledge and skills in ways that are meaningful to their own lives (South Africa DBE 2011). In this regard, the curriculum promotes knowledge in local contexts, while being sensitive to global imperatives. In all three countries' cases, if schools are to teach successfully for situated and multi-dimensional competencies, the challenge still remains as to how they should effectively assess the development of these competencies. In ESD, skills and competencies are learning outcomes that ultimately should lead to the well-being of the individual at the familial, communal and societal levels. The following quote bears this out:

> We need to prepare students not only for employment in a sustainable economy, but also with the skills and values that will allow them to live sustainable lifestyles on this planet. This entails encouraging strong personal development as well as promoting responsible citizenship. (Bell 2016: 55)

An emphasis on such learning outcomes explicates what a learner knows, understands, and is able to do on completion of a learning process (Ibáñez et al. 2010). In ESD, it is expected that learners will develop knowledge, skills, values and competencies. As shown in the Unesco IBE (2013) definition earlier, developing skill and competency in real world contexts is important. Attainment of skills, values and competencies relate well to contextual capability (Dede 2009). Drawing on O'Donoghue (2001) (cf. with papers in Section B of this book), it is important to support the development of contextual capability. This is achieved through seeing knowledge, skills and values as integrated. What is needed for this are situated and contextual engagements that draw on learners' existing knowledge and experience. These can then be expanded through supported learning processes and open enquiry sequences. Capability, in this instance, can be understood from Amartya Sen's capability approach (Sen 1999; Walker 2005). According to Sen, capabilities are what people choose to be and do, depending on what they have reason to value. It follows then that the emergence of competence relates to personal agency, responsibility, autonomous functioning, the capacity for doing, and having the freedom to choose what or what not to do (cf. Section D of this book).

In ESD, the aim is to ensure that learners develop capabilities for creating sustainable futures by providing opportunities for them to acquire relevant skills and competencies. Education, therefore, must nurture learner capability and agency for sustainability. As an instance, the OECD Education 2030 uses the model of the 'learning compass'. This learning compass foregrounds learner agency to depict the notion that learners need to be able to navigate and confront societal challenges by themselves. Learners must have agency for their own learning, setting their own goals, and for reflecting and acting responsibly to effect change. They need to become competent to meet the complex demands of education and of life (OECD 2018). In ESD, creating learner agency becomes a sound rationale for education (Lotz-Sisitka & Lupele 2017). This is also seen in the following quote:

> Agency implies a sense of responsibility to participate in the world and, in so doing, to influence people, events and circumstances for the better. Agency requires the ability to frame a guiding purpose and identify actions to achieve a goal. (OECD 2018: 4)

Learning for agency is important. This is evident in many learning and assessment frameworks that outline contemporary skills and competencies at the start of the 21st century (Dede 2009; Rieckman 2018; Wiek, Withycombe & Redman 2011). Different contexts and premises from which skills and competencies have emerged have implications for research and innovation with regard to next generation assessments.

While competency frameworks have been developed on different premises, they have commonality in the recognition of the complex changes in societies and environments mentioned above. The Unesco Commission on Education for the 21st Century produced a report, *Learning: The Treasure Within* (Unesco 1996). The report presented four pillars of learning: learning to know, learning to do, learning to live together, and learning to be. These are now complemented by a fifth pillar, learning to transform oneself and society (Rieckman 2018). Together, these pillars suggest (i) the need for learners to acquire knowledge of the complex and interdependent issues and challenges in society (societal issues); (ii) the need to focus on learners' personal development and their empowerment; and (iii) the need to empower learners to be reflective and active citizens (personal agency). From this it is clear that learning is proposed to be a purposeful and contextualised activity with a humanistic and social focus to create agency for self-reflection and development and for acting to resolve societal issues. Many contemporary learning, competency and assessment frameworks appear to be elaborating this review of learning for agency. Wiek et al. (2011) identify key interrelated competencies to assess ESD: anticipatory, systemic working, interpersonal, normative, and strategic, which they argue 'come together' at the point of practice. In the next chapter, Mkhabela and Schudel provide a case study of how ESD can develop higher order thinking skills drawn from the official curriculum. They also highlight how, by using Wiek's competencies, we can get a sense of the way in which environmental topics in the curriculum can contribute to both higher order thinking skills and agency.

There is a connection between higher order thinking and the integrated approach suggested in Wiek et al.'s competencies. De Haan (2010) refers to ESD as 'shaping competences', which also indicates that competencies are developed via a process and in interaction with each other, as well as with knowledge, in contexts of emergence and engagement. Rieckmann (2018) aggregates the competencies for a 'sustainability citizen' profiled in the international literature as follows: systems thinking competency; anticipatory competency; normative competency; strategic competency; collaboration competency; critical thinking competency; self-awareness competency; and integrated problem-solving competency.

Rieckmann's approach to competencies complements the Unesco (1996) pillars of learning in fostering capability to engage in socio-political processes and aiming to move societies towards sustainable development. However, while specifically mentioning the need for action-orientated transformative pedagogy, there is no mention of assessments of these types of listed competencies. Giangrande et al. (2019) modified earlier frameworks, adding 'intrapersonal competencies, a self-reflective validation scheme, a focus on non-formal learning, and a special alignment with SDG4.7 requirements' (p. 1). They created a modified key competency list as follows:

- *Intrapersonal:* including, for example, self-awareness, stress management, self-reflection;
- *Interpersonal:* including, for example, communication skills, teamwork, mediation;
- *Future thinking:* including, for example, visioning, backcasting, recognising heritage;
- *Systems thinking:* including, for example, working with complex problems, promoting resilience;

- *Disciplinary and interdisciplinary:* including, for example, critical thinking, expressing multiple ways of knowing;
- *Normative and cultural:* including, for example, development of world views and perspectives, awareness of values, awareness of local context and global trends;
- *Strategic:* including, for example, planning, decision-making, implementing, and addressing challenges.

Together, Unesco (1996), Giangrande et al. (2019), Rieckmann (2018), and Wiek et al. (2011) provide frameworks that point to competencies for personal and social agency in a quest for sustainable development and lifestyles.

Learning taxonomies used for guiding assessment

We now turn to reviewing and evaluating how frameworks of skills and competencies relate to learning taxonomies used in learning and assessment. The learning taxonomy developed by Benjamin Bloom (1956) has been a popular model for developing assessments. In the Curriculum and Assessment Policy Statement in South Africa, Bloom's Taxonomy is used to guide the setting of questions to cover different cognitive levels. For example, in the Natural Sciences and Technology, items are set to reflect the following levels: cognitive levels; knowing science and technology; understanding science and technology; applying scientific and technological knowledge; evaluating, analysing and synthesising scientific and technological understanding (South Africa DBE 2011).

When it comes to ESD, there is a need to go beyond the process skills identified under each of the cognitive levels. The adaptation of Bloom's Taxonomy by Anderson et al. (2001) adds value by identifying the need to develop metacognitive competency in addition to factual, conceptual and procedural knowledge. Further, Anderson et al. revised Bloom's Taxonomy by translating the nouns into verbs and swapping the last two levels of the taxonomy to create the revised taxonomy: remember, understand, apply, analyse, evaluate and create as the highest level. Chapter 14 in this section by Mgoqi and Schudel presents a case study that used the Anderson et al. (2001) taxonomy and showed a connection between quality formative assessment (assessment *as* learning) and the development of higher order thinking in a South African context.

The work of Anderson et al. reflects a significant extension of the original Bloom's Taxonomy (Wilson 2016). This demands new kinds of assessments that lead learners to metacognitive knowledge levels where self-regulation and learning to learn are achieved. Further to this, the revision of Bloom's Taxonomy points to the possibility of basic skills such as remember, understand, or apply being learnt together with higher level cognitive processes and knowledge types, for example, procedural and metacognitive, that denote competencies. It means, too, that high level cognitive processes such as analyse, evaluate and create can be developed for factual or conceptual knowledge types and levels. It also suggests that learning factual knowledge and the ability to apply, analyse and create solutions to problems go hand in hand (Silva 2008). This provides for a framework or taxonomy that can guide effectively innovative assessments of learning that accomplish the simultaneous learning of higher order thinking skills, as well as different knowledge types and knowledge levels, as required for competency. Often, these types of taxonomies also drive the framing of learning outcomes, and are therefore influential in the setting of learning outcomes and competence-based curricula.

The Anderson et al. taxonomy provides a useful two-dimensional characterisation of learning. However, it still lacks a holistic enough representation relevant for the realisation of the scope and types of competencies proffered in ESD discourse, and the true capability and agency (i.e. the situated, contextualised and emergent learning) that ESD aims for (cf. chapters in Section B of this book). Fink's (2003) taxonomy of significant learning is promising in this regard. It tries to present a holistic view of learning outcomes, as opposed to the linear hierarchy found in Bloom's Taxonomy. However, it is not offered as a prescription; rather, it demands criticalness, imagination and creativity among teachers to extend the learning beyond the contents of the subjects to bring personal relevance and significance to real-life contexts. This would be consistent with meeting the CAPS expectation that 'ensures that children acquire and apply knowledge and skills in ways that are meaningful to their own lives' (South Africa DBE 2011: 4). For example, Chapter 13 by Mkhabela and Schudel shows a case study that suggests that incorporating ESD perspectives into assessment is a demanding endeavour which, fortunately, pays off in the higher order thinking that it yields.

Table 1 provides a summary of the six kinds of learning that, together, constitute what Fink (2003) refers to as a significant learning experience. These six types of significant learning are not hierarchical but synergistic. Each kind of learning interacts with and relates to the other kinds of learning, adding something overall to significant learning (as is illustrated in Figure 1). Fink explains that 'achieving any one kind of learning simultaneously enhances the possibility of achieving other kinds of learning as well' (2003: 6). Significant learning is thus the totality of learning achieved when learners have experiences in some or all of the six interacting kinds of learning shown in Table 1.

Later, in Figure 1, we relate significant learning taxonomy as outlined in the framework above to the ESD learning context. This is in light of the fact that significant learning adds value to learner capabilities. Fink (2003) explains that significant learning makes a difference in how people live and the kind of life they are capable of living. This is achievable when a learner has knowledge, can see connections and applications, and can see and care about the human dimension and the planet that is his or her home. It aligns with the 'learning as connection' approach that Lotz-Sisitka and Lupele (2017) and Shumba and Kampamba (2017) have described as socio-culturally and situationally meaningful learning. This approach to learning is an important feature of enabling quality education, and is central to ESD (cf. with Schudel and Lotz-Sisitka, Chapter 1). Significant learning similarly entails seeing the personal and societal value of what is learnt and caring about it; it means continuing to learn and act consistently with developing knowledge, skills and values, in order to improve the quality of life at the personal, familial and societal levels. Fink suggests that significant learning has a process dimension (active engagement) and an outcome dimension (meaningful and lasting change), which aligns well with the intentions of ESD. It features one or more of the following values: enhancing an individual's life; enabling the individual to contribute to the communities in his or her life, that is, familial, community, national and global; and preparing the individual for the world of work. Change resulting from significant learning experiences must thus have relevance and importance for the learner's life (Mandikonza 2019). This makes Fink's Taxonomy relevant for creating assessment frameworks in ESD education and change projects for sustainable development. It also has the potential to add to our growing but fledgling understanding of how ESD and assessment of learning outcomes contributes to educational quality and relevance.

Table 1. Summary of Fink's six kinds of learning and value-added dimensions thereof

Type of significant learning	Definition and value-added dimensions
1. Foundational Knowledge	• Knowing, understanding and remembering specific and valid information, ideas and perspectives, e.g., science of climate change or biodiversity, ecological systems, etc. • Value added: Provides the basic understanding that is necessary for other kinds of learning.
2. Application	• Learning how to engage in critical, creative and practical thinking and action, e.g., engaging in a change project. • Value added: Allows other kinds of learning to become useful.
3. Integration	• Seeing and understanding the connections between different things, ideas, concepts and real-life contexts. • Value added: Gives learners a new form of power, especially intellectual power.
4. Human Dimension	• Learning about self or others, and appreciating personal and societal value of what is learned. • Value added: Informs students about the human significance of what they are learning.
5. Caring	• Acquiring new feelings, interests or values that reflect caring about something or someone. • Value added: Inspires one to want to learn more and make it a part of one's life.
6. Learning how to Learn	• Learning how to be a better student, how to engage in inquiry, or how to become a self-directed learner. • Value added: Enables students to continue learning effectively in the future.

Source: Adapted from Fink (2003)

However, there are challenges to be tackled, especially in the global South where there does not appear to be much in the way of elaboration of contextually relevant assessment frameworks. When we look overall at competencies being put forward as being relevant to education at the start of the 21st century (as outlined above), we see a wide spectrum in their rationality and definition that Silva (2009) conjectures could be running into hundreds of descriptors. We see also that the skills and competencies movement appears to be divided over putting the stress on either knowledge or competency. To Silva, an emphasis on what students can do with knowledge (competency), rather than what units of knowledge they may have, is the essence of the skills needed at the start of the 21st century (2009: 630). Others, however, contend that theoretical knowledge and understanding are essential to being competent, and that mental activity and skilled performance cannot be separated (Ashworth 1992). It is desirable to find or develop a framework that is able to guide on the assessment of values: this is critical to achieving agency as values and knowledge combine to shape motive to act (Kollmus & Agyeman 2002). We appreciate, as Stasz (2001) does, that some of these frameworks (e.g. Wiek et al. 2011; Riekmann 2018; Giangrande et al. 2019) being put forward for learning in an ESD context embrace socio-cultural or situative perspectives, whereas economic and efficiency perspectives dominated thinking about learning and assessment in the past (Lotz-Sisitka & Lupele 2017). While this is broadly understood, there are as yet very few assessment frameworks that allow for assessing the kind of learning described here, and in ESD texts that are guiding education at the start of the 21st century.

It is noteworthy that in the OBE systems of the three countries serving as case studies for this chapter, namely, South Africa, Zambia and Zimbabwe, values are among the learning outcomes that should be assessed. However, this has not been successfully done. In South Africa, subjects such as those in the Further Education and Training Physics and Economics curricula have very little reference to values in their assessment guidance, while others such as the Further Education and Training Life Orientation Geography curriculum work more explicitly with values in their assessment chapters.

Innovating assessment *for* learning and *as* learning

There is a need for innovative assessments that are guided by a mindset that supports the notion that we can learn to face up to developmental challenges of our time, and that as humans we *do* have agency to learn, co-learn and act, even if we are unable to change everything that needs transforming. In this regard, Dweck's (2010) 'growth mindset pedagogy and assessment for learning' is noteworthy:

> … teach students to love challenges, to enjoy effort, to be resilient, and to value their own improvement. In other words, we can design and present learning tasks in a way that helps students develop a growth mindset, which leads to not just short-term achievement but also long-term success. (p. 16)

This necessitates a paradigm shift to embrace assessment *for* and *as* learning, taking us beyond assessment *of* learning, which has thus far been the dominant mode in most formal education systems. Assessment *for* learning is well acknowledged in supporting the ongoing acquisition and continued growth of various skills and competencies (Price et al. 2011). Wiliam (2013) argues that all assessment can be made relevant for formative purposes, and counsels that 'the term *formative* should apply not to the assessment but to the function that the evidence generated by assessment actually serves' (p. 15). A paradigm shift in the way assessment is used to inform teaching and learning is therefore necessary. Price et al. (2011) suggest six 'effective' assessment strategies as follows: rubrics, performance-based assessments, portfolios, student self-assessment, peer assessment, and student response systems. Price and her colleagues suggest that these are innovative and effective strategies 'relevant to the educational context of developing countries' that can 'help teachers foster a 21st century learning environment in their classrooms'. Supporting learners in learning to learn (as outlined in Fick's 2003 notion of significant learning) can also enable assessment *as* learning, where assessing a situation reflexively can help learners to learn new things. These strong claims merit research and innovation to demonstrate the efficacy of these methods in contexts of learning in southern Africa. There is evidence that learners do learn reflexively via situated learning activities and change projects (e.g. Mandikonza 2019; Mandikonza & Lotz-Sisitka 2016), but there is, as yet, little formalised guidance on how to assess this type of learning beyond broad notions of assessment *for* learning and assessment *as* learning. This chapter tries to address this.

With respect to this, we also note that in the case study countries (South Africa, Zambia and Zimbabwe), continuous assessments are now acknowledged to contribute to grade transition and school exit assessments. In the CAPS in South Africa, for example, as much as 75% of formal assessments at Grades 4–6 are schools based; 40% at Grades 7–9; and 25% at Grades 10–12. It would seem that this presents an opportunity for innovation and adoption of rubrics, performance and other assessments that Price et al. (2011) pointed out to be relevant to developing country contexts. However, in considering these assessment perspectives, it is important to relate them to the situation of complexity that we outlined at the start of the chapter. As Lotz-Sisitka mentioned, there is a need to go beyond the technical and discipline-centred approaches to teaching and learning and 'embrace an open-ended notion of epistemological access to enhance reflexivity, agency and responsiveness to risk and vulnerability' (2009: 11), associated with, for example, climate change, biodiversity loss, water shortages, HIV-AIDS, Ebola, COVID-19 and other such conditions.

In Table 1 above, the framework of significant learning by Fink (2003) potentially offers a robust guide to thinking and conduct of assessment practices, more so because ESD requires assessment of skills that go beyond cognitive aspects of learning. Fink's framework integrates the cognitive and affective learning outcomes, unlike Bloom's approach that separates affective, cognitive and psycho-motor learning outcomes into three taxonomies. The Fink model has potential to raise the prominence of skills and competencies that go beyond the cognitive. Learning in ESD does not always follow the hierarchical order that is suggested by dominant taxonomies of learning and assessment, namely from simple to complex as in Bloom's Taxonomy (Bloom 1956;

Anderson et al. 2001), which is widely used for guiding assessment practice and for deriving outcome statements. For example, a learner may start with implementing the reuse of plastic waste by making artefacts from it as a way of generating income. After engaging with the making of artefacts, the learner may later learn about the nature of plastic, the effect of plastic on the environment, and how humans are affecting their environment, other forms of life and, consequently, their own health through plastic pollution. Ultimately, the meaning-making process emerges out of application, where the learner becomes more theoretical and can relate to the notion of plastic pollution from an application to a cognitive and conceptual level. There is a need to assess the development of this complex interaction of knowledge, skills and values.

To address this complex demand for assessment in ESD, we adapt Fink's framework in order to be able to assess the complex and multidimensional nature of ESD learning. We start off by formulating questions that clarify what can be assessed at each of the 'petals' of the Fink model (see Figure 1, where these relate to key aspects of the framework in Table 1). Noteworthy with regard to the adaptation for ESD significant learning, is the addition of ecological dimensions to Fink's 'human dimension' petal, and an Ubuntu perspective, added to Fink's focus on 'care'. This adapts the framework to a southern Africa context where human and ecological aspects are intertwined and reinforced by an Ubuntu worldview of connectedness of the human and the ecological (Le Grange 2015).

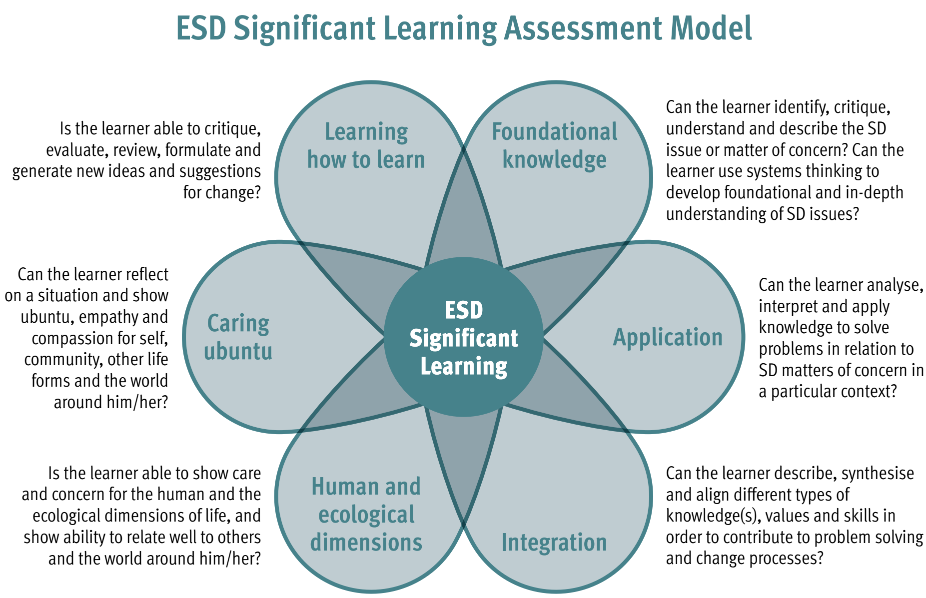

Figure 1. Adaptation (by the authors with permission) of Fink's 2003 framework for assessing significant learning in ESD processes

Table 2. Adaptation of Fink's framework for assessing significant learning in ESD processes, applied to an ESD example

Dimensions of significant learning in ESD processes.	**Questions that help to focus the assessment of significant learning in ESD processes.**	**Applied to an example of a learner dealing with single-use plastic waste.**
Foundational knowledge	Can the learner identify, critique, understand and describe the sustainable development issue or concern? Can the learner use systems thinking to develop foundational and in-depth understanding of sustainable development issues/ concerns?	Learner explains what plastic is and how it has been made. Learner explains why single-use plastic is a problem in the environment. Learner explains how single-use plastic affects the environment, relates this more broadly to how humans are affecting their environment, other forms of life and, consequently, their own health, through plastic pollution.
Application	Can the learner analyse, interpret, and apply knowledge to solve problems in relation to sustainable development matters in a particular context? Can the learner demonstrate agency (thought and action) on a sustainable development concern in ways that seek change / transformation in and of matters of concern?	Learner innovates the reuse of plastic waste by making artefacts from it as a way of generating income (e.g. uses plastic bottles to establish small hanging food gardens). Learners show agency by developing the small hanging food garden and re-using the plastic bottles.
Integration	Can the learner describe, synthesise, relate and align different types of knowledge(s), values and skills in order to contribute to problem solving and change processes?	The learner links scientific knowledge of the problematic substances in plastics to local knowledge on how to grow food. By developing the solution of re-using the plastic bottles, learners show innovation skills.
Human and ecological dimension	Is the learner able to show self-understanding, care, and concern for the well-being of the human and ecological dimensions of life, as well as show ability to relate well to others and the world around him/her?	The learner shows an ethics of care for humans and the environment by reducing plastic pollution and growing food through the re-use of the plastics.
Caring and Ubuntu	Can the learner reflect on a situation and show ubuntu, empathy and compassion for self, community, other life forms and the world around him/her?	By growing food that others can use, the learner shows ubuntu and empathy. By reducing plastic waste, the learner shows empathy for sea creatures that are most heavily affected by plastic pollution.
Learning How to Learn	Is the learner able to critique, evaluate, review, formulate and generate new ideas and suggestions for change? Is the learner able to reflexively engage with knowledge on a continuous basis? Is the learner able to identify something he/she needs or wants to learn and to formulate a strategy to learn that?[1]	The learner is able to identify and review the problem of plastic pollution and come up with a solution, formulating an alternative and applying it to a local context, offering suggestions for change.

1 This question is credited to Dr L. Dee Fink in a personal communication, 18 July 2020.

These questions point to what an educator needs to think about when developing knowledge on any concept and they serve as the outcomes that the learner can achieve as they interact with the knowledge. Assessment will therefore be establishing the achievement of these outcomes. In Table 2 we consider these questions in relation to the example given above of the learner engaging with the problem of pernicious plastic pollution, to illuminate the dimensions of significant ESD learning.

A cautionary note is needed when interpreting and assessing how the learner shows care, empathy and/or Ubuntu values as suggested in Table 2. It is important that the learner demonstrates these. There is a need to show that learners' actions were conducted out of empathy or out of a sense of Ubuntu and not for other reasons. The suggestion here is that assessment needs to move beyond the 'act'. [2] It is important also to reflect on the important issue concerning 'learning how to learn' in Figure 1. In a personal email communication, L. Dee Fink raises issues around our choice of verbs 'critique, evaluate, and generate new ideas'. He sees these terms as being a part of 'application' and clarifies his view of learning how to learn as follows:

> I can see how anyone can see those [i.e. critique, evaluate, and generate new ideas in Figure 1] as helping one to learn, but I guess I mean that phrase [i.e., learning how to learn] a little differently. For example: (i) Study skills: Do students need to learn how to study better or more effectively? (ii) Using ways of generating new insights that are distinct to different realms of knowledge, e.g., the scientific method, historical analysis, etc.? (iii) But especially important in my view is helping students become 'self-directing learners'. To do this, they need to be able do two things: (a) Identify something they need or want to learn, and (b) formulate a learning strategy for learning 'that'. (L. Dee Fink, personal communication, 18 July 2020)

Table 3 expands the possibilities for ESD significant learning further by adapting and integrating the Bloom cognitive taxonomy and Fink's taxonomy, drawing on and expanding the guiding questions in Figure 1. In Table 3, the adaptation involves expanding on the levels (Column 1) and their descriptions (Column 2) in order to harmonise more intangible and non-cognitive aspects of learning. We further integrated verbs (in Column 3) that guide the educator in stating the learning outcomes and the learning tasks.

It is hoped that in addition to proactively defining outcomes of learning, these verbs can help educators (at all levels and in all settings) to design learning tasks that assist learners to learn through assessment, thus realising the assessment *for* and assessment *as* learning processes. The framework can be used for assessment *of l*earning as well as assessment *for* learning and *as* learning. As explained above, our interest is to adapt the Fink and Bloom frameworks to include ESD learning objectives that incorporate the cognitive, social-emotional and ethical, and that also take agency and wider social

2 This point is credited to the editor, Ingrid Schudel, who reviewed an earlier version of the chapter.

learning into consideration. Ultimately, Table 3 provides verbs that enable the educator to create opportunities for higher order learning as well as assessment that encompasses those higher order aspects of social learning that cannot be accessed through cognitive learning processes alone.

Table 3. Adapted assessment framework for ESD significant learning

Levels	Description	Some verbs
Learning to learn; reflexive review and evaluation, transformative agency	Learning how to ask and answer questions, becoming self-directed learner, future's orientation, reflexivity. Develop one's agency for change, developing new solutions/options for change	Critique, evaluate, analyse, act, create, reflect, review, formulate, generate, hypothesise, reflect, theorise, engage
Caring and ethics	Identifying/changing one's feelings, interests, values; showing ubuntu, empathy and care for self, others and the environment	Reflect, interpret, empathise, show care, ubuntu
Human dimensions and life appreciation (respect for and relations with cultural heritage, others and environment)	Learning about and changing one's self and community: understanding and interacting with others and the wider environment (non-human life systems); social learning	Reflect, assess, relational engagement
Synthesis and integration	Make connections among ideas, subjects, people, cultures, science and environment systems	Describe, integrate, compare, critique, align, synthesise, relate, justify
Comprehension, analysis and application	Critical, creative and practical thinking, problem-solving, reflexivity	Analyse, interpret, apply, compare, contrast, argue, solve problems
Foundational knowledge	Understand and remember, systems thinking	Identify, name, list, describe, understand

Source: Adapted from Anderson et al. (2001), Bloom (1956) & Fink (2003)

Building on the framework explicated above in Figure 1 and Tables 1, 2 and 3, we offer an example of how this can be translated into a rubric. An example of a task and the rubric is given in Appendix A. It illustrates how the consolidated framework in Table 3 can be used for assessment purposes. However, use of the assessment framework is not limited to the illustration provided in Appendix A. Depending on the purposes of the assessment, a teacher may choose to expand the rubric to incorporate other learning outcomes, or focus on only one of these outcomes highlighted in the example and then deepen it.

One should be mindful that assessments and assessment rubrics are designed for particular purposes. When using rubrics for formal assessment, the task and rubric are discussed beforehand. When learners know what is expected of them, they work to achieve the outcomes of the task, the process of which helps them to learn the intended knowledge. Using the adapted assessment framework should encourage learners to work with knowledge at a higher order to achieve significant aspects of understanding and caring for human-ecological interactions and to value and strive for sustainable lifestyles, reflexive learning and re-learning in the face of changing real-world contexts.

Conclusion

As we have argued across this chapter, there are a number of frameworks that could be used to guide assessment. We have chosen the few that speak closely to the environment and sustainability knowledge that we are working with in Education for Sustainable Development contexts (Wiek et al. 2011; Riekmann 2018; Giangrande et al. 2019). We find these frameworks to be particularly relevant for developing knowledge that is required in the mainstream schools curriculum, and we have developed an adapted assessment framework that offers a richer platform for assessing ESD learning. Proactive thinking about the learning outcomes suggested in the adapted framework offered in Figure 1 and developed further in Tables 2 and 3, together with the questions therein, may help with structuring teaching and learning processes. It can be helpful for innovating assessment processes *of* learning, towards assessment *for* learning, and also positioning assessment *as* a learning process (i.e. learners learning through the assessment process).

We have also considered the implications of key guiding frameworks that support the achievement of the United Nations objectives for Education for Sustainable Development, which have been defined for broadening education beyond a focus on the cognitive only, and to support learning in relation to the Sustainable Development Goals (SDGs) in ways that include a focus on skills, competencies and agency for change. Sustainable Development Goal 4 requires all educators to integrate this kind of education into their programmes, as it has been determined by Unesco (2014, 2016) that this is an important contributor to achieving educational quality that is relevant to the challenges and conditions of the early part of the 21st century.

This chapter has therefore been positioned to address these new challenges, and provide orientation on how a next generation of assessment practice can be constituted. We contend that some of the skills and competencies associated with, for example, collaboration and problem-solving, working with others, responsibility and community, cannot be fully learned and assessed if taken out of their contexts of local worldviews, such as Ubuntu. We need to be exploring assessment frameworks and policies for 21st-century conditions, with their requisite forms of knowledge, skills and competencies that are cognisant of socio-cultural contexts in which acquisition and learning takes place (Lotz-Sisitka & Lupele 2017; Shumba & Kampamba 2017). In conclusion, we have to concur with Elena Silva when she observes:

> In the long run, new forms of assessment, as well as other yet-to-be-developed measures, will be critical for making assessment effective both for educational purposes – to ensure that teachers and students can monitor and improve the learning process – and for accountability purposes – to ensure that schools are giving all students what they need to succeed. This will require a larger investment in the development and design of assessments and assessment systems. It will also mean more coordination between policymakers, educators, researchers, and test developers, who too often work in isolation of one another. (2008: 10)

In addition, we need to research and validate more case studies in teaching, learning and assessment approaches that elicit and extend higher order skills and competencies, including digital literacies and sustainability challenges that are part of the Agenda 2030 and the SDGs. This chapter provides orientation and guidance for such a process.

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Appendix A: Sample assessment task and rubric

Table 4. Task and assessment rubric for ESD significant learning

Task	***Conduct an audit of environment and sustainability concerns/issues in your institution. Describe causes, effects and manifestations of one of the key issues, showing how these interact. Suggest alternative ways that education can be used to alleviate or eliminate one of these concerns/issues.***				
	Level of Attainment of Significant Learning				
Criteria	*Very good (5)*	*Good (4)*	*Satisfactory (3)*	*Unsatisfactory (2)*	*Scores*
Conducts audit: ability to find out information and conducting of audit	Thoroughly describes the tool used to generate data; explains how and why it was used	Thoroughly describes the tool used to generate data; explains how but not why it was used	Thoroughly describes the tool used to generate data but not how and why it was used	Inadequately describes tool and how and why it was used	
Foundation knowledge: ability to identify, critique and describe the SD issue coherently	Identifies, critiques and describes the SD issue coherently	Identifies and describes the SD issue coherently but without critique	Identifies and describes the SD issue without coherence and without critique	Identifies but inadequately and incoherently describes the SD issue	
Application and problem-solving: ability to analyse, interpret, apply knowledge and demonstrate agency to solve problems	Analyses, interprets, applies knowledge and demonstrates agency to solve problems	Analyses, interprets and applies knowledge but lacks agency to solve problems	Analyses and interprets but inadequately applies knowledge and lacks agency to solve problems	Inadequately analyses, interprets and applies knowledge; lacks agency to solve problems	
Integration: ability to describe, synthesise, relate and align different types of knowledge(s), values and skills in problem-solving and change projects	Describes, synthesises, relates and aligns different types of knowledge(s), values and skills in problem-solving and change projects	Describes, synthesises, relates and aligns different types of knowledge(s); partially relates to values and skills in problem-solving and change projects	Describes and synthesises but only partially relates and aligns different types of knowledge(s), values and skills in problem-solving and change projects	Describes but inadequately synthesises, relates and aligns different types of knowledge(s), values and skills	

Task	***Conduct an audit of environment and sustainability concerns/issues in your institution. Describe causes, effects and manifestations of one of the key issues, showing how these interact. Suggest alternative ways that education can be used to alleviate or eliminate one of these concerns/issues.***				
	Level of Attainment of Significant Learning				
Criteria	*Very good (5)*	*Good (4)*	*Satisfactory (3)*	*Unsatisfactory (2)*	*Scores*
Human and ecological dimension: shows concern for human and ecological well-being and for relating to others locally and globally	Shows care for human and ecological well-being and for relating to others locally and globally	Shows concern for human and ecological well-being but little concern for relating to others locally and globally	Shows concern for human well-being but does not show concern for ecological well-being or for relating to others	Shows concern for well-being of the human and the ecological dimensions of life, but little awareness and concern for interdependence and relating well to others locally and globally	
Care: shows reflectivity and cares for community, ubuntu values, and other life forms, locally and globally.	Reflects on a situation; cares for community, ubuntu values, and other life forms locally and globally	Reflects on a situation; cares for community and ubuntu values but cares little for other life forms locally and globally	Reflects on a situation; cares little for community and ubuntu values and shows little empathy for other life forms	Inadequately reflects on a situation and cares little for community, ubuntu values, and other life forms locally and globally	
Learning to learn: ability to analyse, evaluate, and formulate new ideas, solutions to problems and suggestions for change or to learn better	Analyses, evaluates, and formulates new ideas, changes, or solutions to problems, and to learn better	Analyses, evaluates, and formulates new ideas, changes, or solutions to problems, but not effectively learning independently	Satisfactorily analyses and evaluates but inadequately formulates new ideas, changes, or solutions to problems	Inadequately analyses and evaluates, formulates new ideas, changes or solutions to problems	
Total Scores					

CHAPTER 13

Emergent Curriculum and Sustainability Competencies in Environmental Learning

Antonia Tholakele Mkhabela and Ingrid Schudel

Introduction

This study was influenced by the South African National Diagnostic Report on Learner Performance in the 2012 final examinations, which highlighted learner struggles with 'higher order thinking skills such as application, problem solving, critical thinking, analysis and evaluation' (South Africa DBE 2013: 16). These are skills typically associated with essay questions in examinations. Another issue reported in the above-mentioned document was poorly answered essay questions on Environmental Studies, 'giving the impression that this topic, which is scheduled towards the end of the year, was neglected by both teachers and learners' (p. 121). The problem of weak higher order thinking skills, compounded by difficulty with Environmental Studies, informed part of the research interest for this study: namely, how higher order thinking is engaged when reflecting on environmental issues in Life Sciences classrooms (specifically required for the Environmental Studies topic of 'human impact').

In Life Sciences, the sub-topic of 'human impact' in Grade 11 is supported by a Grade 10 topic of 'biosphere to ecosystems', which includes a suggested activity to investigate an ecosystem in a local biome for 'positive and/or negative human impact on the ecosystem' (South Africa DBE 2011a: 33). The topic of 'human impact' is taught in Grade 11 but (up until 2020) was examined in Grade 12 in the final school-leaving examination. Here, the topic of 'Human impact on the environment: Current crises for human survival: Problems to be solved within the next generation' is more detailed, with the specification of causes and consequences of atmosphere and climate change; water availability and quality; food security; loss of biodiversity; and solid waste disposal. The localisation of the topic requires both general and specific knowledge when an activity is suggested to conduct a 'practical observation of ONE example of human influence on the environment in the local area (e.g. the impact of alien species on biodiversity) [and write a] written report on the chosen example' (South Africa DBE 2011a: 51).

It is in understanding environmental issues with social-ecological complexities, such as 'climate change' and 'population ecology', and understanding and responding to 'human impact', that these Life Sciences topics require the higher order thinking skills that are called for in the subject. To gain a more nuanced understanding of the higher order skills listed by the DBE above (application, problem-solving, critical thinking, analysis and evaluation) in the context of environmental learning, this study analysed the development of these skills in relation to the sustainability competencies outlined by Wiek et al. (2011) (see Shumba, Mandikonza and Lotz-Sisitka, Chapter 12). While these competencies were developed by Wiek et al. for the higher education context, we suggest that at the school-leaving level, when learners are expected to discuss the complexity of human impact, these competencies, designed for their role in addressing contextualised and complex 'problem constellations' (Wiek et al. 2011: n.p.) would provide relevant insight. Thus, the study's interest can be elaborated as an interest in how teaching towards the development of sustainability competencies can complement teaching for higher order thinking in environment and sustainability topics in Life Sciences classrooms.

This research interest is reflected in the study's overarching research question:

> How can the development and emergence of higher order thinking skills in environmental and sustainability topics in Life Sciences classrooms be complemented by teaching for the development of sustainability competencies?

Competencies in assessment

This section begins by detailing the way in which cognitive levels are outlined in the Natural Sciences Curriculum Assessment Policy Statement (CAPS). This is followed by a description of the sustainability competencies that are used in the chapter, in order to gain a deepening understanding when assessing Life Sciences lessons that focus on environmental topics. Finally, the section draws on critiques of a competence-based curriculum, in order to identify three challenges for a quality approach to competence discourse in school-based assessment practice.

Cognitive levels

In the Natural Sciences CAPS curriculum, guidelines are given as to what types, and the relative weighting, of questions considered to be at low, medium and high order cognitive levels in: knowing science; understanding science; applying scientific knowledge; and evaluating, analysing and synthesising scientific knowledge (Table 1). The descriptors of the verbs in the table support the identification of cognitive levels in the analytic work of this study, namely in the lesson plans, classroom conversation and assessment tasks.

Table 1. Cognitive levels for the assessment of content in Natural Sciences (South Africa DBE 2011b: 87)

Setting tests and tasks for different cognitive levels	Knowing science	Understanding science	Applying scientific knowledge	Evaluating, analysing, synthesising scientific knowledge
Percentages indicating the proportion of low, middle and high order questions in tasks, tests and exams	**Low order questions 40%**	**Middle order questions 45%**		**High order questions 15%**
Useful verbs to use when setting questions	State, Name, Label, List, Define, Describe, and others …	Explain, Compare, Rearrange, Illustrate, Give an example, Calculate, Make a generalisation, and others …	Predict, Apply, Use knowledge to demonstrate, Solve, Implement, Judge, and others …	Select, Differentiate, Analyse, Infer, Suggest a reason, Interpret, Discuss, Categorise, and others …

These cognitive levels and associated verbs are a useful starting point for thinking about assessment. However, verbs indicating the medium and higher order cognitive levels, especially, are applied differently depending on the type of science one is doing. For example, to analyse data in an experiment is a different process to analysing complex social-ecological phenomena such as those addressed in Education for Sustainable Development (ESD) (see Schudel and Lotz-Sisitka, Chapter 2; Shumba, Mandikonza and Lotz-Sisitka, Chapter 12). In order to obtain a more nuanced perspective on these cognitive levels when dealing with ESD topics, sustainability competencies were used as an additional lens for analysing assessment practice in the classroom.

Sustainability Competencies

De Haan described a competence-based approach to education as an output-focused approach (as opposed to 'input'). That is, one which 'asks what problem-solving strategies, concepts and abilities for social action' a learner should have (De Haan 2006: 22). Wiek et al.'s (2011) model outlining sustainability competencies is relevant for applying knowledge specifically to problem solving in the context of ESD. They argued that sustainability education should enable learners to analyse and solve sustainability problems, anticipate and prepare for future sustainability challenges, and also to recognise opportunities for sustainability. Because sustainability problems and challenges have specific characteristics, analysing and solving these requires the particular set of interlinked and interdependent key competencies proposed by Wiek et al.

The five competencies central to a sustainability approach to learning were used as lenses for reviewing the development of Life Sciences curriculum competencies in the context of environmental learning. This perspective helped in reviewing learner competencies for working on solutions for real-world sustainability challenges. They are described as follows:

1. Systems thinking and modelling is when a learner demonstrates the ability to analyse sustainability problems cutting across different domains and scales (from local to global).
2. Anticipatory tracing and imagining (future thinking) is the ability to employ future thinking in sustainability problem solving.
3. Strategic competence (action-orientated competence) involves activities that can make a sustainable vision happen, including strategic plans for how to mitigate sustainability problems.
4. Interpersonal engagement and communication or collaboration is the ability to initiate, facilitate and support different stakeholder groups for effective sustainability problem solving. It includes the skills of knowing how to work in teams, communicate, present and facilitate meetings, as well as work effectively with different stakeholders.
5. Normative competence is the ability to specify, compare, apply, reconcile and negotiate sustainability values, principles, goals and targets, informed by concepts of justice, equity and responsibility in various processes, including visioning, assessment and evaluation. (Wiek et.al. 2011)

A critical perspective on competencies

While sustainability competencies are part of international debates in the field of ESD, competence-based education has received some criticism in curriculum debates in the general field of education internationally. There are a number of axes of tension regarding the notion of competencies as they are interpreted and enacted in different ways and with different intentions in different contexts. Drawing on an international perspective regarding the notion of competencies offered by Barnett (1994), and a South African perspective offered by Christie (1997), the authors propose three challenges for a quality approach to competence.

- Responsiveness and transferability of competencies in different contexts (as opposed to a context-bound approach).

- Reflexivity in open-ended problem-solving contexts (rather than employing competencies in an instrumentalist approach to education).
- An integrated (rather than fragmented) approach to knowledge acquisition.

The first challenge – responsiveness and transferability – is important because coping with profound societal and ecological change, locally and globally, cannot simply be covered by the concept of standardised competencies. Competencies are needed that enable learners to respond to sustainability knowledge which is 'rapidly changing and developing as scientists strive to understand environmental issues better and come up with possible solutions and alternative practices' (Fundisa for Change Programme 2013: 7). Wiek et al. appear to have responsiveness and transferability in mind when they define competencies as a 'complex of knowledge, skills and attitudes that enable successful task performance and problem solving with respect to real-world sustainability problems, challenges and opportunities' (2011: 204).

Implementation of competency frameworks has been criticised for not being able to support responsiveness to new contexts. For example, overly specified competencies have been criticised as being 'tied to specific contexts and events … [and] only understandable within that specific context and the material base it rests upon … Because meaning is context specific, meaning is consumed by that context and can't easily be applied elsewhere' (Wheelahan 2007: 639). While this critique comes from a specific vocational education and training context, it has relevance in any educational setting in which problem solving in context is needed. Such a context-bound approach in developing competencies is to be avoided if diverse problem-solving skills in ESD contexts are needed.

In this chapter, we argue that Wiek et al.'s set of five competencies needs to be developed in such a way as to support transference to a variety of contexts in an expansive and responsive manner. Such a view of competencies as transferable is consistent with the view of competencies influencing South Africa in the development of an outcomes-based approach to education. This view of competencies was influenced by an Australian report that described competencies as 'the ability to apply skills to performing a task, and encompass theoretical understanding of the task, as well as the ability to transfer knowledge, skills and understanding to another context' (Christie 1997: 56).

The second challenge – that of reflexivity within open-ended problem-solving contexts – relates to Barnett's statement that 'we live in an unpredictable age, and corporate life is one of living effectively with continuous change' (1994: 173). He claims that a competence-based approach to education can represent people and their actions in an instrumentalist way, that is, expecting learners to tackle the world by trying to cope with its challenges, but failing to reflect on problems in the world or form judgements on these. In South Africa, the notion of outcomes-based education has been similarly critiqued for its 'means-ends' stance and linear approach to education (Jansen 1998). In this study, reflexive competence is seen as critical for the transformational pedagogies on which ESD relies. Reflexive competence is a competence that builds on practical competence – 'demonstrated ability to perform a set of tasks' – and foundational competence – 'demonstrated understanding of what we or others are doing and why'. This is in order to 'integrate or connect performances with an understanding of those performances, so that we learn from our actions and are able to adapt to changes and unforeseen circumstances' (Gamble 2009: 3).

The sustainability competencies model on which this study relies are not founded on instrumentalist outcomes or linearity, nor do they demonstrate a lack of reflexivity. According to Wiek et al. (2011), sustainability competence (particularly strategic competence) aims to develop students who will be able to design and implement systemic interventions and transformational actions. These interventions, operating in an unpredictable system, necessitate open-ended responses, and therefore overly specified and pre-determined outcomes or competencies cannot be preempted. Additionally, normative competence with its strongly principled, comparative and negotiating features is supportive of reflexivity. Wiek et al.'s approach to sustainability competencies requires that learners look back critically (reflexively) at their own ideas and practices and change them as a result of this reflection (Fundisa for Change Programme 2013: 14).

The third challenge for a competence-based approach is the argument that curriculum competencies should be seen in an integrated rather than reductionist sense (MacFarlane & Lomas 1994). For this study, it is assumed that the five competencies as suggested by Wiek et al. above also specifically guard against reductionism, in that they are a functionally linked complex of knowledge, skills and attitudes. This point is highlighted when the authors describe sustainability competencies as 'conceptually embedded sets of interlinked competencies' (Wiek et al. 2011). This interlinking of competencies can be said to be an integration of skills and knowledge around a particular problem in a particular context. De Kraker, Lansu and Van Dam-Mieras (2007: 109) also highlight the importance of integration when working with the notion of competencies, noting that, 'learning should focus on integrative competences required in professional life, and not on the acquisition of isolated skills and pieces of knowledge'. They emphasise that this is a different perspective on competencies beyond a list of competencies.

The above discussion highlights some of the challenges posed by critiques of a competency-based approach to learning, including limitations to responsiveness and reflexivity, and the danger of fragmentation. However, what becomes evident to us as authors, as the pros and cons of competency frameworks in education are discussed, is that often the problem is traceable to either a narrow interpretation of, or a difficulty with, implementation, rather than any inherent problem in the notion of competence itself.

Research methodology

The study was conducted with four Life Sciences teachers in four schools offering Life Sciences in Grades 10–12 in the KwaZulu-Natal Midlands near Mooi River. All were farm schools, of which three were no-fee paying and one was a fee-paying school. All teachers were qualified to teach Life Sciences.

The study employed qualitative research methods, namely a questionnaire, stimulated recall interviews, observations (of lesson plan implementation in classrooms) and document analysis (lesson plans, assessment tasks and learners' work) to generate data.

Analysis included descriptions that took cognisance of the following:

i) Descriptions of high, medium and low order development and achievement in classroom activities and tasks. Each question in the assessment tasks was described as either low, medium or high order. Achievement was described as a percentage for each question. For ease of analysis, achievement was described in three categories: 60% to 100%; 30% to 59%; and 0 to 29%. Six examples of learners' work per classroom were analysed: two whose overall grade was the lowest; two whose overall grade was the class average; and two whose overall grade was the highest. Some tasks did not lend themselves to such a detailed breakdown and these were described qualitatively.
ii) Emergent sustainability competencies in the environmental learning processes (influenced by Wiek et al. as elaborated earlier).
iii) A quality engagement with competence influenced by the three critical perspectives on competencies as described above: responsiveness and transferability, reflexivity, and integration.

The results of this analysis are described below in the form of narratives for each teacher and the lessons presented in each classroom. The selected data has been extracted from a more extensive master's dissertation (Mkhabela 2017). The narratives present a holistic perspective on the teachers' intentions as well as the applicable cognitive levels that the assessment practices target in relation to sustainability competencies in each classroom.

Presentation of data

In the first case described, the teacher focused on the topic of population ecology. She began with an exploration of natality, mortality, immigration, emigration and migration which supported the development of **systems thinking competence**. She also aimed at developing investigation skills, namely: following instructions, knowing how to make estimations, performing simple calculations and applying knowledge of theory to practical situations. Evidence of an interest in developing higher order thinking is in her explanation that: '*The problem is calculation, application and interpretation. So, with this lesson I wanted to address these three because I know and have noticed that my learners are struggling on these competencies.*'

During the lesson presentation the teacher tested the learners' ability to explain the logic of the mark recapture method:

> *Teacher: You took a handful beans and put them back, then now for the first time you were not supposed to close your eyes, but for the second time now you need to close your eyes, why?*
> *Learner: So that I will not take the marked beans only.*

These 'why' questions are critical for preparing learners for higher order thinking. However, despite the teacher using this questioning strategy in preparing the learners for the assessment task that followed, none of the six learners was fully able to answer the higher order questions about how reliability of the method could be improved, and none could answer a critical thinking question (related to the quoted dialogue above) on why moths should be marked on their 'underside'. Only one of the six could interpret the data giving a reason for differences in the two populations of moths. This affirmed what the teacher said in the interview when asked about the curriculum competencies of her learners, that: *Basically they [learners] are good at competencies where one word is needed … They struggle to support the statement to say 'why are you saying that'.*

With the topic of Environmental Studies, of which 'Population ecology' is a part, the CAPS curriculum intends 'learners to become more informed and more sensitive to environmental issues and to modify their behaviour to lessen their impact on the environment' (South Africa DBE 2011a: 49). During the lesson, the teacher asked learners to explain the impact of an increase of population on the environment. Learners anticipated that if the population increased, there would be a shortage of houses, water, clean air and food. It is not surprising that this discussion was not conducted in much depth as the quantitative modelling activity did not give them the capital to answer the question. To answer more fully, learners would have required more detail on human-environment relationships (beyond just understanding population dynamics) and more time to research the detail (as learners in the next case were given).

Noticeable, with respect to these competencies, was that there was no **integration** between systems thinking and anticipatory competence. Learners were asked to anticipate a human-environment relationship based on tacit knowledge, while the systems thinking knowledge of population dynamics and quantitative modelling set up as a precursor to the topic of human impact in the curriculum was not helpful in providing the specific systems perspective needed for understanding human-environment relationships.

In the second teacher's lesson, learners were given a questionnaire to assess their individual carbon footprints and compare differences between their carbon footprints. The carbon footprint calculation activity raised learners' awareness of their impact on the environment and they compared individual footprints among group members. This supported an aspect of **normative competence** as described above, which is to 'specify and compare'. This activity would have been good grounding for further development of **normative competence** if, for example, learners had been asked to discuss different ways of reducing their carbon footprint in response to the teacher's intention of developing learners' knowledge of how humans negatively impact on the environment, as well as how to counteract these actions.

This footprint task was followed by a task where learners were expected to submit a research report on the impact of humans on the environment. The discussion below of deforestation and the carbon footprint effect preceded this research task and is an illustration of preparing learners for understanding social-ecological systems (**systems thinking competence**).

> *Teacher: How is deforestation going to affect the level of carbon dioxide (CO2) in the air?*
> *Learner: By removing trees …*
> *Teacher: How will it affect the level of CO2. Is it going to increase or decrease?*
> *Learner: It will increase.*
> *Teacher: Why will it increase?*
> *Learner: It's because trees that use it had been destroyed and CO2 that human beings exhale would accumulate in the air and no trees to absorb.*
> *Teacher: What other impacts will the rise of human population have on the environment?*
> *Learner: Soil erosion*
> *Teacher: What do you mean?*
> *Learner: The increase of population lead to people building houses even on steep slopes. They remove plants that hold the soil particles together and plants are also destroyed.*

This type of discussion, if dealt with in sufficient depth, is the beginning for integrating **systems thinking** (such as the relationship between forests and carbon dioxide and soil stability) **and anticipatory competencies** (what will happen if …?). Part of the research project mentioned above was for learners to research and report on three examples of human impact in terms of causes, effects and solutions. Four out of six learners achieved above 60% in describing the causes, two out of six achieved above 60% in describing the effects, and one out of six in suggesting solutions. The systems thinking and anticipatory thinking stimulated during the classroom discussion might have supported capacity to describe cause and effect, but the **strategic competence** required to suggest solutions was neither supported during the lesson nor adequately achieved in the assessment task when learners were asked to suggest solutions.

In reflecting on environmental content the teacher commented: *The challenge of environmental content knowledge is, we rely on theory that we get from the textbooks. Teachers and learners will understand environmental content knowledge much better if it is a hands-on lesson*. However, the analysis above suggests that classroom engagement and resources used might be missing content on responses to issues; namely sustainability practices such as policy, conservation and other agential interventions (O'Donoghue, Snow and Misser's Chapter 10 explores important nauances of a problem-solving approach in ESD). Thus, insufficient content coverage could possibly be a more convincing explanation than a lack of 'hands-on' learning.

The third teacher's lesson focused on the topic of human impact, with coverage of the sub-topic – 'water quality and availability'. With this topic, the CAPS curriculum intends to 'emphasise the interrelatedness and interdependence of human impacts and the environment' (South Africa DBE 2011a: 51). The teacher intended learners to look at the causes and consequences of problems with water quality and availability as well as solutions to these problems. Learners were taken on a field trip to a local river to observe and discuss human influence on water quality at different points in the river between a weir and another point, eight kilometres downstream. E-coli measurements had been arranged by the teacher in preparation for the trip. As an assessment task, learners completed a worksheet. In the worksheet, one learner demonstrated **systems thinking** by noting:

> *They release hot water in to the dam. It is not the long-term problem but it affects the living things in the water. In the sewage farm, the use of chlorine to clean the water kills bacteria but not the metals, batteries and all the other chemicals that get flushed down to the toilet. There were also lot of sewage leakage that come flow straight into the river from Bruntville, the E. coli count was 1500 per million at Helen's bridge.*

The extract above demonstrates **anticipating** the effect on living things through thermopollution Anticipatory thinking was also demonstrated when a learner commented that diseases like cholera might occur due to poor water quality (risks). The teacher followed by adding that: '*It can be any type of diseases because lot of kids play here.*'

Solutions in the worksheet demonstrating competence for thinking **strategically** included:

> *People need to be educated by the municipality about the importance of water and the municipality must monitor the condition of the river frequently working closely with uMngeni water board. Another specific comment was: We can prevent this by revamping smaller pipes into bigger ones and restrict dumping from water.*

However, learners did not perform well regarding strategic thinking, all of them receiving between 30% and 60% for this question. The above extract also demonstrates the foundations (if not reflexive realisation) of **interpersonal competence** which is described above the ability to initiate, facilitate and support different stakeholder groups in developing sustainability competence.

For the worksheets, all six learners achieved more than 60% for higher order questions that required:

- An analysis of water quality at the weir and at a second point further downstream.
- A discussion of the ecological impact of dams.

Fewer learners (four) achieved at more than 60% for a higher order discussion on the effects of the following on water quality: (a) Exotic trees, (b) Destruction of wetlands, (c) Poor farming practices and (d) Irrigation. This suggests that at least two thirds of the class were developing the **systems thinking competence** needed for discussing social-ecological complexities of environmental issues. In a final question where learners were expected to discuss water management and solutions to the problems (**strategic competence**), no learners achieved at above 60%, thus demonstrating a difficulty in **transferring** of strategic competence to a different context.

Significantly, the curriculum emphasises cause and consequence explicitly, but 'solutions' are only mentioned implicitly with respect to some of the proposed human impact topics (not within the water quality sub-topic). For example, under the biodiversity loss sub-topic, the curriculum suggests looking at 'indigenous knowledge systems and the sustainable use of the environment' (South Africa DBE 2011a: 52). In this respect, the teachers' explicit interest in solutions as described above was a useful refinement and extension of curriculum content from an environmental perspective.

The rationale for the field trip method used by the teacher was: '*The use of DVDs and textbook put a barrier between learners' lives and the problem, but if they see what is happening in their area, it becomes real.*' This point supports the teacher's argument in the above case that practical work is important for environmental studies and can support a **responsive** approach to competence. Also, in this case, the fairly high levels of achievement (compared with the other lessons discussed) illustrate how field work can support achievement of higher order thinking. Yet, as in the above case, it does not explain why the higher order thinking skill of 'finding solutions' appears to be difficult for some learners.

The formal assessment task was a test addressing different aspects around sustainability challenges and learners were expected to suggest reasons and solve environmental problems. Knowledge of different aspects of human influence on the environment was assessed, such as ozone depletion, greenhouse effect, global warming, and over-utilisation of natural resources. Mkhabela (2017) includes a full analysis of the test, but it is worth noting here that one of the higher order questions from the test that related to water, which was: 'Water quality is rapidly becoming a more critical problem than water availability in South Africa. Why is this the case?' was achieved at above 60% by two of the learners, between 30% and 60% by two learners and less than 30% by two learners. This implies that the field trip had not necessarily prepared learners to achieve higher order thinking as successfully in a written test as they had achieved in the field trip worksheet and indicates that the **transferability** of competence displayed during the field trip activity was not necessarily achieved.

The fourth teacher's lesson was also about human impact on the environment, with a focus on the sub-topic 'food security'. He gave learners the local newspaper and asked them to discuss an article in which local farmers raised concerns about veld fires and drought and the impact of this on food production. Learners were divided into six groups and asked to discuss and develop a presentation on one of the following:

- The impact of exponential growth on food availability.
- How natural environmental occurrences can impact on food security.
- How the agricultural sector impacts on food security.
- How fuel and food price increases, poverty and monopoly of seed production could contribute to food insecurity.
- Intervention measures to address the problem of food insecurity in South Africa.

During presentations, the teacher and learners analysed a sustainability problem (food security) by discussing the dynamics across multiple domains. These domains were: exponential increase of human population; occurrences such as droughts, floods, climate change (ecological); the rise of petrol and food prices (economy); and the use of fertilisers by farmers (technology) which are related to food security (**systems thinking**). During discussions, learners anticipated that as the human population increases, poverty and high unemployment rates would be experienced (**anticipatory competencies**). However, the anticipatory competence demonstrated in this discussion did not necessarily realise the full complexity of the systems thinking developed during the presentations. This indicates that a greater integration between systems thinking and anticipatory competence might strengthen the higher order thinking needed for understanding the problem of food insecurity.

As a formal assessment task, learners were given an assignment to research how the Chimanimani people in Zimbabwe use permaculture farming to mitigate against food insecurity. In the formal written task, learners were expected to conduct a higher order discussion about the Chimanimani community's engagement with issues of sustainable food security as well as ways to enrich the soil. This task was mainly unsuccessful in terms of learning outcomes as all but two learners cut and pasted their entire answers from an internet site. Only two of the learners presented original work by creating their own arguments from internet-based research. This indicates that because higher order thinking often requires creative thinking in terms of analysing and discussing, it needs to be supplemented with formative support for meta-cognitive skills such as learning how to research and how to construct original arguments.

Of the two learners that were able to construct original arguments, the argument by one of the learners on the importance of engaging in collaborative decisions (as illustrated in the Chimanimani case study) revealed the potential of such case studies to raise foundational understanding of **interpersonal competencies**. Another learner reported how the community acted to retain spring water by planting trees on the hilltop catchment (foundational for **strategic competence**). This learner also reported how community members developed permaculture gardens for the elders and orphans. This showed learners' consciousness of the sense of responsibility among community members and indicated potential for developing foundational understanding of **normative competence**. Significant in this lesson was that all five sustainability competencies were integrated across the two tasks.

Discussion and Recommendations

Understanding human impact requires sustainability competencies

Looking across the four cases outlined above, the findings indicate that CAPS Life Sciences environmental studies content knowledge, and particularly the topic of human impact, requires higher order thinking skills such as analysis, discussion of complex social-ecological phenomena, and problem solving. In implementation, this topic also seems to require all five sustainability competencies.

In all four lesson presentations, systems thinking and anticipatory competencies were supported and they appear to have been effectively integrated in two of the four schools (Teacher 2 and Teacher 3 lessons). In these two schools, it appears that these competencies were supporting learners 'to become more informed and more sensitive to environmental issues' (South Africa DBE 2011a: 49). Where there was no **integration** between competencies, the ability of learners to demonstrate understanding of sustainability challenges was compromised. This occurred in the first case, which did not build understanding of social-ecological complexity, and in the fourth case where social-ecological understandings from the first part of the lesson were not brought into the anticipatory discussions in the second part of the lesson.

In three of the lessons, learners were expected to extend systems thinking and anticipatory competence and draw on strategic competence to research a range of issues (in the case of Teacher 2's research project), look at how others had resolved environmental problems (in the case study of the Chimanimani), or think hypothetically about how the problems of water pollution could be resolved (in the case of the field trip). Strategic competence was demonstrated by only one learner in the research report; it was attempted in the field trip worksheets but not achieved at a satisfactory level of performance, and was demonstrated in the form of foundational understanding by a limited number of learners reporting on the Chimanimani case.

Normative competence (to a limited degree) was only addressed in one of the cases. However, without the **reflexivity** of a more extensive engagement in **normative** competence (which could have been achieved through thinking about ways to reduce their respective carbon footprints and/or through thinking about resolutions to environmental issues), learners were not supported in the curriculum intention to 'modify their behaviour to lessen their impact on the environment' (South Africa DBE 2011a: 49). We suggest that the features of normative competence, such as negotiation, reconciliation and visioning, as elaborated earlier, are important in problem solving to respond to this need to 'lessen impact'.

Interpersonal competence was foundational for understanding the role of stakeholders in sustainability practices, in response to problem situations highlighted during the field trip (the role of educators and the municipality were highlighted) as well as in the Chimanimani case study (the role of community partnerships was highlighted). The curriculum emphasis on modifying learners' individual behaviour, as noted above, is a significant limitation in supporting the development of such interpersonal competence.

We suggest that for more effective problem solving, the curriculum needs to call for a deeper understanding of agency and change beyond individual behaviour.

Strengthening higher order thinking in ESD contexts

While the cases described in the results demonstrated an intention, as well as some successes, to develop higher order thinking, there are also some lessons that can be learned from these cases that might enable the strengthening of higher order thinking in Life Sciences classrooms. The questioning strategy used by Teacher 1 in the classroom appears to be leading learners to the right kinds of thinking; however, their struggles with formal tasks suggests that even more classroom time needs to be spent on formative assessment for the purpose of developing higher order thinking, and more time responding to 'why' questions in different forms and different ways. Another important aspect of formative classroom work appears to be the need for focusing on developing meta-cognitive skills such as researching and constructing arguments, as implied by the difficulty learners had with Teacher 4's research task.

There appear to be some contradictory suggestions in the evidence regarding the importance of practical work in developing understanding of environmental issues. While learners generally performed well in Teacher 1's practical activity, this did not necessarily lead to performing well with higher order thinking skills, nor with the human impact question asked of them as a follow on. Similarly, with the field work task, learners performed fairly well in answering some of the higher order questions but were not as successful in the problem-solving questions either in the field trip worksheet or the test that followed. Thus, the data suggests that practical work needs to be supported by appropriate content coverage in order for higher order thinking to be strengthened, and that teachers should be careful of an over-reliance on tacit knowledge regarding full understanding of complex environmental issues.

Above, we discussed the lack of integration between systems and anticipatory competence in the first case. In this regard, we suggest that curriculum developers need to consider whether the topic of population ecology is the best lead-in to the topic of human impact, in order to develop understandings of such social-ecological relationships and how this may lead to a fragmented approach underpinning the topic of human impact. One teacher indicated the usefulness of drawing on Grade 10 ecological understandings to support understanding of the human impact topic. Thus, progression in the lead up to the topic of human impact appears to be an important point for review in the curriculum and teacher training (see Mmekwa and Schudel who trace how problems with progression arise, Chapter 3).

In the discussion on competencies in the section above we suggested that work on competencies needs to take heed of a number of challenges before it can be seen to support quality learning. These include responsiveness and transferability, reflexivity, and integration. Reflexivity and integration have been discussed in the previous section. Regarding responsiveness and transferability, the best examples to draw on were cases 3 and 4, because they moved from responding to local contexts, to general and specific 'neighbouring' contexts. Teacher 3 moved from a study of a local river to a test about a variety of environmental issues. It was pleasing to see that learners achieved well in higher order thinking (60% and above) for both the local task and the test. In a different shift, Teacher 4 moved from studies of environmental issues in local newspapers to a Zimbabwean case study in a neighbouring context. Even though learners did not generally perform well in the case study, the two teachers demonstrated different teaching methods that can be designed to help learners in transferring competencies from local to general application and from one context to another.

Summary and conclusion

This study has shown that the section on Environmental Studies in the Grade 11 curriculum (which includes 'population ecology' and 'human impact') requires higher order thinking skills such as analysis, problem solving and discussion. It suggests that social-ecological systems thinking (beyond the thinking developed by population ecology) is important for fully understanding environmental issues and that curriculum progression is an important consideration in building this thinking. The study also illustrates how the three challenges to competence-based approaches to learning play out in classroom contexts. First, social-ecological systems thinking is important to bring forward in an integrated way in supporting extended sustainability competencies. Second, we suggest that strategic, normative and interpersonal thinking needs strengthening in classroom situations as part of a reflexive approach to competence development, especially where finding solutions to environmental issues is important. Engaging in content around sustainability practices (as opposed to problem contexts only) can be an important springboard for developing these competencies. Third, the study indicates that transferability of competencies is not automatic when moving from local studies to general contexts or different contexts. It suggests that even though engaging different contexts through different teaching strategies shows promise, salient content (especially regarding solutions to issues) needs to be developed to support the problem-solving needs in ESD contexts. Pedagogical suggestions from the study are that teachers need to continue using questioning strategies in the classroom to build learners' experience and confidence in answering higher order questions in formal assessment tasks, and that meta-cognitive skills are also important considerations for developing higher order thinking.

Overall, this study has shown that environmental topics, especially those with an emphasis on human impact (and the natural extension into sustainability practices) require higher order thinking skills such as analysis, problem-solving and discussion. It suggests that taking cognisance of sustainability competencies can strengthen the development of these skills. It is hoped that the knowledge about the relationship between environmental content, higher order thinking, and sustainability competencies developed in this chapter will be of value to assessment thinking in other subjects and other environmental topics, as well as to other countries working either with competence-based or content-based curricula.

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CHAPTER 14

Formative Assessment for Quality Environmental Learning in Natural Sciences Classrooms

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Background and context

The study that informs this chapter aimed at exploring how teachers used formative assessment strategies to support higher order thinking in environmental topics taught in Natural Sciences classrooms (Mgoqi 2019). Higher order thinking is used widely by educational curriculum developers and assessment experts to design test items that measure a variety of thinking skills (Haladyna 2004). For example, the Curriculum Assessment Policy Statement (CAPS) Natural Sciences developers have framed low, middle and high order cognitive levels for guiding classroom assessment (South Africa DBE 2011). These levels describe the way in which learners are expected to work with knowledge as follows: knowing (low order); understanding and applying (medium order); and evaluating, analysing and synthesising (high order). These cognitive levels are closely linked to Bloom's Taxonomy of Learning which Zohar and Dori (2003) used to describe higher order thinking as analysing, evaluating and creating. These latter three levels build on the lower order thinking levels of remembering, understanding and applying. These higher order thinking skills are important for environmental learning which promotes 'critical thinking, understanding complex systems, imagining future scenarios, and making decisions in a participatory and collaborative way' (Unesco 2014: 33). In this chapter, a revised Bloom's Taxonomy as proposed by Krathwohl (2002) is discussed and used as a lens to review the cognitive levels evident in the activities planned and implemented by teachers.

Black and Wiliam (1998a; 1998b) argued that formative assessment, when used properly, could raise classroom standards. According to this assertion, we consider how formative assessment can contribute to the development of higher order thinking. Wylie and Lyon (2013: 7) define formative assessment as 'a process used by teachers and students during teaching that provides feedback to adjust ongoing teaching and learning to improve students' achievement of intended instructional outcomes'. According to Black (1998), teaching and formative assessment are indivisible. He argued that effective teaching begins with planning activities that elicit evidence of learning; in other words, activities should be justified in terms of the learning aims that they serve. This suggests that formative assessment is important to all learning. However, Taylor (2017) argued that there is little coherence within most South African schools regarding the use of assessment to improve teaching and learning. He described the general focus as summative assessment and learner promotion, rather than formative assessment which focuses on giving learners feedback in relation to their learning.

This study combines the concepts of higher order thinking with the practice of formative assessment to create an interest in how Natural Sciences teachers use formative assessment strategies to raise classroom standards and foster higher order cognitive development of learners. Zohar and Dori (2003) suggest activities for developing higher order thinking, such as the construction of arguments; posing research questions; making comparisons; solving non-algorithmic complex problems; handling controversies; and identifying hidden assumptions. We suggest that these are useful activities to use in supporting formative assessment practices in classrooms.

The study that informs this chapter sought to answer the following question:

> What are teachers' perspectives, experiences and challenges in using formative assessment for supporting higher order thinking in the teaching of environmental curriculum content?

For the purposes of this research, the environmental topic of focus was biodiversity, which has substantial coverage in the Natural Sciences (see Mmekwa and Schudel, Chapter 3).

Theoretical framework

The Vygotskian theory of the Zone of Proximal Development (ZPD) provides useful insight into formative assessment processes (Vygotsky 1978). The ZPD is an area of dialogue and interaction for teacher-learner and learner-learner, in which the teacher can support learners by using different formative assessment techniques. The concept of scaffolding, which is related to the concept of ZPD, is also used in this study to look at *how* teachers used the teaching and learning activities and tasks to support student learning. In education, the idea of scaffolding originated from the work of Bruner who defined scaffolding as:

> A process of setting up the situation to make the child's entry easy and successful and then gradually pulling back and handing the role to the child as he [sic] becomes skilled enough to manage it. (1993: 60)

Scaffolding, as a metaphor used in teaching and learning, offers the relevant description of how teachers provide successive levels of temporary support that help learners reach higher levels of comprehension and skill acquisition that they would not be able to achieve without assistance. It is a useful concept for conceptualising how formative assessment can support movement from low to medium to higher order thinking. Scaffolding can include a variety of instructional techniques used to move learners progressively towards stronger understanding and, ultimately, greater independence in the learning process or within their ZPDs. According to Larson and Marsh (2006), a teacher can create activities in the classroom to promote learning that is outside the developmental level of his/her learners and provide any necessary scaffolding (help) to broaden the development. Like physical scaffolding, the supportive strategies are incrementally removed when they are no longer needed, and the teacher gradually shifts more responsibility for the learning process to the learners.

Ten dimensions of formative assessment

One of the analytical lenses used in this study was Wylie and Lyons' (2013) 'Ten dimensions of formative assessment' which reviewed the detail of the kind of work teachers can do to support formative assessment in the ZPD. This includes: clarifying goals/learning intentions; sharing criteria for success; tasks and activities that elicit evidence of student learning; questioning strategies that elicit evidence of student learning; instituting feedback processes during questioning; descriptive feedback, peer-assessment, self-assessment and collaboration. Wylie and Lyons saw these dimensions as areas that could bring out the hidden integrations of formative practices. Hence, they argued: 'Focusing on just a single dimension likely would not result in a robust implementation of formative assessment. Rather an integrated approach is required' (Wylie & Lyon 2013: 12).

Below, brief descriptions of each dimension of formative assessment practices is presented. The descriptions highlight specific aspects of learner involvement and engagement with formative assessment across the 'ten dimensions'. In some cases, the dimension may directly focus on the learner's role in the formative assessment process (e.g. peer assessment or self-assessment). In other cases, the degree to which learners are involved may be minimal compared to the teacher's role (e.g. in the clarifying of goals and criteria of success). What is significant across all dimensions is the role of the teacher in facilitating the process in a way that enables learners to be deeply engaged at all levels and take ownership of their learning.

Dimension 1: Clarifying goals/objectives

The focus of this dimension is on the teacher's presentation of the learning goals/objectives. Teachers need to clarify the goals and write them in a language that is accessible to the learner (Wylie & Lyon 2013).

Dimension 2: Clarifying criteria for success

The focus of this dimension is on how the teacher identifies the criteria for success in a lesson and explicitly shares this with his/her learners. Formative assessment begins when teachers share achievement targets with learners, presenting those expectations in learner-friendly language accompanied by exemplary learners' work (Stiggins 2007).

Dimension 3: Tasks and activities that elicit evidence of student learning

This dimension focuses on the activities or tasks that the learners are engaged in, excluding classroom discussions. Here the learners need to show that they have learnt something through being engaged in those activities or tasks (Wylie & Lyon 2013: 33). Teachers' teaching and learning activities and tasks should match the intended learning target both in terms of what the students learn (content) and what they can do with the learning (cognitive complexity).

Dimension 4: Questioning strategies that elicit evidence of student learning

The focus here is, first, on the key questions the teacher plans to ask the learners and, second, on how the teacher orchestrates classroom discussion in order to collect evidence of learning. The questions should be those that will encourage learners to use cognitive processes or dispositions. Questions that require learners to respond with complex answers, such as asking them to explain their answers, can be a better view into learners' thinking and their ability to move forward to solve subsequent problems. Responses to such questions could also provide evidence of metacognition and can help teachers to elicit evidence of student learning (Erickson 2007). Setting and asking these questions is not enough. It is only through paying careful attention to students' responses and allowing them to ask their questions in relation to what they are engaged with, that the teacher can collect evidence of learning (Wylie & Lyon 2013).

Dimension 5: Feedback loops during questioning

This dimension focuses on the teacher providing ongoing feedback that will help learners to develop science ideas and content. The formative assessment dimension of the feedback process informs both teacher and learners about learner understanding and what can be done to increase knowledge. However, assessment is formative only if both teacher and learner do something with the feedback to facilitate 'shifting' forward the learner's understanding within the ZPD so that new challenging activities can be presented that draw on the child's previous experience. Feedback can be used in closing the gap between current learning and intended learning (Wylie & Lyon 2013).

Dimension 6: Individualised descriptive feedback (written or oral)

This dimension focuses on the teacher as the provider of feedback. This feedback should be in relation to the intended outcomes and the criteria for success. Learners, in return, need to attend and respond to the feedback (Wylie & Lyon 2013).

Dimension 7: Self-assessment

The importance of the self-assessment dimension is to provide students with an opportunity to reflect on or assess their learning (Wylie & Lyon 2013). This is an opportunity to think meta-cognitively about their learning. Students should take ownership of their learning, as self-regulated learning is a key outcome of formative assessment. Self-regulated learning can be defined as a child's capacity to plan, guide and monitor his/her behaviour within the changing circumstances (Diaze & Amaya-Williams 1990). Student self-assessment, therefore, serves a cognitive development purpose as well as increasing learners' responsibility for their own learning, thus making the relationship between teachers and learners more collaborative. The role of the teacher in the self-assessment dimension is to make sure that learners are effectively and successfully engaging with the process of self-assessment.

Dimension 8: Peer assessment

The peer assessment dimension focuses on learners' thinking about other learners' work, and the process allows learners to support their peers. Some of the scholars of formative assessment (Black & Wiliam 2009; Black & Harrison 2004) saw the role of learners in formative assessment as important not only in order for them to assess themselves, but because once they master self-assessment they should be able to look at their peers' work and give them feedback. Harlen (2004) argued that peer-assessment should go beyond the simple and obvious form that we see operating in many classrooms, where learners mark each other's test or activity. True peer assessment would mean learners helping each other with their learning by giving each other feedback and suggesting the next steps to be taken to improve their work.

Dimension 9: Collaboration

The collaboration dimension focuses on classroom culture, on the relationship between teacher and learners and learner-learner interactions. It capitalises on an open learning and teaching environment, where teachers and learners are partners in learning. How the teachers and learners work together towards a common goal is key in this dimension.

This common goal is evidenced by the clear focus on learning, collaboration, respect and an appreciation for multiple viewpoints (Wylie & Lyon 2013).

Dimension 10: Using evidence to inform teaching and learning

The focus of this dimension is on how the teacher collects and uses evidence to adjust his/her teaching. This dimension highlights that assessment should not be designed solely to measure learners' progress but also to advance teaching (Miller & Seraphine 1993). The teacher gathers evidence from engaging with learners and observing them as they explore science concepts. The evidence can be gathered through learner oral or written work. The dimension focuses on how the teacher capitalises on the opportunities to collect evidence that prevail during the teaching. Assessment becomes formative once the teacher uses the evidence gathered, or feedback, to adjust teaching and learning (Exploratorium 2006).

Student cognitive development

Krathwohl's 'Revised Bloom's Taxonomy' (2002) was a second analytic tool used in the study for insight into cognitive development in classroom contexts. In this taxonomy, objectives are classified in a two-dimensional fashion. Cognitive processes, namely the ability to remember, understand, apply, analyse, evaluate and create, are set in a matrix against knowledge described at three levels, namely facts, concepts/principles, procedures and meta-cognitive knowledge. The taxonomy enables teachers to consider what cognitive processes are being employed at what level of knowledge. The higher levels of analysing, evaluating and creating (or synthesising, as included in the CAPS curriculum) are those that are considered to constitute higher order thinking (Zohar & Dori 2003; South Africa DBE 2011).

The taxonomy table is further meant to help teachers and other educators in at least three ways:

1. It can help teachers and educators answer what is referred to as the 'learning question' – What is important for learners to learn in the limited school and classroom time available?
2. It can help teachers answer the 'teaching question' – How does one plan and deliver content that will result in high levels of learning for large numbers of learners? And also the 'assessment question' – How does one select or design assessment instruments and procedures that provide accurate information about how well learners are learning?
3. It can help teachers to answer the 'alignment question' – How does one ensure that the objectives, instruction and assessment are consistent with one another? (Anderson et al. 2001: 6–10)

However, a limitation of the taxonomy is that higher order thinking can be over-simplified when only defined by cognitive processes and levels. Further insight into higher order thinking is offered by Resnick (1987) who suggests the following broad characteristics of higher order thinking:

- Non-algorithmic: That is, the path of action is not fully specified in advance.
- Complex: The total path is not 'visible' (cognitively speaking) from any single vantage point.
- Yielding multiple solutions, each with its own costs and benefits, rather than unique solutions.
- Involving nuanced judgement and interpretation.
- Involving the application of multiple criteria, which sometimes conflict with one another.
- Involving uncertainty. Not everything that pertains to the task at hand is known.
- Involving self-regulation of the thinking process.
- Involving imposing meaning and finding structure in apparent disorder.
- Effortful: There is considerable mental work involved in the kinds of elaborations and judgements required.

Methodology

Seven primary school Natural Sciences teachers in Cape Town, Western Cape, participated in the study. Data was generated through semi-structured interviews with the initial seven teachers, as well as a lesson observation with one of the teachers (including a pre-lesson discussion, stimulated recall interview, and analysis of the summative assessment task handed out at the end of the lesson). The observation was done on the teaching of biodiversity in a Grade 7 Natural Sciences lesson. In this lesson, the teacher conducted the following activities:

- Biodiversity cards were arranged to spell out the word BIODIVERSITY.
- Learners watched a video clip on biodiversity after which the teacher asked questions about what they had seen.
- Learners read notes on biodiversity.
- Learners read passages from the textbook and the teacher asked questions about what they had read.
- As a summative assessment task, learners were given a research project guided by eight questions with a marking rubric.

As the initial interviews had focused on the general perspectives of teachers on formative assessment, the lesson observation was important in the study for giving insight into the challenges of formative assessment practices when applied to the teaching of an environmental topic. In this case that topic was biodiversity.

Teachers' perspectives, experiences and challenges regarding the use of formative assessment for supporting environmental learning

The findings presented in this section describe the data in terms of the 'Ten dimensions of effective formative assessment', with additional reflections on what the implications are for higher order thinking as described above.

Regarding the first dimension of quality feedback, namely clarifying goals and objectives, the teacher expressed her intended learning goals in the interview. These were: to give information about biodiversity; raise awareness of human impact on biodiversity; and for learners to research ways of protecting biodiversity. However, the objectives were not made explicit to the learners at the beginning of the observed lesson. This is not to suggest that to hand out and discuss a summative task is equivalent to sharing learning objectives, but only to point out that had the teacher shared the summative assessment task at the beginning of the lesson, it may have helped learners implicitly to see these objectives and understand the point of the formative tasks leading up to this one.

Regarding the second dimension, namely clarifying criteria for success, the teacher in the observed lesson was clear on both the expectations and criteria by which learners would be judged through her sharing of the summative task and rubric for assessment. On a number of occasions, she reminded learners to take note of the important information that would help them to succeed in their project. This can be seen in the three quotes below:

> *Now just bear in mind, how does this apply to your project? That is what you should think about all the time. Yes, it's nice, but how does it apply to your project that we've got to do? That's what I want you to keep on thinking about … I want you just to pick up few points about our topic, biodiversity. I want you to be able to use these notes in your project.*

And:

> *Grade 7s are we getting the idea of these terms? I need to see them in your project, right? They are so important. That's why I've spent so much time talking about them yesterday.*

And:

> *Look at the rubric now, keep that next to you, but cast your eye on the rubric please so you can see how the questions match the rubric … Number one, what is biodiversity? ... so, in the first criteria it says 'Knowledge of biodiversity, definition … do you see that? Question one is asking what is diversity? Is that not a definition?*

The detailed summative task developed for the observed teacher's lesson included the following questions:

- *What is biodiversity?*
- *When is an area regarded as having a high biodiversity?*
- *What is meant by preserving biodiversity?*
- *Why is it so important to preserve our natural plants?*
- *Why has it become so important to be serious about protecting biodiversity?*
- *Why is South African biodiversity regarded as being so important?*
- *List at least 5 ways in which humans have negatively affected the earth's biodiversity.*
- *List at least 4 ways in which you can help in preserving biodiversity.*

The first three questions are pitched at a lower order cognitive level, requiring simply the recalling of definitional skills. The three 'why' questions are moving towards the medium order cognitive level at least, requiring understanding and application to the South African context and, depending on the degree to which learners would need to search for and synthesise information, also requiring higher order cognitive skills. The assessment rubric for this task requires '*excellent interpretation*', '*excellent understanding*' and '*excellent insight*' for the 'why' questions, respectively. If Resnick's conception of higher order thinking, as explained above, was applied to these 'why' questions, the teacher might be able to find evidence of complexity thinking and nuanced judgement here.

The last two questions, requiring simple 'listing', were also pitched at a lower cognitive level. However, the assessment rubric presents an illogical order in the cognitive level, with the level 3 criterion for these questions being described at a medium or higher order request for explanation. The criterion reads: *Mostly capable of explaining the importance of human involvement in the situation.* This would be expected to be more difficult to achieve than the lists required at the level 4 criterion which was: *All five ways of negative impact and all four human contributions are evident*. Additionally, there is inconsistency between the instruction in the task (to 'list') and the assessment criterion (to 'explain' at level 3). Noting inconsistency in alignment is one of the affordances offered by the New Bloom's Taxonomy raised by Anderson et al. (2001).

Had the questions and rubric been tightly aligned with the notion of 'explaining', higher order thinking skills such as complexity thinking, cost-benefit analysis, nuanced judgement and interpretation, and application of multiple criteria might have been useful for the teacher in assessing the task. However, this is not to argue that all questions should be set at a higher order level, but to point out the potential for environmentally focused tasks to develop higher order thinking. An important consideration was for the teacher to have fewer questions set for higher order thinking, considering that the CAPS curriculum requires 15% of tasks to be set at higher order levels (South Africa DBE 2011). One of the teachers highlighted the importance of targeting a variety of cognitive levels, as well as being aware of the different levels at which learners can perform. This understanding was evident in the teacher's statement that: *There should be different types of questions, lower order, and the higher order, depending on the level your learners are at.*

The above quote also raises an important caution in the South African curriculum, which highlights that high knowledge and high skills need to be attainable for *all learners* (South Africa DBE 2011). Thus, it is important to know 'where learners are at' (in the sense of their prior knowledge) but still teach towards developing higher order thinking for all. Zohar and Dori (2003) described a significant study in which they asked the question as to whether higher order thinking and low-achieving students are mutually exclusive. The conclusion from the study was that, while using certain methods in their study, they 'reached both low and high academic level students and prepared them to function in the increasingly sophisticated environment of the world today, and more so tomorrow' (p. 175).

Additionally, the importance of higher order thinking was highlighted by a number of teachers and is consistent with the CAPS curriculum principle requiring 'high knowledge and high skills' (South Africa DBE 2011: 4) to be set for each grade. Interviewed teachers implicitly highlighted the role of formative assessment in developing high knowledge and skills, as evidenced in the following quotes:

- *I mean when learners understand and pass well a piece of work they were doing,* [formative assessment] *indicates to me whether I achieved sufficient depth and scope.*
- *It is used to assess the deep understanding of the learners regarding the concepts taught.*

The third dimension of formative assessment was: tasks and activities that elicit evidence of student learning. Some teachers were clear regarding the kinds of formative assessment tasks that elicit evidence of learning. For example, one teacher explained that formative assessment is given orally and in written form. Another pointed out that:

> *Informal assessments in the form of classwork, home-works, and group work and formal assessment tasks e.g. tests, examinations and assignments and projects are requirement of the WCED (CAPS) nationally.*

Regarding the link between formative assessment and learning, understanding was implicit in the statement that: *Critical thinking is essential, and this is assessed via questioning techniques and worksheets and giving them many opportunities.* Another teacher indicated the use of formative questioning: *To see if they understood the lesson.* A third teacher said that formative assessment is used to: *Assess if the set of objectives of the lesson have been reached or if the skills have been acquired.* Lastly, one of the teachers explained that: *Formative assessments are yardsticks to assess where learners are in their ability to understand test questions asked and their ability to answer them.*

Teachers further indicated the value of these tasks for identifying the need for further scaffolding of learning. For example, one teacher stated that formative assessments: *Help me to come up with activities so that I can help to close the gap my learners have*. Another teacher explained the use of Bloom's Taxonomy to: *Oversee all learners' abilities and also to know where to assist or give support.* A third teacher explained that formative assessment enables a teacher to: *Check misconceptions … identify individual learning problems, design individual work to suit different learners*.

Teachers acknowledged that one of the reasons for formative assessment is for strengthening success in summative tasks. Another explained that she gives her learners tests frequently so that they can be familiar with written examinations with regard to both processes and environment, while two others argued that formative assessment builds confidence for summative assessment.

In the observed lesson, the summative task (research on human impact on biodiversity) called for the learners to use what they learned in class and take it further by looking for more information on this topic, and then to show by listing or stating, ways in which they could prevent biodiversity loss. All prior activities were aimed at preparing the learners for this research task, as was repeatedly pointed out by the teacher. These were opportunities for the teacher to elicit evidence of learning at each stage of the process, although the dimensions below illustrate that there were problems with the follow-through of these opportunities.

Regarding the fourth dimension of effective formative assessment, questioning strategies that elicit evidence of student learning, the teacher in the observed lesson raised questions as a direct way of checking student learning. However, the observation revealed that few learners were answering questions. Even though thought-provoking questions were asked, the waiting time for learners to engage and respond to the questions was not provided. Therefore, there was not much effective elicitation of evidence of student learning at the time of observation. The teacher indicated language-related problems with the questioning strategies at two levels. The first was a lack of reading ability, where she highlighted: *Reading to understand is different from just reading*. The second was: *To get students to understand the questions asked*.

The fifth dimension of effective formative assessment is the need for feedback to be given during questioning. As mentioned above, there was no evidence of such feedback in the observed lesson as the learners were not responding to the questions, and so it was hard to get insight into this challenge.

Regarding the sixth dimension of effective feedback, namely individualised descriptive feedback, the observed teacher's intention in the pre-lesson discussion was for the learners to have multiple submissions so that she could give them feedback and they could rework their project.

> *A plan is for them to bring their work, whether as a draft in their draft books or typed task so that I can give them feedback. The big challenge, as you know is time. I'm not sure if this will be possible to fit in, but it's a plan.*

Evidence of whether the above-mentioned plan for individual feedback on drafts was ultimately achieved was not available for this study. However, further insight into the challenges of individual feedback (both written and spontaneous engagement during class) were obtained from the interviews with the larger group of teachers. Two mentioned the difficulties associated with large classes (one teacher had more than 50 learners in the classroom). Another explained: *The classroom that is dedicated for science experiments is small and the floors have holes. This makes it impossible to check if all learners are working*. Additionally, as with the above-mentioned questioning strategies, teachers do not necessarily get the required work in from learners in order to respond. One teacher explained: *Learners absent themselves, not submitting tasks. This is a problem to give them feedback*.

Regarding the seventh dimension of effective formative assessment, namely self-assessment, the observed lesson did not elicit relevant evidence of this. This is to be expected as a teacher cannot use too many strategies in one lesson. However, from the interviews, a significant deepening perspective on the role of formative assessment in the meta-cognitive aspects of learning (Krathwohl 2002) came from teachers who saw formative assessment not only as a tool for the teacher, but also for the learner to track their own learning. This was evident in the explanation that: *These practices affect learning by challenging both the teachers and learners to focus on [the] learning and teaching process. Enabling learners to see where they are weak or strong*. Another teacher explained that: *Learners can be asked to mark their work and identify their mistakes and this can help them when writing the test*. A third teacher stated: *It is better when the learner explores and learns by himself*.

The eighth dimension of effective formative assessment, namely peer assessment, was not evident in practice from the single observation reported in this study. However, teachers demonstrated understanding of the opportunities offered by formative assessment for peer learning. The following quotes are indicative of this:

- *Peers appreciate being evaluated by peers especially when it is positive.*
- *Informal and formal assessment is done so that peer and group can be involved in the assessment.*

The ninth dimension of effective formative assessment, namely collaboration as a practice, was indicated by a teacher who explained: *The class is grouped heterogeneously and given a section of work to share with the class. This encourages them to help one another.* The fact that collaborative formative assessment is valued as a tool to promote inclusivity and participation was seen in the following quote: *Quality learning is when all learners engage and feel a sense of achievement*. The next quote also supports the perspective of the value of participation: *Quality learning is when learners are interacting. They are responding to the subject matter in a meaningful way, they ask questions. They are not afraid to give their opinions. They are learners that are not only recipients, they are participants*.

The tenth dimension of effective formative assessment is, 'using evidence to inform teaching and learning'. Interviewed teachers showed understanding of the role of formative assessment for increasing their own reflexivity. The first move for reflexivity is recognising that one's own teaching needs to be critically considered. One teacher demonstrated recognition of this by stating: *Sometimes you might think your teaching is good, but when you assess you get the opposite of what you expected*.

The second move in reflexivity is adjusting one's teaching accordingly, and a number of teachers indicated that they use formative assessment in this way. One teacher explained that assessment could inform future planning, with the statement that formative assessment is: *Very important in guiding one's planning*. Another said: *It is important to give formative assessment during discussion to really know if learners are with you or understand. This helps me to re-teach it*. A third explained the use of formative assessment to: *Correct my methods or strategies, improve on my approaches*. While a fourth claimed that formative assessment: *Helps me to adjust the method, approach or even to divert the whole lesson to something of greater importance they should know before the concept at hand*.

Thus, while teachers clearly showed evidence of understanding the importance of using formative assessment to improve their teaching, in the context of practice, there is a limitation for this ideal. As one teacher expressed it: *The CAPS pacing does not allow time for even get deeper to content. It does not give time to look back and re-teach concepts that learners don't understand*.

Conclusion

Overall, the interviews illustrated that teachers had a good understanding of the strategies for, and possibilities offered by, formative assessment practices. They demonstrated awareness of the value of formative assessment in guiding scaffolding practices by teachers; developing meta-cognitive skills through self-assessment; supporting collaboration; and encouraging inclusivity for all learners. Peer assessment did not receive much attention, although one teacher commented that it was 'appreciated' by learners. Significantly, three of the teachers highlighted the role of formative assessment in teaching towards summative assessment, and, notably, the only 'criteria for success' offered to learners in the observed lesson were those in the summative assessment task. This, and the repeated emphasis on the assignment, indicates an emphasis on assessment-driven learning.

While much of the understanding and practice of formative assessment is generic for all quality education, the study revealed that there is a need for developing higher order thinking for environmental learning. Equally, the study revealed that environmental learning can require lower order thinking if questions are posed simply, for example with questions requiring learners to 'list'. The study illustrated that if 'clarifying criteria for success' is important for formative assessment, then care should be taken that low, medium and high order thinking requirements are consistently presented between assessment tasks and associated rubrics, and also that criteria are logically ordered in rubrics. Teachers demonstrated an awareness of the need for developing low, medium and higher order thinking in their teaching as well as the role of formative assessment in developing critical thinking. Where higher order thinking is required, a more nuanced perspective on higher order thinking, such as Resnick's (1987), may be useful for guiding teachers' formative and summative assessment practices.

The teachers demonstrated an understanding of the value of teacher feedback in formative assessment, both during questioning in class and in written form (teacher-learner engagement), as well as learner-learner collaboration. However, four significant structural problems highlighted why this is not always successful. These were: time limitations in a full CAPS curriculum; language difficulties impeding learner understanding of questions during classroom questioning; exceptionally high numbers in classrooms; and learner absenteeism (failure to submit work). These problems need to be addressed especially if higher order thinking is to be achieved among learners.

The study highlights that formative assessment is a fundamental part of developing higher order cognitive skills, and fundamental to critical thinking and problem solving in environmental learning. Generally, teachers have a good understanding of formative assessment, but help with implementation strategies appears to be necessary in teacher professional development. Additionally, an over-emphasis on assessment-driven learning may over-shadow a broader perspective of what it means 'to learn' in a classroom. Furthermore, socio-economic, organisational and language problems, in both curriculum and schools, need to be addressed if higher order thinking is to be enabled in classrooms.

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SECTION D

Teacher professional development for environment and sustainability learning

CHAPTER 15

Teacher Professional Development in Environment and Sustainability Education

Zintle Songqwaru and Sirkka Tshiningayamwe

Introduction

No education policy, no matter how well designed, can succeed without a teacher (Sanyal 2013). Additionally, a change in policy alone is not sufficient to improve an education system (Livingstone 2012), no matter how well meaning. The quality of teachers' professional practices determines to some extent the quality of teaching and learning in the schooling sector. Teacher quality, and not only teacher supply, is important for learning; hence, teacher professional development should be a priority in all education and development strategies (Unesco 2015a).

According to Villegas-Reimers (2003), professional development for teachers is a lifelong process that begins with initial teacher training and continues until teachers retire. Initial teacher education cannot cover all the knowledge that a teacher will need throughout their teaching career (Unesco 2015a). The development of professional practices is a continuing process that lasts for the duration of one's teaching career (South Africa DBE & SACE 2008). Continuing professional teacher development is essential for upgrading and updating teachers because the rate of social and educational change makes initial teacher training an inadequate basis for long-term professional competence (Luneta 2012). Teachers need to constantly update their knowledge and skills to be relevant to changing contexts. Continuing professional teacher development is therefore an essential component of any education system that aims to improve the quality of teaching and learning.

It is important to note that teacher professional development is not an event but a process (Harwell 2003). The process of learning and transformation in teaching practice resulting from professional development is time-consuming (Villegas-Reimers 2003). Teachers and other professionals do not change overnight. Any form of professional development requires a long-term, gradual progression to change.

There is no single form of continuous professional development programme that is appropriate for all teachers. What is required is an optimal mix of activities that suit particular teachers at different stages in their individual development (Guskey 2003). A 'one size fits all' approach to professional development does not work. Teachers tend to be at different stages of their development at different times in their careers, and these stages need to be considered because teachers' needs and dispositions may vary during the different stages (Villegas-Reimers 2003).

Significantly, with reference to the South African context, the Department of Basic Education has observed that:

> Much professional development is still organised as isolated and onetime trainings, lacking a coherent strategy, monitoring and follow-up. Research has indicated that these one-off initiatives often fail to have durable effects on teaching and learning. Research also stresses the importance of working together as a cornerstone of effective professional development. (South Africa DBE 2015: 4)

Irrespective of which approaches are used to develop teachers professionally, there should also be a focus on aligning programmes with changing societal needs and challenges, such as sustainable development concerns. Internationally, in the field of Environmental Education or Education for Sustainable Development (ESD), many researchers have investigated professional development models used in addressing teacher challenges related to environment and sustainability education. A key finding emerging from these studies in 2011 was the need for a national synergistic effort to strengthen the systemic impact of Environment and Sustainability Education teacher education efforts (Lotz-Sisitka 2011). This led to the conceptualisation and implementation of the Fundisa for Change Programme (Fundisa for Change Programme 2013; Songqwaru 2019). Since the establishment of the Fundisa for Change programme in South Africa in 2011, researchers have explored similar issues within the Fundisa for Change programme itself. It is with this more recent focus in mind that this chapter provides literature on professional development in environment and sustainability education and includes case examples of research that has been done in the Fundisa for Change programme, exploring effective professional development models as well as how these models can be evaluated.[1]

1 Earlier synthesis studies on professional development in Environment and Sustainability Education Teacher Professional Development can be found in Janse van Rensburg and Mhoney (2000), Reddy (2011), Lotz-Sisitka (2011), and Schudel (2017). These studies provide wider background and complementary texts to this chapter.

Teacher professional development modalities

Researchers have different views on what effective professional development is. From the United Kingdom, Guskey (2003: 749) asserted that effective professional development requires that teachers work together, reflect on their practice, exchange ideas, and share strategies. Desimone (2009), writing from the United States, observed that professional growth of teachers can best be understood within the social contexts of their work. Writing from the same context, Darling-Hammond, Wei, Andree, Richardson and Orphanos (2009) argue that the most effective professional development is sustained, intensive, ongoing, connected to practice, and addresses the teaching of the specific curriculum content. Mokhele and Jita (2010) from South Africa observed that in order for professional development to be effective, it has to be aligned to teachers' personal circumstances and motivations.

Professional development for environment and sustainability education needs to be contextual, responsive, emergent, participatory, critical and praxiological (Robottom & Kyburz-Graber 2000; Janse van Rensburg & Mhoney 2000; Reddy 2011; Schudel 2017). This allows teachers opportunities to be active, reflective and responsive within their own teaching practice (Fundisa for Change Programme 2013). Such professional development enables teachers to be not merely passive recipients of others' expertise, but creators, disseminators and preservers of knowledge in their own right (Wood 2007). Teachers are intellectuals who can think, inquire and conceptualise their own knowledge (Wood 2007; Janse van Rensburg & Mhoney 2000; Reddy 2011; Schudel 2017).

There are different modalities of professional development. Among these are: seminars, conferences, workshops, coaching, mentoring, formal courses and collaborative models (Stoll et al. 2006; Mizell 2010; Darling-Hammond et al. 2017). Professional development also happens in informal contexts such as conversations with colleagues, independent reading and research (Mizell 2010). Seminars, workshops and conferences are traditional models of professional development (Darling-Hammond et al. 2017). These modalities are grounded in the assumptions that the purpose of professional development is to convey knowledge to teachers (Vescio et al. 2008). Most of these professional development activities last for only a few hours. They are generic, discuss one or two structured topics and are disconnected from teachers' classroom activities (Darling-Hammond et al. 2009). Traditional models of professional development usually do not allow teachers time to reflect on their classroom practice and thus have a minimal effect on teachers' practice and learners' achievements (Wood 2007). More collaborative professional development models represent a fundamental shift away from the traditional models, by assuming that teachers are not only implementers of others' ideas but also creators of knowledge, and that practice is a central aspect of this knowledge co-creation process for teachers (Wood 2007; Janse van Rensburg & Mhoney 2000).

Collaborative models allow for ongoing, sustained professional development activities and enable teachers to focus on one issue at a time in detail (Stoll et al.

2006). These models recognise the importance of teachers' agency (South Africa DBE 2015; Schudel 2012). Teachers who participate in collaborative models have greater confidence, develop enthusiasm for collaborative working, greater commitment to changing practice, and are willing to try new things (Darling-Hammond et al. 2017). The lesson study is an example of a collaborative professional development model (Lewis & Hurd 2011). This approach continues to be a paradigm shift for most educators outside Japan. The lesson study model has been experimented with in some parts of South Africa (i.e. the Western Cape, Mpumalanga and Free State provinces) to help new teachers (especially in Maths and Science) begin their journey, and experienced teachers to deepen their work (Mokhele & Jita 2010). This approach provides teachers with a learning structure to reflect on their own practice, build a shared knowledge base, foster intrinsic motivation and build a culture that emphasises continuous improvement and collaboration (Lewis & Hurd 2011). Lewis and Hurd point out that the lesson study model allows teachers to seek answers from one another, from specialists, from research and from carefully studying their learners during lessons. Unlike other professional development models, these models are not 'one size fits all'. They are usually teacher directed, teacher driven and teacher orientated. Professional Learning Communities (PLC) is one of the collaborative professional development models being promoted in the South African policy landscape and has been explored in some of the Fundisa for Change research, as discussed later in this chapter and elsewhere in this book (see Tshiningayamwe and Lotz-Sisitka, Chapter 16 and Thomas and Songqwaru, Chapter 17).

Teacher professional development in environment and sustainability education

Environmental issues and risks are global concerns experienced worldwide (Le Roux & Ferreira 2005). The 2016 Global Education Monitoring (GEM) Report (Unesco 2016) states that the planet is in a dire state due to overexploitation of natural resources, loss of biodiversity and a rise in carbon levels leading to climate change. There have been various responses at global, regional and national level to the environmental challenges facing us. Policy, legislation, agreements, treaties and conventions have been established to address environmental degradation in an attempt to mitigate, combat and reverse some of the environmental threats. Education programmes have also been developed in formal and informal sectors to address these issues and risks. There is an urgent need for all sectors of society to work together to address environmental challenges and create a sustainable world (McKeown & Hopkins 2014).

In 1998 a call was made to the United Nations Educational, Scientific and Cultural Organization (Unesco) to develop guidelines for reorienting teacher training to address sustainability in education (Unesco 2005). In 2013, the United Nations Economic Commission for Europe (UNECE) developed guidelines that support the empowerment of educators for a sustainable future. The guidelines share principles that underpin an educational change process that reflects the ethos of competence in ESD

(UNECE 2013). One of the principles resonates with the Fundisa for Change teacher professional development programme as it speaks about understanding, and building on, the context. This principle calls for the utilisation of existing structures and making use of ongoing processes and initiatives.

Subsequent to the UNECE guidelines, the Global Action Programme was launched with an emphasis on building the capacity of educators. The Global Action Programme is a post-2015 development agenda, a follow-up to the Decade of Education for Sustainable Development (DESD) that recognises that sustainable development cannot be achieved by political agreements, financial incentives or technological solutions alone (Unesco 2014). GAP Priority Area Three calls for the integration of Education for Sustainable Development (ESD) into pre-service and in-service teacher education programmes to increase the capacities of educators and trainers for the delivery of ESD (Unesco 2014).

At the end of 2015 there was a launch of seventeen global Sustainable Development Goals (SDGs). Goal Four of the SDGs focuses on quality education which seeks to ensure that all learners acquire the knowledge and skills needed to promote sustainable development. To achieve this, teachers need to be trained to use appropriate and relevant teaching and learning methods and relevant content that meets the needs of all learners (Unesco 2015b). Educators are viewed as change agents who can deliver the educational responses needed to achieve SDGs (Unesco 2017). In the southern African region a programme called 'Sustainability Starts with Teachers' has been established by Unesco to support teacher educators to integrate ESD into teacher education (www.sustainabilityteachers.org).

International imperatives have shaped and influenced how South Africa has integrated environment and sustainability education in the education sector. In 1995, a policy initiative on the integration of environmental education was tabled in South Africa, which led to the integration of environmental education as a principle of the 1995 White Paper on Education and Training (RSA 1995), which was one of the first post-apartheid policies to guide the restructuring of the education and training system in South Africa. This policy called for the integration of environmental education into all levels and phases of the education sector, including teacher education. In the schooling system this call was translated into a guiding principle that continues to underpin the national school curriculum. The principle highlights a relationship between social justice, human rights, a healthy environment and inclusivity (South Africa DoE 2002). Integration of environment and sustainability education into the schooling sector has implications for how teachers are supported to engage with this kind of education. Ongoing international policy developments and reviews, and new strategies on integration of environment and sustainability education, have continued to influence South African national policies and strategies, as well as the implementation of environment and sustainability education in both formal and non-formal education sectors. However, due to challenges related to limited resources and educators' capacity, implementation of environment and sustainability education has not been fully successful. Different interventions have been put in place to address these challenges. Among other initiatives, Fundisa for Change was implemented to capacitate teachers with regard to environment and sustainability education, in order to enhance the systemic impact of programmes orientated towards supporting implementation of environment and sustainability content in the school curriculum. The Fundisa for Change programme continues with various other forms of support with this in mind. The Department of Higher Education and Training is currently revising the teacher education minimum qualification requirements to integrate ESD as a cross-cutting concern for teacher education, which offers an important platform for taking the Fundisa for Change teacher education work forward in South Africa.

Teacher professional development in environment and sustainability education in South Africa

Stevenson (2007) argues that collaborative teacher professional development models are recommended for environment and sustainability education. He observes that teachers have their own ideas that emerge from experience, circumstances and understanding of teaching and learning, a point also made by Janse van Rensburg and Mhoney in 2000 in the South African Learning for Sustainability project. There have been many initiatives in South Africa which aimed at supporting teachers in environment and sustainability education in the post-apartheid period. The Learning for Sustainability project was piloted in the Gauteng and Mpumalanga provinces between 1997 and 2000 (Janse van Rensburg & Lotz-Sisitka 2000). The project followed a three-pillar approach of integrating environmental education in the curriculum: teacher development, curriculum development and materials development. The Learning for Sustainability project was shaped by influential educational theories such as learner-centred education, critical pedagogy and reflective practitioner theories (Janse van Rensburg & Lotz-Sisitka 2000).

In the year 2000, the National Environmental Education Project for General Education and Training (NEEP-GET) expanded upon the Learning for Sustainability Project, taking it into all nine provinces (NEEP-GET 2004). NEEP-GET was established by the South African Ministry of Education to support professional development of subject advisors and teachers. NEEP-GET also aimed at strengthening environmental learning in the South African curriculum, within an outcome-based, learner-centred curriculum framework, which was the policy of the national government at the time (NEEP-GET 2004). Professional development processes and programmes were structured around a spiral, cluster-based model (Du Toit & Sguazzin 2000; Lotz-Sisitka 2004). NEEP supported the emergence of a draft Education for Sustainable Development Strategy in South Africa (Lotz-Sisitka 2011). In the NEEP-GET synthesis report, Lotz-Sisitka (2004) discussed the key outputs of the project as well as achievements and challenges. One of the outputs she highlighted was the implementation of teachers' professional development in environmental education within which she observed the following achievements:

- Improved understandings of environment and environment in the curriculum;
- broader exposure to, and knowledge of available teaching and learning support materials for environmental learning;
- a more in-depth understanding of the contextual nature of environmental issues, and contextual approaches to lesson plans; and
- improved understanding of active learning processes. (2004: 13)

However, despite the above gains, the project was not able to develop an in-depth focus on the environmental aspect in the learning areas, and there is still an issue of superficial interpretations of environmental knowledge in theses learning areas (Lotz-Sisitka 2004: 13). This is a point made in earlier research in the Learning for Sustainability Project (Janse van Rensburg & Lotz-Sisitka 2000). Lotz-Sisitka recommended further support for teachers in environmental learning to ensure that learners are not exposed to superficial knowledge on environmental issues, a noticeable trend in South Africa over the years. In more recent work, Lotz-Sisitka (2011) acknowledged the good practices and positive influence of the above-mentioned projects (Learning for Sustainability Project and NEEP-GET) on the curriculum. She emphasised, however, that very little has been achieved in ensuring that environment and sustainability issues are consistently and coherently integrated into teacher education (2011: 33). Due to inadequate capacity to make a wide systemic impact, achievements were noted mainly at the pilot level. Fundisa for Change was established in 2011 as a response to this (Lotz-Sisitka 2011). Since then, research has been conducted on how Fundisa for Change has provided professional development to teachers on environment and sustainability education (Schudel 2012; Songqwaru 2012; Tshiningayamwe 2016; Thomas 2019; Songqwaru 2019; Nkhahle 2021; Heath 2021). Details of some of these studies are elaborated in other chapters of this book (see Songqwaru, Chapter 19; Tshiningayamwe and Lotz-Sisitka, Chapter 16; Thomas and Songqwaru, Chapter 17; Heath and O'Donoghue, Chapter 5).

Below are elaborations on two of the studies conducted to explore how Fundisa for Change enhanced teachers' professional development.

Professional Learning Communities (PLC) as a potential model for teacher professional development in environment and sustainability education

PLCs are 'teachers who work collaboratively to reflect on practice, examine evidence about the relationship between practice and student outcomes, and make changes that improve teaching and learning for the particular students in their classes' (McLaughlin & Talbert 2006: 3–4). Fulton, Doerr and Britton (2010) unpacked the concept of PLC by noting that *professional* means engaging educators in the development of their professional practice; *learning* means focusing on both the learning of the educators and of the students; and *community* requires common vision, goals, purposes and a shared sense of trust, as well as collaborative work (p. 6). Reflected in these definitions of PLCs is that the focus of learning is not on individual teachers' professional learning but rather on professional learning within the community context. The community aspect of a PLC enables collegial support for individuals (Stoll et al. 2006). Salomon's (1993) notion of distributed cognition presumes that members of the community take responsibility for their contribution to the group and to individual learning processes.

Reviews of the PLC literature conclude that PLCs support teachers' acquisition of new knowledge and skills, thus improving teachers' content knowledge and professional practice (Stoll et al. 2006; Vescio et al. 2008). PLCs provide spaces for teachers to raise questions about their teaching, discuss content knowledge, and experiment with diverse models of students' problem-solving methods, resulting in improved teaching practice. Vescio, Ross and Adams (2008) pointed out that teachers in PLCs share successful teaching strategies, develop new approaches to shared problems and share the specific subject content knowledge. Tshiningayamwe and Songqwaru (2017) conducted a review of PLCs and collaborative models of professional developments in Namibia and South Africa. In their review, they noted that PLCs have proven to be effective models of teachers' professional development. Therefore, for effective ESD, PLCs should be considered in the planning of teacher professional development initiatives. This will support teachers to address challenges of quality teaching, learning and sustainable development issues.

To pilot the concept of PLCs in Fundisa for Change, a study explored the conversion factors, functionings (valued doings and beings), agency and structures in Professional Learning Communities with regard to Life Sciences teachers' biodiversity knowledge (Tshiningayamwe 2016). The teachers' valued beings and doings, as well as conversion factors associated with these beings and doings, were discussed within the conceptual framework of the capability approach using three PLCs in South Africa (see Tshiningayamwe and Lotz-Sisitka, Chapter 16; Thomas and Songqwaru, Chapter 17). The PLCs involved in this study were course initiated and were positioned in the Fundisa for Change programme. To illuminate constrained capabilities and how, and to what extent, the Life Sciences teachers' empirical actions are related to these, the concepts of the capability approach were underlaboured with critical realism's causal view of human action (Tshiningayamwe 2016). A critical realist theory of causation was useful in explaining how the teachers' valued beings and doings, conversion factors and capability sets can be partly accounted for via an understanding of underlying mechanisms that are generative of events and empirical experience. This is similar in some ways to the work of Brundrit (see Chapter 18) which shows how contextual dynamics filter teachers' abilities and agency for change.

Tshiningayamwe (2016) reported four main functionings valued by teachers: subject content knowledge; teaching practices; assessment practices; and use of teaching and learning support materials. These functions were also reported by Thomas (2019), who further explored how PLCs in the Fundisa for Change programme contribute to the development of teachers' capabilities and achievement of valued functionings related to teaching environmental education (see Chapter 17). Tshiningayamwe discussed these valued functionings in light of the beings and doings in the PLCs and the underlying mechanisms related to teachers' biodiversity teaching. Conversion factors associated with the teachers' valued beings and doings were discussed in line with the capability approach's environmental, social and personal conversion factors (Tshiningayamwe 2016). The study found that most of the conversion factors within the PLCs and the Fundisa for Change professional development programme (such as good facilitation, collaborative learning space, individual teachers' capabilities, teaching and learning support materials, and policy documents) were enablers to the teachers' capabilities for biodiversity teaching, and thus enhanced teachers' knowledge for biodiversity teaching. The study further found that teachers realised some of their achieved functionings in their actual teaching of biodiversity content in the Life Sciences curriculum (see Chapter 17).

Evaluating environment and sustainability education teacher professional development programmes

A re-thinking of the process of professional development and how programmes are evaluated can assist in addressing some of the challenges that indicate that teacher professional development programmes are inadequate for improving the quality of education, particularly in South African schools (Bertram 2011; Mokhele & Jita 2012).

According to Haji, Morin and Parker (2013), the acknowledgement of the minimal effect of professional development programmes on intended outcomes should lead to a conclusion that either little of what is done makes a difference, or that current programme evaluation approaches are inadequate to capture what is of interest. It thus seems that questions asked are inadequate to reveal the full scope of what should be focused on to improve professional development programmes.

To extend our knowledge of teacher education programmes, Borko (2004) suggested that focus should be on four key elements that make up any professional development system, namely: the professional development programme; the teachers who are the beneficiaries of the programme; the programme facilitators; and the context in which the professional development occurs. Additionally, there is a need to look at how each element works in relation to the others. Fullan (2007) argued that professional development programmes sometimes fail to give teachers the support they need partly because of the assumptions of programme designers and implementers about how change in practice occurs. What needs to be changed often varies inversely with knowledge about how to work through a process of change. Programmes are conceptualised based on professional experience, insights and beliefs about interventions in a particular field (Birckmayer & Weiss 2000). Surfacing programme assumptions can assist in explaining why certain professional development programmes, and their variants, work in the ways they do to produce the desired results (Desimone 2009).

It has been noted in the past that there are two constraints under which environmental education programmes operate: limited financial resources, and the criticism that environmental education is ineffective (McDuff 2002) in the face of the challenges it is aiming to address. According to Scott and Gough (2003), evaluations of environmental educational programmes tended, at that time, to focus on measuring the effectiveness or quality of a programme, and participants' knowledge after attending the programme.

McDuff (2002) suggested that a needs analysis be conducted prior to designing both training and programme evaluations. He reasoned that this would enable programme designers to design programmes that respond to the needs of the participants, and the evaluation would therefore focus on how and whether those needs were met or not. Another suggestion from Rovira (2000), also writing around the same period of approximately 20 years ago, is that social differences need to be taken into account when evaluating an environmental education programme. She argued that the social context determines the potential for environmental education programmes to effect actual change of attitudes and behaviour in participants, a point that was made by Janse van Rensburg and Lotz in 2000 when they argued for contextual profiling in environmental education evaluation research.

Zint, Dowd and Covitt (2011: 471) stated that evaluations are critical to the success of individual environmental education (EE) programmes and can contribute to advancing the field of EE. They argued that when evaluation results are analysed and synthesised they can add to the body of knowledge regarding the benefits of environmental education and effective environmental education practices.

While these important points were made many years ago, what has emerged is that environmental education literature lacks a systematic approach to the development and evaluation of environmental education programmes (Riemer et al. 2014). According to O'Donoghue (1986: 20–21), evaluation in environmental education, when viewed as an emergent process of facilitating change, should have the following characteristics:

1. Context-specific and grounded in action.
2. Participatory and collaborative without necessarily being directed by an outside researcher or evaluator.
3. Emergent as a continuous process wherein new constructs illuminate and stimulate further inquiry.
4. Simple, evolving towards increased sophistication.
5. Theory-driven and seeking to illuminate and understand rather than merely to provide evidence of worth and success.

O'Donoghue (1986), more than twenty years ago, advocated for rejection of a limited conception of evaluation as a means of measuring outcomes and instead called for an integrated critical approach to evaluation within a process of social change.

More recently, Tao (2012) noted that evaluations of environmental education programmes have been challenged by a lack of clearly articulated programme objectives. This critical step is essential for identifying outcomes and structuring an appropriate evaluation plan. A related challenge identified is a misalignment between the programme's stated objectives and actual programme activities. Goals and objectives should be explicitly linked but what has been observed is that there are environmental education programmes that either have not identified their programme objectives, or have incorporated activities not aligned with programme objectives. There tends to be a mismatch between long-term outcomes of the programme and actual programme activities. Tao (2012), drawing on critical realism, suggested that evaluations of environmental education programmes can assist with identification of the underlying assumptions framing the programme, to provide clarity for programme stakeholders in aligning their short and long-term goals with programme activities.

Early proponents of theory-based evaluation, Karachi, Abbott, Catalano, Haggerty and Fleming (1999: 713) noted that:

> A program evaluation enhances its utility by examining the theoretical basis of the program and the intervening and contextual factors that mediate the relationship between the program and the ultimate outcome. Thus, information generated from this type of evaluation can improve intervention conceptualization while it contributes to theory development and validation.

Arguably, without surfacing programme assumptions (which affect the delivery of a programme), even if it is sound, the programme cannot be fully understood. Coryn, Noakes, Westine and Schröter defined a theory-based evaluation as

> any evaluation strategy or approach that explicitly integrates and uses stakeholder, social science, some combination of, or other types of theories in conceptualizing, designing, conducting, interpreting, and applying an evaluation. (2011: 201)

A theory-based approach to evaluation has potential to benefit environmental education programmes (see Songqwaru, Chapter 19). A programme's articulated theory of change would enable programme stakeholders to observe the synergy (or lack thereof) between articulated assumptions and programme activities, as was shown in recent evaluations of the Fundisa for Change programme (Songqwaru 2019; Mukute & Mandikonza 2020) and other environmental learning programmes (such as Enviro Champs).

Astbury and Leeuw (2010) stated that theory-based evaluations unpack programmatic 'black boxes' and explain how and why programmes work (or fail to work) in different contexts and for different programme stakeholders. A 'black box' evaluation refers to the practice or tendency of focusing only on the effects of a programme without attending to how the effects were produced. A focus on the outcomes of a programme, which excludes contexts and assumptions (beliefs, theories) held by all the stakeholders, is inadequate to account for the complexities that exist in educational programmes. It also fails to generate meaningful understanding of factors that lead to programme success or failure, as well as the interaction of these factors in open systems (Haji et al. 2013).

The black box, according to Weiss (2000), can have many theories (assumptions) for the same programme which do not get to be examined. Weiss argued that there are many ideas that implementers, stakeholders and concerned parties have about how a programme should work and these 'theories' need to be brought to light; this is important for contextualisation of programmes, as is shown in Chapters 17, 18 and 19.

Although a theory of change framework integrates both a programme and an implementation theory, it predominantly engages with uncovering a programme's implementation theory (Blamey & Mackenzie 2007). A realist evaluation approach is needed to enable engagement with a programme's programme theory, as is also shown in Chapter 19 (Songqwaru) and the work of the Enviro Champs.

An implementation theory describes the steps to be taken in the implementation of a programme. Programme theory refers to the mechanisms that mediate between the delivery and receipt of the programme and the emergence of outcomes in a particular context (Weiss 1998).

A realist evaluation starts with articulating the initial programme theory, by identifying the mechanisms that are likely to operate, the contexts in which they might operate, and the outcomes that will be observed if they operate as expected. According to Dalkin, Greenhalgh, Jones, Cunningham and Lhussier (2015), mechanisms are what generate observed outcomes. Mechanisms in realist evaluation are a combination of resources offered by the programme and participants' reasoning and responses to bring about intended programme outcomes. A Context-Mechanism-Outcome (CMO) framework is used in realist evaluation to unpack a programme's theory (Pawson & Tilley 1997; see also Chapter 19).

Programme resources, that is mechanisms, may be material, cognitive, social, and/or emotional. Programmes work when these resources resonate with programme participants (Pawson 2003). According to Westhorp (2012), participant reasoning includes preferences, norms and beliefs, and these underpin decisions that lead to particular actions, which in turn enable or constrain outcomes. Partly, the success or failure of programmes is due to the reasoning and personal choices of different participants (Pawson et al. 2005).

Cheyne et al. (2013) stated that the context in which a programme is implemented shapes the mechanisms and the outcomes. Hence a programme evolves when introduced into different contexts, as context tends to influence what people do and how they will act. When a programme is implemented in another context, there are inevitably differences in infrastructure, institutions, stakeholders and participants. Consequently, some critical causal configurations on which programme success depends might be broken by the shift. A programme can still obtain the same objectives in different sites but by different means (Pawson 2001). Pawson and Manzano-Santaella (2012) stated that there will always be multiple contexts, for example, individual, institutional and infrastructural features, that condition the action of the mechanisms.

Pawson and Tilley (1997) argued that all programmes are conceptualised and implemented into pre-existing social contexts. This is also shown by the work of Brundit and Schudel in Chapter 18, Thomas and Songqwaru in Chapter 17, Tshiniganyamwe and Lotz-Sisitka in Chapter 16 and Heath in Chapter 5. Context has an influence on the success or failure of a programme. Pawson and Tilley (1997) listed four contextual components that may determine whether the new ideas will lead to participants making the programme work or not: (i) the individual capacities of facilitators and participants, (ii) the interpersonal relationships created between them, (iii) the institutional balance and (iv) the wider infrastructural systems.

The four contextual factors that shape the implementation of social programmes were further elaborated on by Macfarlane, Greenhalgh, Humphrey, Hughes, Butler and Pawson (2011) in the following way:

- Individual capabilities are defined as values, roles, knowledge and purposes of programme stakeholders to take the programme forward.
- Interpersonal relationships supporting the programme include communication, collaboration, network and influences that stakeholders have in the social systems where the programme is embedded.
- Institutional settings, informal rules of engagement, culture within the programme, leadership, resource allocation, and local priorities. Leadership that provides strategic guidance and management of the programme.
- The infrastructural system is the political support a programme receives.

The work of authors in this section of the book also points to the historicity of these contextual factors and how this shapes contemporary contextual dynamics, a point that has been highlighted in many professional development studies in South Africa (see Janse van Rensburg & Mhoney 2000; Lotz-Sisitka 2011; Reddy 2011; Schudel 2017). This adds to the complexity of the setting in which professional development is implemented and evaluated (see Reddy 2011).

Recommendations and conclusion

This chapter has revealed that professional development programmes can be an important conversion factor that enables the expansion of teachers' environment and sustainability education in ways that have the potential to reshape teachers' classroom practices. The chapter recommends that teachers' professional development programmes should:

- Promote subject content discussions, as well as group and individual learning.
- Create supportive conditions that will expand teachers' capabilities in teaching environmental content.

- Explicitly take into account teachers' valued functionings and conversion factors that can enable teachers to develop their professional capabilities.

A theory-based approach to evaluation enables evaluators to assess not only whether a programme has worked or not, but also why. In this regard, it is important to identify contexts that condition the operation of programme theories. Insights gained from a theory-based approach to evaluation contribute theoretical knowledge on transferrable lessons about programme implementation theory and programme theory

Programme evaluation should lead to an understanding of the mechanisms that translate intention into action, as well as surface the programme mechanisms and contextual factors that could lead to programme outcomes. The same mechanism can have different degrees of responses with participants, depending on the contextual dynamics. This does not necessarily mean that the desired outcomes are not achieved, but that they are achieved to varying degrees by different participants, influenced by contextual dynamics. It is therefore critical to identify supportive mechanisms and consider the contextual dynamics carefully for various groups and individuals to ensure maximum benefit of professional development programmes. This can help to develop a body of theory that is backed up by practical experience on what works for whom in what conditions. Insights from a theory-based approach to evaluation provide an organising framework which abstracts a particular set of conditions from a programme (in this case, Fundisa for Change), which can then be applied to new programmes. A programmes's theory of change can thus be developed further via this contextually iterative and responsive approach. Through this process, a progressive understanding can be developed, and transferable knowledge achieved.

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CHAPTER 16

Enhancing Capabilities of Life Sciences Teachers: Professional Development, Conversion Factors and Functionings in Teachers' Professional Learning Communities

Sirkka Tshiningayamwe and Heila Lotz-Sisitka

Introduction and context

South Africa is rich in biodiversity and is home to about 95 000 known species (South Africa DEA 2014; SANBI 2019). Yet, compared to other southern African countries, the country has a high number of threatened species (Driver et al. 2012). Approximately 12 million South Africans depend on the natural environment to meet their needs. Among other factors, overharvesting of biological resources is one of the main causes of biodiversity loss in the country (South Africa DEA 2014; SANBI 2019). In line with assessment of biodiversity reports, Unesco (2018) notes that biodiversity loss is a global phenomenon. Emphasis in these reports is that over 7 billion people in the world rely on biodiversity to maintain and enhance their well-being. The realisation of biodiversity conservation as a global concern has resulted in various international conventions, policies, legislation and educational programmes that foreground biodiversity (Shava & Schudel 2013). Aligned with international trends, South Africa also has national policies and legislation aimed at protecting biodiversity. Among these is the National Environmental Management Biodiversity Act which introduces a legal framework for governing sustainable development in the country, and includes a clause for all training and education programmes to integrate education for sustainable development (RSA 1998). Thus, like many other countries in the world, South Africa has incorporated biodiversity components in its ongoing curriculum reforms including in the Curriculum Assessment Policy Statement (CAPS).

An analysis of the CAPS curriculum clearly shows that Life Sciences as a subject covers a considerable amount of biodiversity-related elements (South Africa DBE 2011a). However, due to inadequate pedagogical content knowledge of new curriculum areas such as biodiversity among Life Sciences teachers, the implementation of this area of the curriculum lacks systemic coherence (Songqwaru 2012). Efforts have been made to support teachers to enhance their subject knowledge for effective implementation of environmental learning by including biodiversity content in the curriculum; however, very little has been achieved in ensuring that environmental issues such as loss of biodiversity and climate change are consistently and coherently implemented in the school curriculum (Lotz-Sisitka 2011; cf. Mmekwa and Schudel, Chapter 3 and Lotz-Sisitka and Mandikonza, Chaper 6). Many professional development initiatives have been described as one-off trainings, often with little relevance to the needs of teachers (South Africa DBE 2015). For professional development programmes to be successful, they have to be personally meaningful to the participating teachers, and should be aligned with their needs (Darling-Hammond 2008). In response to this and in line with international trends, South Africa calls for collaborative learning as a main strategy to support the ongoing professional learning and development of teachers. This is through providing support systems that promote the establishment of Professional Learning Communities (PLCs) (South Africa DHET & DBE 2011; cf. Thomas and Songqwaru, Chapter 17). PLCs aim to transform teachers from being subjects in their learning spaces to becoming educational change agents (South Africa DHET & DBE 2011). In South Africa, PLCs are a relatively new policy concept; thus, limited research exists on how PLC approaches contribute to teachers' professional development.

In line with the South African policy landscape, Fundisa for Change aims to pilot and develop the concept of PLCs within the context of environmental learning (Lotz-Sisitka 2011). Using the capability approach and the critical realist theory of causation, this chapter aims to answer the following question:

> How can a continuing professional development programme act as a conversion factor that expands and/or constrains the conversion factors and functionings in teachers' PLCs related to the teaching of biodiversity?

The chapter explores how PLC approaches can enhance Life Sciences teachers' capability for teaching biodiversity content in the curriculum. This has the potential to contribute to the South African policy landscape on teacher professional development and related global policies such as the Education for Sustainable Development 2030 Agenda (Unesco 2020), as well as transforming and strengthening teachers' practices.

Professional Learning Communities

PLCs are defined as 'on-going groups ... who meet regularly for the purpose of increasing their own learning and that of their students' (Lieberman & Miller 2008: 2). PLCs comprise 'teachers who work collaboratively to reflect on practice, examine evidence about the relationship between practice and student outcomes, and make changes that improve teaching and learning for the particular students in their classes' (McLaughlin & Talbert 2006: 3–4). In the South African context, PLCs are defined as 'communities that provide the setting and necessary support for groups of classroom teachers to participate collectively in determining their own developmental trajectories, and to set up activities that will drive their development' (South Africa DHET & DBE 2011: 14). Examples of PLCs are: teacher learning communities, teacher networks, and critical friend groups. Reflected in these definitions of PLCs is that the focus of learning is not on individual teachers' professional learning but rather on the professional learning within the community context. This communal conception of learning, according to Sfard (1998), assumes an inextricable bond with identity formation. The community aspect of a PLC enables collegial support for individuals (Stoll et al. 2006). Borko (2004) claims that professional development is situative and that outcomes are influenced by personal and group processes.

PLCs are grounded in adult learning theories aligned with socio-cultural learning, grounded in the work of Vygotsky (1978). Through Vygotsky's theories, the idea of scaffolding was identified by Bruner (1993), which implies that people learn at a much higher level when support for their learning gap is provided through peer interaction, or the contribution of a more knowledgeable other (Vygotsky 1978). In the case of PLCs, this suggests that Life Sciences teachers must understand their own acquisition of biodiversity knowledge, and its relationship within the social context, in order to enhance their knowledge. This requires a forum for teachers to construct biodiversity knowledge through a continuous cycle of learning rooted in reflection, social collegial interaction, professional dialogue, and processes that can provide scaffolding for improved knowledge for teaching (Stoll et al. 2006). In this chapter, the focus is on a course-initiated PLC and explores the potential of this approach for enhancing teachers' biodiversity knowledge. Of particular interest are PLCs that operate outside the school and consist of Grade 10–12 Life Sciences teachers from various schools in one district. This is motivated by the model used by the Fundisa for Change programme. Fundisa for Change support to teachers is subject, grade and environmental-issue specific (Fundisa for Change Programme 2013). PLCs provide spaces for teachers to raise questions about their teaching, improving teachers' content knowledge, teaching strategies and professional practice (Stoll et al. 2006). This implies that Life Sciences teachers can use PLCs to collaborate on their knowledge of biodiversity and experiment with new teaching methods that are encouraged for biodiversity teaching. This has the potential to improve learners' knowledge of biodiversity and, ultimately, contribute to the conservation of South Africa's biodiversity.

Theoretical framework

The study used the capability approach and critical realist theory of causation. The capability approach is developed by Amartya Sen. Among the core concepts of the capability approach are functionings, capabilities and conversion factors. Functionings are 'the various things a person may value doing or being' (Sen 1999: 75) which constitute the practical realisation of one's chosen way of life. Capabilities are 'the alternative combination of functionings that are feasible for [a person] to achieve; they are the substantive freedom a person has to lead the kind of life he or she has reason to value' (Sen 1999: 87). Conversion factors are factors that can allow teachers in PLCs to convert resources to new functionings (Robeyns 2005). Robeyns distinguished between three sources of conversion factors that can constrain or enable people's capabilities. These are:

- *Personal conversion factors*: those determined by one's mental and physical aspects. They are internal to the individual, such as intelligence.
- *Social conversion factors:* those determined by the society in which one lives, such as curriculum policies.
- *Environmental conversion factors*: those determined by or emerging from the physical environment in which a person lives. These can be aspects of one's geographic location, such as proximity to an ocean.

Robeyns further noted that personal, social and environmental conversion factors are interrelated. Therefore, the capability of individual Life Sciences teachers in the PLC is likely to be dependent on these interrelated conversion factors. The capability approach is not aimed at understanding causal structures and mechanisms that influence the conversion factors; for this reason, critical realism was used to understand and explain the causal structures and mechanisms that influence PLC functionings.

Critical realism is a philosophy of natural and social sciences developed by Roy Bhaskar (1978). It is based on the assumption that there are real generative mechanisms underlying the events of the world and our experiences of it (Benton & Craib 2001). Critical realism posits that natural and social phenomena are real but that our knowledge about them is theory-laden, imperfect and fallible (Sayer 2000). Critical realist researchers base their explanations of how people experience a phenomenon on mechanisms that operate at deeper levels of reality. The three levels of reality are: the empirical, the actual and the real. Benton and Craib (2001) asserted that scientific research employing a critical realist methodology goes beyond what is experienced, to uncover the underlying dynamics that give rise to generative mechanisms. A generative mechanism is 'the way of acting of things' (Bhaskar 1978: 14). The empirical is the layer of reality that is most accessible to us. It refers to our personal observations and experiences of the world (Danemark et al. 2002). This layer consists of knowledge that is fallible and unstable, meaning that knowledge is not static and can change. Empirical knowledge pertaining to Life Sciences teachers is their conceptions of their valuable beings and doings as teachers and participants in PLCs. The actual is the layer of reality that consists of the events of the world, whether experienced by people or not (Danermark et al. 2002). An example would be the actual practices of Life Sciences teachers. The real refers to anything that exists that has power to cause events and experiences at the level of the actual and empirical (Sayer 2000). It is within the level of the real that causal mechanisms and causal powers are found. Martins (2006) differentiates between the concepts of structures, power and mechanisms as three fundamental concepts of critical realist ontology, noting that:

> Structures are the underlying conditions of possibility that enable or facilitate the occurrence of a given phenomenon. Structures comprise powers that may or may not be exercised and, when exercised, may or may not be actualised in actual events and states of affairs. Mechanisms refer to the mode of operation of structures and exist as the power that a structure possesses of acting in a given way. (2006: 676)

Bhaskar (1978) argued that mechanisms are ways in which structured entities, by means of their powers and liabilities, act and cause particular events. Sayer (2000) posited that the same structures and mechanisms operating in different conditions cause different observed events. He notes that causal mechanisms do not act deterministically. Bhaskar (1998) asserted that causal mechanisms are better understood as tendency, which can be explained as activities that may or may not be actualised in concrete events and states of affairs. Tendencies can be linked to courses of action that one would take: for example, Life Sciences teachers participating in the PLC activities in order for their valued beings or doings to come to fruition (Tao 2013).

Critical realism argues that reality is a differentiation between open systems and closed systems (Shipway 2011). Bhaskar (1978) noted that open systems result in a situation where particular mechanisms cause certain effects and those effects are observable. Education programmes such as Fundisa for Change always take place in open systems. Tendencies operate within the open systems (i.e. in the PLCs) of the social world among counter-tendencies. Archer (2007) noted:

> If there is a congruent relationship between an individual's tendency with concurrently operating tendencies, there is enablement of action: but if there is incongruence, there is a constraint. At that point, an individual has the power to reflect upon one's circumstances and to decide what to do in them or to do about them; and this reflexive deliberation may result in compliance to counter-tendencies (in which original course of action is negated), or evasion of it (in an attempt to realise the action, albeit in a constrained way). (2007: 20)

Also important is to understand the causal factors and causal processes that explain how the generative mechanisms relate to the Life Sciences teachers' PLC activities, and the conversion factors that enable or constrain their capabilities (their valued beings and doings as teachers). This is linked to the critical realism concept of causality. 'To ask the cause of something is to ask what makes it happen, what produces, generates, creates or determines it, or more weakly, what enables or leads to it' (Sayer 1992: 104). As outlined above, significant to critical realism is the notion of social structures (Sayer 2000). Like natural entities, social structures emerge from relations: the relations between people, and relations between people and nature (Easton 2010). Martins (2006) noted that structures can be physical, biological, psychological or social.

What inspired the use of the capability approach and critical realism in this chapter is Tao's (2012, 2013) analytical framework (see Figure 1).

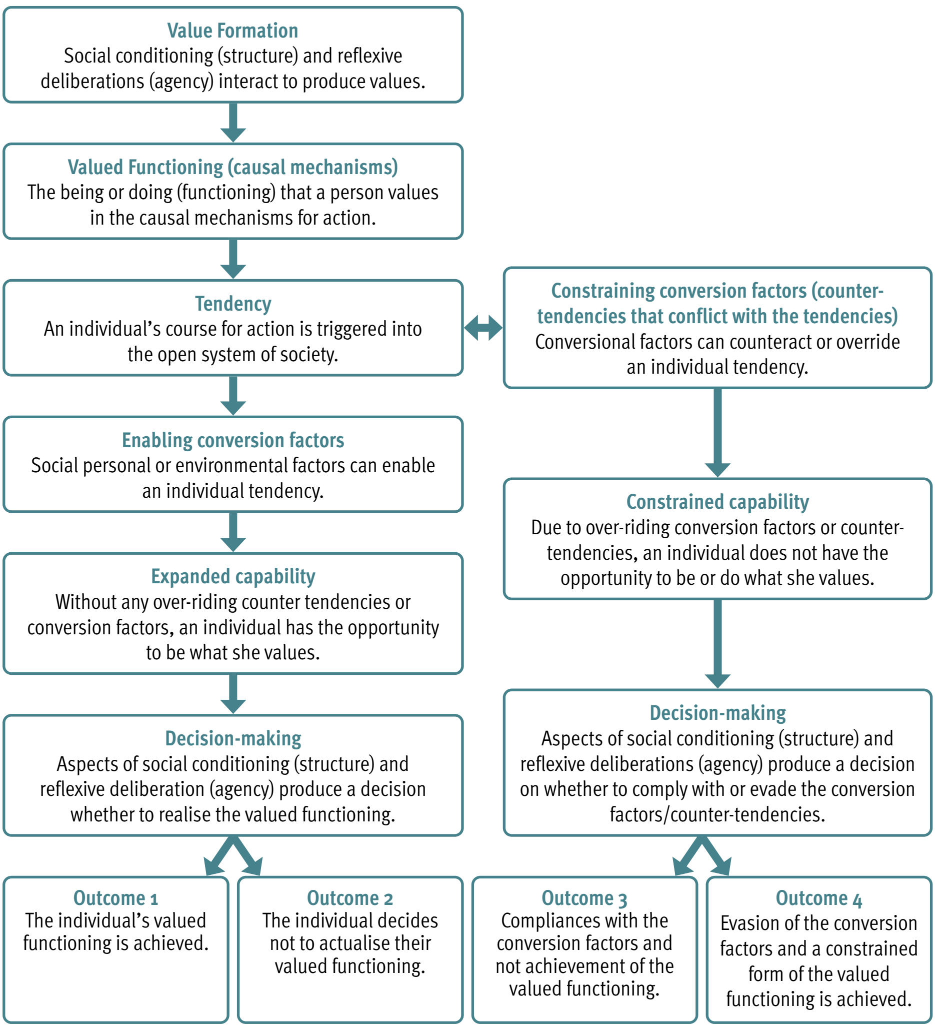

Figure 1. Locating capability approach concepts in a critical realist theory of causation (Tao 2013: 9)

To unpack this framework at the level of the real, structures and agency can interact to develop a functioning that an individual values (Tao 2012). These factors can be seen as causal mechanisms that trigger an individual's tendency of action. This happens in an open system (Collier 2005). Within the open system are conversion factors that can either enable or constrain the Life Sciences teachers' capabilities to achieve their valued functionings (Tao 2012). If the conversion factors are enabling, the teacher's functionings will be achieved and the individual then decides whether to actualise the functioning (Outcome 1) or not (Outcome 2). If the conversion factors are constraining, this may result in an individual teacher complying with the constraint (Outcome 3), or being content with the counter-tendencies that can result in a constrained version of the valued functioning (Outcome 4) (Tao 2012). This brief discussion clarifies how such a framework can be helpful in identifying causal mechanisms in the PLC as well as the conversion factors, and exploring how the agents (i.e. Life Sciences teachers) can deliberate on whether to realise their achieved outcomes in the PLCs or not.

Drawing on Archer's (1995) perspectives, the agential ability for teachers to reflexively deliberate on social structures explains why teachers do not respond in the same ways under the same circumstances. Agency refers to the reflexive, creative, innovative and purposeful actions of people (Archer 1995). It explains the choices that people make in their daily lives which either reinforce existing structures and cultures or transform them.

Drawing on the critical realist theory of causation explains why specific interventions such as Fundisa for Change will only generate particular outcomes. The outcome will depend on both the context and the generative mechanisms that exist (Smith & Seward 2009). Similarly, even though teachers participating in the PLC activities may be receiving the same resources, different contextual factors and mechanisms will determine how teachers can or will convert them into new functionings (Robeyns 2005; cf. Thomas and Songqwaru, Chapter 17).

Research design

The research was conducted as a qualitative case study, stressing the ontological foundations of the socially constructed nature of empirical experiences; the intimate relationship between researcher and what is studied; and the situational constraints that shape inquiry and practices (Denzin & Lincoln 2011; Bhaskar 1978). Case study methodologies are significant for learning about environmental learning (Lotz-Sisitka & Raven 2004) as they enable research into environmental issues such as biodiversity. All three PLC activities happened in two contact sessions (three days per session). Both sessions were attended by the same ten Life Sciences teachers and three facilitators. The teachers were qualified to teach Life Sciences and all had one or more qualifications in the field of education. Their qualifications varied from a Senior Secondary Teaching Diploma in Education to a Bachelor of Education Honours degree. Data was generated through ten semi-structured interviews with teachers, conducted by six facilitators, and with observations of the contact sessions. Document analysis was done on the

Life Sciences CAPS documents, which served as primary data sources (Harland 2014). The data generated was analysed using the capability approach and critical realist theory of causation described above. Careful attention was given to ethical issues that confronted the researcher, such as policies regarding informed consent, confidentiality and anonymity (Harland 2014).

Research findings and discussions

The teachers' valued functionings were mainly to expand their content knowledge, pedagogical practices and assessment practices related to the teaching of biodiversity (Tshiningayamwe 2016). Teachers also valued improving their confidence for teaching biodiversity, exploring study opportunities on marine biodiversity, receiving teaching and learning support materials, and expanding other capabilities such as having a good-looking curriculum vitae and supporting learners and the community to be knowledgeable on biodiversity. As discussed previously, capabilities can be expanded or constrained by conversion factors (Robeyns 2005). In PLCs there are different factors that enable or constrain the teachers in achieving their valued beings and doings. These include policies, teachers' qualifications, and the context in which PLC activities take place. Tao (2013, 2015) has argued that when located within a critical realist theory of causation, teachers' valued functionings can be viewed as the causal mechanisms that generate much of their actions as they relate to the teaching of biodiversity. She has developed an analytic framework that helps explain how causal mechanisms can lead to realised achieved functionings, or not. Using Tao's analytic framework here will provide an explanation of how the causal mechanisms among teachers in the PLCs can lead to realised functionings, or not. Figure 2 offers a visualisation of the intersections of capability approaches and critical realism with the realist causality that shapes the emergence of teachers' functionings in the PLCs.

Figure 2 outlines a process that begins at the level of the real with the dialectical interaction between structure and agency that produces the valued functionings of teachers as they relate to the teaching of biodiversity. The interplay was between Life Sciences teachers (agency) and the policy documents (structures) on teaching practice and professional development, such as the Life Sciences CAPS documents and the opportunity to participate in the PLCs. Teachers engaging in a reflexive deliberation process determined to what extent, as individuals, they wanted to be knowledgeable Life Sciences teachers, with improved practices on biodiversity. As shown in Figure 2, it is evident that the teachers' valued beings and doings related to biodiversity is an interplay between structures and agency. It is evident that in South Africa, contributing to teachers' lack of biodiversity knowledge is the fact that after 1994, school and teacher education curricula were implemented in a country with high poverty and social inequalities. It is also evident that unsuccessful or poorly monitored education policies, such as the Integrated Quality Management System, contributed to teachers' lack of biodiversity teaching knowledge. Another causal mechanism for teachers' lack of biodiversity knowledge is the ongoing curriculum change in South

Africa (Tshiningayamwe 2016); at the time of writing, teachers had already had to adapt to three different versions of the national curriculum since 1994. The curriculum changes in South Africa introduce concepts and content that teachers are not trained to teach, including the concept of biodiversity. This implies that the education system and policies in South Africa are among the generative mechanisms that influence teachers' valued beings and doings as they relate to the teaching of biodiversity.

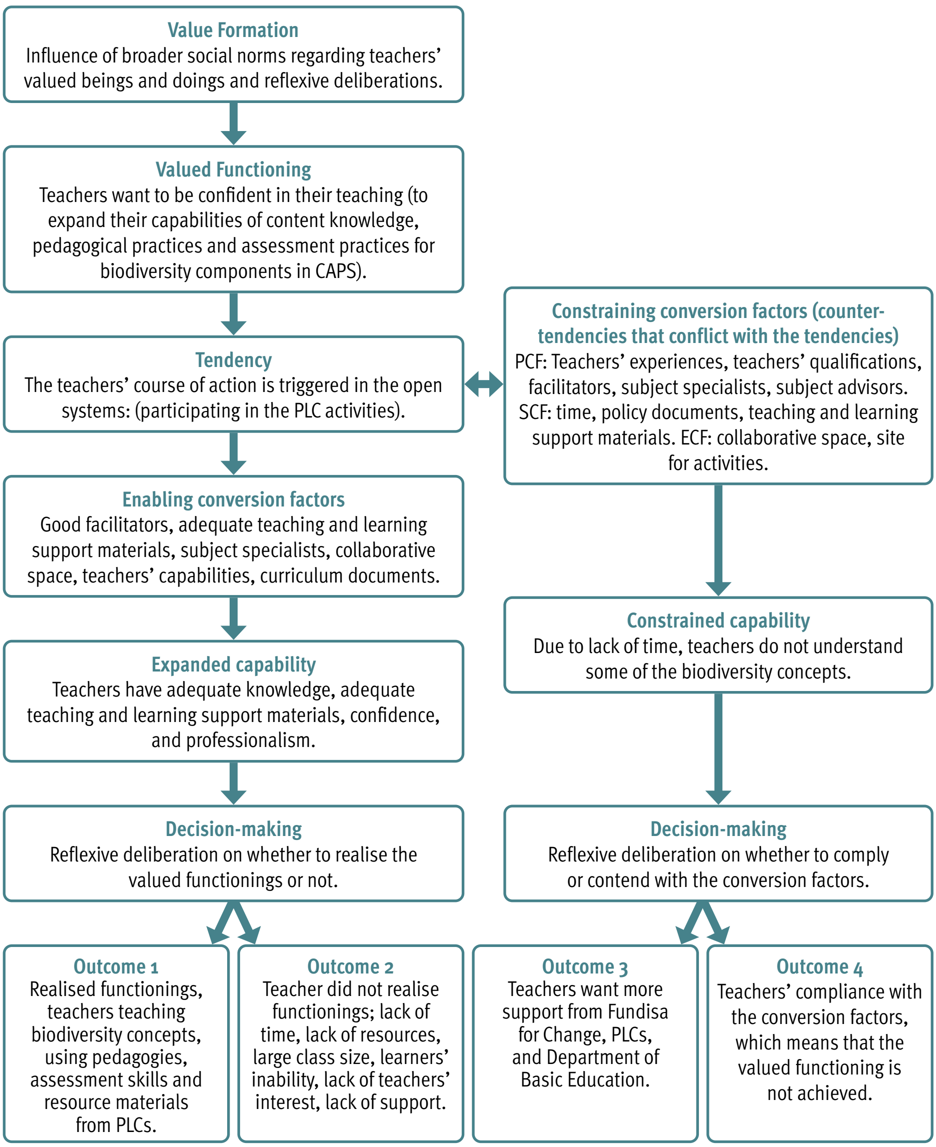

Figure 2. A visualisation of critical realism and capability approaches (SCF = social conversion factors; PCF = personal conversion factors; ECF = environmental conversion factors)

As discussed earlier, critical realism bases explanations of how people experience a phenomenon on mechanisms that operate at deeper levels of reality. At the level of the actual, the causal mechanism triggers a person's tendency for action (Tao 2013). People's courses of action are triggered in open systems. The individual teacher's course of action was triggered in an open system that entailed teachers participating in the PLC activities to achieve their valued beings and doings. Some practising teachers do not have formal qualifications for the subjects they teach (South Africa DHET & DBE 2011b).

The teachers' differential qualifications have been influenced by the apartheid legacy and social inequalities (Tshiningayamwe 2016). This has an impact on both the teachers' lack of biodiversity knowledge and the quality of education in South Africa. It was therefore evident that teachers' different experiences and qualifications – personal conversion factors – influenced their biodiversity teaching.

Good facilitation among the facilitating team in the PLC was an important personal conversion factor that enabled teachers to expand their capabilities for biodiversity teaching in the PLCs (Tshiningayamwe 2016; Songqwaru 2020) (see Brundrit and Schudel, Chapter 18 for insight into aspects of facilitation appreciated by teachers). The Fundisa for Change partners who facilitated the PLC activities had different experiences (i.e. as teachers, teacher educators or subject advisors) and qualifications (i.e. master's and PhDs in Sciences and Environmental Education) that enabled them to facilitate the PLC activities together, drawing on this diversity of pedagogical, subject specialist, and facilitation expertise (Tshiningayamwe 2016). The facilitators' experiences and qualifications, related to environmental learning and related active learning pedagogies, were found to be contributing factors to the facilitators' good facilitation skills. In addition to teachers' capabilities and good facilitation, it was evident that in PLCs, another personal conversion factor that enabled teachers to expand their capabilities for teaching biodiversity was subject specialisation (Tshiningayamwe 2016). The Minimum Requirements of Teacher Education Qualification in South Africa notes that different subjects have different disciplinary or subject matter knowledge (South Africa DHET 2011: 8). Therefore, subject specialists who are knowledgeable in the subject matter in the PLCs enabled teachers' capabilities for teaching biodiversity.

In the Fundisa for Change PLCs, an important social conversion factor that enabled teachers to achieve their valued functionings was teaching and learning support materials and policy documents used in the PLCs and professional training programme. These were provided by the Fundisa for Change programme and were specially designed for enhancing Life Sciences Biodiversity knowledge, pedagogy and assessment practice in a context where good teaching and learning resource materials for teacher education programmes are rare (Tshiningayamwe 2016). This lack has been caused by inadequate support for teachers and teacher educators to develop quality teaching and learning support materials (Fundisa for Change Programme 2013). In some institutions of higher education, teachers have not been adequately prepared to design their own resources for teaching and learning (South Africa DHET & DBE

2011b). In some cases, there is a lack of curriculum understanding among those who support teachers with their professional development needs (Tshiningayamwe 2016). For this reason, the Fundisa for Change teacher education materials were designed specifically to be important social conversion factors in the PLC context for supporting biodiversity content knowledge, pedagogy and assessment practice.

The environmental conversion factors that enabled teachers to achieve their valued functionings in the PLCs were: collaborative spaces; sites for PLC activities (the presence of the botanical garden, wetland and ocean); and the actual beings and doings (the activities) in the PLCs (Tshiningayamwe 2016). The collaborative space is associated with the teachers' professional modalities that encourage teachers to share best practices together (Schmoker 2006). This is in response to a situation in South Africa where once-off models were among the popular models used for teachers' professional development, despite these having been found inadequate for substantive teacher professional development. These models have not fully transformed teachers' practices; in fact, they have contributed to teachers having inadequate biodiversity knowledge and expertise for their teaching. It is this historical situation that led to the introduction of the policy on PLCs in South Africa (South Africa DBE 2015) and motivated the more substantive response in the Fundisa for Change teacher education programme.

Another causal mechanism influencing environmental conversion factors of teachers' functionings is linked to the loss of biodiversity. As with most countries, biodiversity in South Africa is under threat as outlined above. This is due to the development model used in the country (Abdu-Raheem 2010). Land has been cleared for development purposes and loss of habitats has led to loss of biodiversity and/or species being threatened with extinction (Abdu-Raheem 2010). Long histories of occupation have produced human activities that have had impacts on natural habitats, leading to habitat destruction. Even though there is legislation at both international and national levels that aims at protecting biodiversity, some of the policies have not been fully implemented. In response, the South African government, as in other countries, has sought to integrate the concepts and content of biodiversity in the formal school curriculum, including the Life Sciences CAPS curriculum.

The personal, environmental and social conversion factors discussed above enabled the individual teachers' tendencies in the PLCs. Archer (2007) noted that if there is a congruent relationship between a teacher's tendency and the social, personal and environmental conversion factors, then the teacher's capabilities are expanded: for example, when teachers were able to convert the social conversion factor of good learning materials into their aspirations for improved teaching of biodiversity lessons; or where the social conversion factor of good facilitation provided teachers with better pedagogical knowledge and experience on how to go about teaching biodiversity in the outdoors. Here, the conversion factors were the enabling of teachers valued beings and doings, especially as these related to their intentions to improve their biodiversity teaching in the Life Sciences. As shown above, however, some of the conversion factors in the PLCs were constraining of teachers' capabilities, for example, the personal conversion factors that were constrained by inadequate qualifications or opportunities for obtaining qualifications that included biodiversity knowledge.

With the enabled conversion factors, the teachers had expanded capabilities for the teaching of biodiversity. Thus, teachers, through reflexive deliberations, had to decide what to do with their enabled or expanded capability of teaching biodiversity. Most teachers who participated in the Fundisa for Change PLCs realised their achieved functionings that resulted from expanded capabilities (Outcome 1). Tao (2013) noted that if teachers' valued functionings are expanded they are likely to be actualised. The expanded capabilities were in line with teachers' valued functionings, thus some teachers had actualised their expanded capabilities. This was mainly through teaching some of the biodiversity concepts they had learnt in the PLCs, and the use of pedagogical approaches and assessment practices learned in the PLCs. In this way they transformed their actual classroom practices related to biodiversity teaching. This outcome was reported by other Fundisa for Change researchers including Chitsiga (2015), Isaacs (2015), Songqwaru (2020) and Nkahle (2021), as well as in other environmental learning professional development research (Schudel 2012). The researchers observed that the Fundisa for Change programme has the potential to expand the valued beings and doings of teachers (i.e. their capabilities) and their professional learning interest, both in expanding their own environmental knowledge and teaching practices and in successfully teaching the curriculum (cf. with Songqwaru 2020).

As shown in Figure 2, some of the teachers who had expanded capabilities did not realise their achieved functionings (Outcome 2). This was mainly because of external constraints such as inadequate teaching and learning support materials; finances to take learners on field-work trips; large class sizes; too much CAPS content which allowed little time for teaching biodiversity concepts adequately; and learners' struggles with reading and writing.

It is arguable that teachers not realising their achieved functionings is also due to aspects that affect their agency (or passive agency). For example, in terms of teaching and learning support materials as required in the CAPS curriculum, they could have improvised to realise their achieved functionings. However, as noted by facilitators in the PLCs, some teachers were still not feeling confident to realise their achieved functionings. Even though teachers did not mention lack of confidence as one of the reasons for not realising their expanded capabilities, it is implied in the valued new functionings.

In the PLCs some individual tendencies were met by counter-tendencies or conversion factors that constrained capabilities. Social environmental factors such as lack of time spent on the activities were the main conversion factor that constrained teachers' capabilities (see Figure 2). As a result, some of the teachers did not expand their capabilities to teach all of the biodiversity concepts. Through reflexive deliberation they decided to contend with the conversion factors by expressing a need for further support in the PLCs to expand their capabilities with those biodiversity concepts not dealt with (Outcome 3). Some teachers' valued functionings were to explore study opportunities around marine biodiversity. That valued functioning was not achieved in the PLCs, therefore, as shown in Figure 2, teachers contended with this valued functioning by expressing a need for funding from the Fundisa for Change programme to study marine biodiversity further. Alternatively, as shown in Figure 2, through reflexive deliberations, teachers could have complied with the conversion factors, in which case a constrained form of the valued functioning would be achieved (Outcome 4). An example of this outcome would be teachers giving up on the PLC activities or not expressing a need for more professional development activities to expand their constrained capabilities related to the teaching of biodiversity. However, as shown in Figure 2, there was no evidence in the teachers' data that pointed to compliance of a constrained capability.

It is evident from Figure 2 that the critical realism theory of causation offers an explanation as to why teachers in the PLCs value ongoing support for their professional development. In these PLCs the same causal power can produce different outcomes, depending on the individual teachers' capabilities and contexts in which they work (Sayer 2000). Critical realists argue that because 'events are not pre-determined before they happen but depend on contingent conditions, the future is open – things could go in many different ways' (Sayer 2000: 15). This implies that the same causal mechanisms will not necessarily produce the same outcomes in the future. Thus, even though teachers in this study have expressed the need for continued participating in the PLC activities to expand their capabilities for biodiversity teaching, their ongoing participation might lead to different outcomes. However, by identifying that one of the key causal mechanisms in the PLCs is the teachers' valued functionings, and that conversion factors enable teachers' achievement of what they value in PLCs, we can improve teachers' practices on biodiversity components in the Life Sciences CAPS curriculum through understanding and addressing these mechanisms and/or their conversion factors in PLCs and in professional learning programmes more generally.

Conclusions and recommendations

This study shows that simply to criticise teachers' poor teaching practices in relation to biodiversity content in the Life Sciences CAPS curriculum is an inadequate response that fails to recognise the need for a better foundation for programmes and professional learning. The study shows that teachers have valued functionings and capabilities that need to be appreciated when it comes to their teaching practices. It also demonstrates a need to give adequate time to understanding the root causes of teachers' observed practices, their expressed valued beings and doings, and the support they desire to achieve their capabilities. What emerged is that the causal power that has led to teachers' poor content knowledge, pedagogical approach and assessment includes the following factors: inadequate training; lack of professional development support; ongoing changing curricula; apartheid legacy and social inequalities; lack of and/or poor policy implementations; and education quality. It is clear that relying on empirical observations of teacher actions is only helpful in offering an understanding as to what extent a particular action occurs; but drafting policy on teachers' poor teaching practices, for example, will require a deeper understanding of the mechanisms that create the observed practices.

Unpacking teachers' practices related to biodiversity teaching, and understanding the underlying structures, mechanisms, tendencies and counter-tendencies that produce these observed practices is important. This provides information for programmes such as Fundisa for Change on the kind of support teachers need to expand their capabilities to transform classroom practices. This will enable programme initiators to put in place the requisite interventions to ensure that teachers' biodiversity practices are improved. It is important that such interventions take heed of teachers' capabilities, because these are the valued beings and doings that, as Sen (1999) described, are central to the types of lives that teachers would like to lead. If interventions such as the Fundisa for Change programme are aligned to teachers' valued beings and doings, then this could lead to improved teacher practices around biodiversity. It is also important that interventions aim to address the constraining conversion factors (counter-tendencies) such as time constraints. It can be argued that if professional development activities do not consider teachers' valued functionings and the constraining conversion factors, they are less likely to positively impact on the teachers' teaching practices as they relate to biodiversity.

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CHAPTER 17

Developing Teacher Capabilities and Valued Functionings in Professional Learning Communities: Focus on Environmental Content Knowledge in Natural Sciences

Kgomotso Thomas and Zintle Songqwaru

Introduction

This study explored how professional learning communities can contribute to the development of teachers' capabilities and the achievement of their valued functionings related to teaching environmental content knowledge in the 'Life and Living' strand of Grade 8 Natural Sciences (NS). This is in the context of the Natural Sciences Curriculum Assessment Policy Statement (CAPS) which is strongly content-referenced and is committed to learning approaches that are active and critical, and to environment and sustainability content knowledge (Lotz-Sisitka 2011). The integration of environmental education in the school's curriculum is of significance as it addresses global and local environmental issues by preparing and actively involving learners in the planning, improvement and protection of the environment for the future (Unesco 2012). The successful implementation of CAPS requires that teachers attain necessary subject content knowledge and pedagogical content knowledge (PCK) for the integration of environment and sustainability concerns into the South African National Curriculum (Lotz-Sisitka 2011). Teachers are also required to have the requisite skills to implement pedagogical approaches that support environmental education. However, it is apparent that the implementation of environment and sustainability content knowledge in CAPS has certain challenges due to teachers' lack of subject knowledge, poor pedagogy and poor assessment practice in relation to environmental education (Songqwaru 2012). Researchers in South Africa (Tshiningayamwe 2016; Songqwaru 2012; Lotz-Sisitka 2011) have noted that there is a lack of adequate environment and sustainability content knowledge among teachers, and that the solution would be for teachers to participate in ongoing professional development activities to enhance their knowledge. However, many of these teacher professional development programmes have been described as once-off in-service workshops, which do not offer continuous meaningful support and training. These once-off trainings do not have a noticeable impact on improving teachers' teaching practices (Moodley 2013).

Teacher professional development

Robottom (1987, in Riordan & Klein 2010) emphasised that teachers' professional development should promote pedagogical approaches which differ from traditional approaches, to support teachers in environmental education. Professional development includes many concepts such as staff development, in-service training, professional learning, and continuing education (Darling-Hammond et al. 2009). Mokhele and Jita (2010) view teacher professional development as involving systematic efforts to bring about a change in classroom practices of teachers, their attitudes and beliefs, and in the learning outcomes of learners. This study uses Evans's concept of professional development, defined as 'all types of professional learning undertaken by teachers beyond the point of initial training, the concomitant skills learnt and developed in these learning processes, and changes in approaches to practice resulting from them' (2002: 134). Effective professional development should offer teachers opportunities to collaborate with each other and to engage with ideas and materials. The focus should be on building teachers' skills, competencies and attitudes, rather than on mere transfer of information (Darling-Hammond & McLaughlin 1995; Du Toit & Sguazzin 2000; Hinde 2003). Furthermore, professional development should provide a foundation for inquiry, reflection and experimentation, and take into account teachers' contexts in teaching and their prior knowledge and experiences. Researchers who focused on teacher development in biodiversity have noted that in South Africa there is a lack of biodiversity knowledge among teachers, and that the solution would be for teachers to participate in ongoing professional activities to enhance their biodiversity knowledge (Lotz-Sisitka 2011; Songqwaru 2012; Chitsiga 2016; Isaacs 2016; Tshiningayamwe 2016).

Literature on professional development contains a lot of critiques regarding the many teacher training programmes which offer once-off in-service workshops. Hargreaves (1995, in Songqwaru 2012) noted that these workshops expose teachers to new curriculum changes without continued meaningful support and training; and as a result they do not have a noticeable impact on improving teachers' current practices. Mokhele and Jita (2010) argued that for professional development programmes to be effective, they need to have personal meaning to teachers who are participating in them, and should be relevant to their needs. They concluded that teacher development programmes should be continuous and aligned with teachers' personal needs and motivations. To strengthen teacher professional development and promote collective participation in professional activities for professional development, professional learning communities were introduced in South Africa.

Professional learning communities

Professional learning community refers to 'a group of teachers sharing and critically interrogating their practice in an on-going, reflective, collaborative, inclusive, learning-orientated, growth-promoting way to support innovation and knowledge sharing' (Stoll et al. 2006: 223). There are different terms used in relation to the concept of professional learning communities, including professional learning groups, collaborative learning communities, critical friends groups, communities of practice, study groups, teacher research collaboration, and professional networks, to name just a few (Great Schools Partnership 2014; Norman et al. 2015). A general agreement across the different definitions of PLCs is that a PLC emphasises relationships, shares ideas, and develops a strong culture committed to improved student learning.

The Integrated Strategic Planning Framework for Teacher Education and Development (ISPFTED) (South Africa DHET & DBE 2011) clearly indicates that teachers should be the central focus of PLCs, and take leadership roles. This is supported by Brodie and Borko (2016) who argued that if PLCs are to become widespread and truly professional, teachers are the ones who should conceptualise and lead PLCs, with some support from the districts, and other institutions such as universities.

Characteristics of professional learning communities

The benefits for teachers participating in PLCs include reduced isolation, increased commitment to goals, shared responsibility, increased knowledge of effective teaching practices, increased professional aspiration, and embedding systemic change (Hord 1997, in Underwood 2007). The hallmarks of PLCs, according to the ISPFTED, are 'open and democratic collaboration, conflict management and mutual problem-solving, which in turn promote the identification of specific individual and group developmental needs along with actions aimed at addressing these needs' (South Africa DHET & DBE 2011: 80).

PLCs appear to have five main intertwined characteristics as given by Stoll et al. (2006):

- Shared values and vision,
- collective responsibility,
- supportive conditions and shared leadership,
- reflective professional inquiry, and
- promotion of group and individual.

Professional learning communities allow teachers to see themselves as primary agents for change in teaching and learning processes (Wood 2007). They support and encourage teachers to examine their practice, and collectively construct and share new knowledge (Hord 2004). With that point highlighted, this study has focused on how professional learning communities can develop and assist teachers in acquiring the necessary content knowledge and skills to teach and assess environmental topics, as guided by the following research question:

> How can professional learning communities contribute to the development of teachers' capabilities and the achievement of their valued functionings as related to teaching environmental content knowledge in the 'Life and Living' strand in Grade 8 Natural Sciences?

Sub-questions

- What functionings do teachers value most in teaching environmental content knowledge in the 'Life and Living' strand of Grade 8 and what conversion factors are associated with these functionings?
- What are teachers' valued functionings in a professional learning community and what conversion factors in the professional learning community are associated with these functionings?
- How can a professional learning community provide Natural Sciences teachers with experiences that develop the knowledge and skills they need to engage learners when they teach environmental content knowledge in the 'Life and Living' strand of Grade 8 Natural Sciences?

The capability approach (Sen 1999) was used as the theoretical framework to explore teachers' valued functionings, as well as the conversion factors related to those functionings.

Theoretical framework

The capability approach developed by Sen (1999) was used in this study. The key concepts in the capability approach are: capability, functioning, agency, human diversity, and public participation in generating valued capabilities (Walker 2005). However, for this study the main concepts being explored are capability and functioning. According to Sen (1987: 36):

> A functioning is an achievement, whereas a capability is the ability to achieve. Functionings are, in a sense, more directly related to living conditions, since they are different aspects of living conditions. Capabilities, in contrast, are notions of freedom, in the positive sense: what real opportunities you have regarding the life you may lead.

Sen (1999) further explains that a functioning relates to the various things a person may value doing or being. For this study, functionings are the things that teachers value doing or being in relation to teaching environmental content in Natural Sciences, and in belonging to a professional learning community. Walker (2005) says the capability approach is about freedom and the development of an environment suitable for human flourishing. She further states that capability refers to what people are actually able to be and do, rather than what resources they have access to. Robeyns (2005) clarifies further, claiming that the difference between a functioning and a capability is similar to the difference between an achievement and the freedom to achieve something, or between an outcome and an opportunity. She emphasises that the core characteristic of the capability approach is its focus on what people are effectively able to do and to be. The capability approach focuses on developing people's capability to choose a life that they have reason to value. For this study, capabilities are what Natural Sciences teachers are able to do in a classroom and/or in the PLC, what they value from belonging in the PLC as well as the kind of teachers they can be if the PLC provides a suitable environment for their professional development. Understanding teachers' functionings and capabilities is important in their professional development.

Also of importance in the capability approach is the concept of conversion factors. They are factors that can enable teachers in PLCs to convert resources into new functionings (Robeyns 2005). Functionings and capabilities can be both expanded or constrained by conversion factors, which can be grouped into the following categories:

1. Personal conversion factors (such as intelligence, physical condition, and skillsets). In this study, personal conversion factors may be the teachers' qualifications, experience in teaching Natural Sciences, level of confidence, and personal time.
2. Environmental conversion factors (such as geographical location, infrastructure and logistics). The schools surrounding or in the location where the PLCs are held would fall into this category because they could have an influence on how teachers approach environmental content lessons.
3. Social conversion factors (such as public policies, social norms, gender relations, roles and identities). In the case of this study, social conversion factors may be school practices, power relations, teaching resources, the national education policies, or school codes and systems. The PLC, its activities and how they are conducted, and the role of each participant, are also examples of social conversion factors. (Robeyns 2005)

According to Robeyns, the personal, environmental and conversion factors are interconnected.

Methodology

Research site and participants

The study was conducted in Mahikeng, in the North West Province. Data was generated through observations, semi-structured interviews and questionnaires. The research participants were 13 Natural Sciences teachers who filled out a questionnaire; two of these were observed in the classroom and interviewed post observation, and four were interviewed post PLC observation. The teachers' qualifications ranged from Diploma of Higher Education to master's degree, with years of experience in teaching Natural Sciences that ranged from three months to fifteen years. Of the thirteen teachers, eight majored in Education while five had Bachelor of Science degrees (B.Sc.) with Postgraduate Certificates in Education (PGCE). The teachers majored in different specialisations such as Life Sciences (Biology), Natural Sciences, and Mathematics.

All the teachers were from different schools, and all were part of the professional learning community under study. Those who attended the PLC session on the day of observation numbered around 35, but only 13 of them returned the questionnaires.

Classroom observations were done with two teachers, two lessons being observed for each teacher. Both teachers were qualified to teach Natural Sciences. One of the teachers had a Further Diploma in Biology teaching with an Advanced Certificate in Education (ACE), and 23 years of teaching experience, two of them in teaching Natural Sciences. The other teacher had a Biomedical Sciences degree and a PGCE; with one year's teaching experience. The purpose of classroom observation was to get some insight into how teachers teach environmental content in Natural Sciences. An observation of the PLC was also done to develop a deeper understanding of teachers' valued beings and doings in the PLC, and how these related to their functionings in teaching environmental content in the classroom. A further purpose was to get insight into conversion factors related to those valued beings and doings. The data was analysed using the capability approach.

Findings and Discussion

The study found that teachers have different valued functionings related to teaching environmental content in the 'Life and Living' strand of Grade 8 Natural Sciences. Teachers' valued beings and doings related to teaching environmental content are discussed under the three conversion factors of the capability approach, namely: personal, social and environmental. The study found that teachers' qualifications, experiences, passion for environmental content topics, level of confidence, availability and access to teaching and learning resources, as well as learners' interest and participation, support from subject advisors, and school and classroom environments were among conversion factors that either enabled or constrained teachers' valued functionings in teaching environmental content.

Findings also revealed that teachers have different valued functionings related to belonging to the PLC, namely: shared responsibilities, shared values and vision, collaboration, and discussion of environmental subject content knowledge aspects. The conversion factors related to these functionings were found to be learning space, timing and duration of the PLC activities, types of activities in the PLC, teaching and learning resources, teaching experience, and facilitation.

Teachers' valued functionings related to the PLC

Sharing responsibilities among teachers and the subject advisor

Teachers valued taking active roles in the PLC and sharing responsibilities with the subject advisor. They noted that they had limited roles in the PLC. It emerged that the subject advisor did almost everything in the PLC, from setting up the agenda to giving presentations, leading discussions, and providing materials. For example, one teacher commented as follows: '*She does everything. She would normally start the meeting with some motivation. Then she goes into policies and administration things. Hey, she takes a lot of time in that. Then she will talk about school performances for previous exams. Basically, she does almost everything in the PLC.*' Teachers mentioned some of the roles they would like to play in the PLC, such as helping with the planning of activities, facilitation, and doing more practical tasks. This is in accordance with what is stipulated in the ISPFTED, that teachers should be at the core of PLC activities and take leadership roles (South Africa DHET & DBE 2011). Professional learning communities should offer supportive conditions and shared leadership as argued by Hord (2004).

Shared values and vision to guide the discussions

PLCs are spaces where teachers can have conversations that can help them to reflect on their classroom practices. It was evident that another valued functioning was having shared values and vision, and the freedom to make decisions about points of discussion in the PLC meetings. Teachers commented as follows: '*I wish the subject advisor could allow us teachers to come with our own points of discussion. Especially for content discussions*'; '*If we could be given an opportunity to say what we as teachers want to discuss*'. Other aspects that teachers wanted to discuss besides subject content were teaching strategies and experiences, classroom challenges, and topics that are difficult to teach. A shared value-base provides a framework for shared, collective, ethical decision-making, and a vision focused on student learning and shared values guides discussions and decisions about teaching and learning, while enabling individuals to act autonomously (Stoll et al. 2006).

Collaboration

Collaboration is one of the key characteristics of effective professional development (Darling-Hammond & McLaughlin 1995). In the interviews and questionnaires, there were teachers who indicated that it would be beneficial to invite different organisations to offer workshops on different topics; and to have other subject specialists in some of the PLC meetings. Another form of collaboration suggested by teachers was for neighbouring schools to have their own mini PLC sessions and workshops.

Discussion of subject content

Most teachers valued discussing subject content, especially on topics they find difficult. What was observed and what teachers expressed was that much of the PLC time was spent on administration-related activities. Teachers thought it would be better to have separate PLC sessions: one that dealt with administration only, and another that focused on subject content only. One teacher noted the following: '*We need more workshops that deal with administration and then ones that deal with content, that supply past question papers that have been written and then us as teachers we break it down and come up with ways to improve the subjects.*' Other teachers shared similar sentiments. The following extracts give evidence of the teachers' views: '*I will like us to discuss content…*'; '*I am interested in discussing content*'; '*Spend more time discussing subject content, that's what matters at the end of the day*'; '*Focus on how to teach biodiversity. Hear from other teachers, or even have the subject specialist teach the topic, or other teachers*'. Effective professional development should offer meaningful intellectual engagement with ideas, and take explicit account of the contexts of teaching and the experience of teachers (Hinde 2003). This assertion is supported by Du Toit and Sguazzin (2000) who note that professional development should enable teachers to build increasingly sophisticated understandings of their work and context. A focus on environmental content discussions will enhance teachers' knowledge, understanding and teaching practice. Teachers' valued functionings related to teaching environmental topics in Natural Sciences were also explored, and are discussed in the next section.

Teachers' valued functionings related to teaching environmental topics in Natural Sciences

Through questionnaires and interviews, teachers expressed their valued functionings in teaching environmental topics in Natural Sciences. A summary is given in Table 1 below.

Table 1. Teachers' valued functionings in teaching environmental topics in Natural Sciences

Expanding knowledge in environmental topics	Improving teaching practices	Field work	Support
• Studying further for short courses like Nature Conservation. • Affiliating with certain programmes to develop in teaching and get more knowledge. • Learning more about the topics, improving skills in teaching them, and having the confidence to teach them.	• Getting interactive teaching materials. • Having small numbers of learners in the class. • Finding an easy way of making the learners relate the topic to the real environmental issues. • Being helped with better teaching strategies for those topics. • Relating the topic to the real environmental issues that are local. • Bringing back learners' interest in NS.	• Taking learners on excursions to Mahkeng Game Reserve. • Doing outdoor lessons.	• Getting help with topics of adaptation, conservation of ecosystems, extinction and biodiversity. • Attending different workshops. • Support from the subject advisor.

Conversion factors related to teachers' valued functionings

The conversion factors related to teachers' functionings were clustered under Robeyns' (2005) conversion factors: the personal, environmental, and social. Conversion factors are factors that can enable or constrain teachers. Through questionnaires, post-classroom and PLC observation interviews, teachers noted the conversion factors that either enabled or constrained them in achieving their valued functionings.

Personal conversion factors

Teachers' qualifications and experience

For some teachers, their qualifications were an enabling factor to teaching Natural Sciences and environmental topics specifically. For example, one teacher said: '*I am a Life Sciences major, and have a bit of chemistry from my qualification. Therefore, I can teach and enjoy teaching topics related to the environment.*' Other teachers expressed how their qualifications were a constraining factor; one teacher noted that he had to teach Natural Sciences because there was no science teacher at that school. He explained that he did not enjoy teaching the subject because he did not know the content; his majors were Electronics and Computer Science. This shows that the teacher did not have the freedom to choose what he valued doing and being.

It was also evident that the difference in experiences enabled teachers to work together and learn from each other in their schools. For example, one teacher, who had two years of teaching experience, expressed: '… *I have two senior teachers who are helping me … Everytime I need help with some topics that I find difficult I go to them.*'

However, in the PLC it appeared that experience was a constraining factor, mainly due to how the PLC sessions were structured. Teachers with more years of teaching experience noted that they no longer found the PLC beneficial to them because the focus is, most of the time, on orientating new teachers. They felt there was a need to have a separate session for inducting new teachers.

Passion and interest in environmental topics

One of the teachers who was observed during a lesson demonstrated passion in the way she delivered her lesson on conservation of ecosystems. Her enthusiasm (the tone of her voice, facial expressions and body language) in presenting the lesson showed passion. The learners were showing interest in the lesson because of how she taught the topic. Learners were actively involved during the lesson, asking and responding to the teacher's questions. In her interview she said: '*I love teaching the Life and Living topics in term one. It's part of what I teach in Life Sciences …*'

There were, however, teachers who indicated that they do not have passion for teaching Natural Sciences and environmental topics. In a follow-up interview one teacher said: '*Honestly I don't enjoy it because I have never taught it before … It's not for me. I am just doing it for those children.*'

Acquisition of knowledge and skills

Teachers noted the need to gain knowledge and skills in teaching environmental topics as an enabling factor. Another teacher observed: '*Maybe if they made it possible for us to register for short courses like Nature Conservation, so that we can increase our knowledge in those topics.*'

Findings in this study revealed that there are still challenges around teachers' in-depth knowledge of environmental content, as pointed out by other researchers (Lotz-Sisitka 2011; Songqwaru 2012; Chitsiga 2016; Tshiningayamwe 2016). Teachers valued enhancing their knowledge of environmental topics but the PLC, as mentioned earlier, did not offer them time to engage in subject content discussions.

Environmental conversion factors

Learning space

The PLC was viewed by some teachers as a space that enables collaboration among them and learning from each other. Teachers used phrases such as '*learning from each other*', and '*gaining knowledge*', when commenting on the PLC as a learning space. This resonates with what Hipp and Huffman (2000) emphasised, that PLCs should have supportive conditions that allow time for collaboration, empowering teachers and reducing isolation.

However, it emerged that some of the teachers who have been part of the PLC for many years did not find it to be a learning space for them. This was noted by one teacher, who said: '*Not anymore. The meetings are mainly aimed at empowering beginner teachers. They are now becoming less and less relevant for us experienced teachers.*' The teachers' participation in the PLC was to some an enabling factor to achieve their valued functionings, while to others it was a constraining factor.

Physical space where the PLC is held

The PLC was held in a school situated in the urban area. The venue for some teachers was in itself a constraining factor because they had to travel a very long distance to attend the session, and leave before the end of the session. Also, the classroom used for the session was not an enabler; it was too small, and the seating arrangements did not promote space for engaging in discussions or working in groups. PLCs should develop an environment suitable for teachers to flourish and achieve their valued functionings (Robeyns 2005).

Social conversion factors

Duration of PLC activities

Time emerged as a main conversion factor that constrains teachers from achieving their valued functionings in the PLC. Teachers expressed that the frequency as well as the duration of the PLC sessions were not enough. They wanted extended time so that they can discuss different topics, as one of them noted: '*If the Department can schedule PLC meetings during school holidays to allow us more time to engage in content discussions and other issues. 2 hours is not enough.*' The issue of time was emphasised in the ISPFTED (South Africa DHET & DBE 2011), noting that time should be scheduled for teachers to participate in PLCs and engage in quality teacher development.

Natural Sciences CAPS document

The CAPS document was used in the PLC session and it enabled teachers' achievement of their valued functionings. The subject advisor used it to orientate teachers who were new in teaching Natural Sciences. Teachers were also given an opportunity to use it during a group activity of setting practical tasks for assessment. They were not familiar with the skills that must be assessed in a practical activity. The use of the CAPS document in PLCs should not be a mere transfer of information, but should be used to build teachers' skills, competencies and attitudes to enable them to achieve their valued functionings in teaching the environmental topics and the Natural Sciences subject in general.

Availability of and access to teaching and learning resources

During the PLC, teachers were given subject policies, but there were no materials to expand teachers' knowledge in environmental topics or in the Natural Sciences subject generally. Teachers mentioned their need to be supplied with materials, and they perceived availability of and access to teaching and learning materials as an enabling factor in teaching Natural Sciences. For example, one teacher stated: '… *another thing* *is lack of enough resources. I need charts, videos … I would love to get help with teaching materials that are interactive, like videos, for learners to see how different animals adapt to the environment.*' The ISPFTED clearly states that it is the role of Districts to support PLCs with resources and expertise on facilitation skills, development of teaching resources, and the use of Information and Communication Technology.

Activities in the PLC

There were a few activities that took place in the PLC, and teachers had different perceptions about them. Experienced teachers noted that the presentations by the subject advisor, which were focused on administration, analysis of results and orientation of new teachers, were a constraining conversion factor for them. Although the Department of Education's (2015) PLC guideline highlighted these topics as some of the activities to be done in PLCs, balancing the activities to accommodate all the teachers is crucial. There should be a balance in terms of meeting the needs of both novice and experienced teachers.

One teacher noted that '*workshops are mostly aimed at empowering beginner teachers*; *about 80% of the time is spent on admin issues. I don't benefit from that unless there are new requirements.*' Group discussion activities were identified as an enabling conversion factor; teachers saw it as an opportunity to learn from each other, share knowledge and discuss subject content. For PLCs to be effective in developing teachers, they should consider what teachers value and incorporate that in the activities of professional development.

Conclusion

Findings revealed that teachers have different valued functionings related to their professional development in the PLC and the teaching of environmental content. Teachers valued active participation, taking leadership roles and responsibility, discussing subject content, learning from each other, and being provided with teaching and learning resources. There were conversion factors that were, to some teachers, enablers, while to others they were constraints. This suggests that teachers' professional development programmes within PLCs need to identify teachers' functionings and align them with the programmes' activities. Teachers' individual professional needs should be taken into account. PLCs need to offer teachers a platform to create knowledge collectively by having more time to engage in discussions on subject content, classroom practices, and sharing ideas and strategies. For PLCs to be effective in developing teachers' capabilities and valued functionings, teachers must be at the centre of the system, take the lead with their own professional development, and be offered continuous support through the PLCs.

The findings from this study can inform the Department of Basic Education (DBE) towards establishing new PLCs and strengthening existing ones. The DBE could look into the already existing teacher clusters to see how they can be strengthened to become better functioning PLCs. Additionally, other teacher development programmes can see how they can support professionals within PLCs.

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CHAPTER 18

Teacher Contexts as Amplifiers and Filters to Environmental Pedagogical Content Knowledge within a Professional Development System

Susan Brundrit and Ingrid Schudel

Contextualising the research question

The chapter draws on the contextual work underpinning a broader study that aimed to understand how environmental pedagogical content knowledge is supported and constructed in the Fundisa for Change teacher professional development (TPD) courses (Brundrit 2018). Necessary to this was an understanding of the contextual realities (amplifiers and filters) of the system in which the course occurs, leading to the question:

> How do school and classroom contexts act to amplify and filter the environmental pedagogical content knowledge learning of teachers in a teacher professional development programme?

Pedagogical content knowledge and teacher professional knowledge

The framework underpinning this contextual work is informed by pedagogical content knowledge (PCK) research that has grown out of Shulman's conceptualisation of the notion in the mid-1980s. In October 2012, a PCK Summit was held in Colorado Springs, USA, that aimed to work collaboratively towards consensus around the definitions, terminology and assessment of the concept of PCK, as well as to guide future research. In the definition that emerged from the PCK Summit, PCK is portrayed as personal or private professional knowledge held by an individual and which relates directly to classroom practice. In this sense, while teachers' knowledge and pedagogical practices are socially formed through professional learning, interaction and practices, the PCK of one teacher would not be the same as the PCK of another. Classroom practice is divided into two related parts: the planning for teaching and the skill involved in the act of teaching. It is described as the space in which personal PCK interacts with classroom context (see Thomas and Songqwaru, Chapter 17 who argue the importance of taking cognisance of PCK in context). At the Summit, PCK and the construct PCK and Skills (PCK&S), were defined as follows:

- *Personal PCK is the **knowledge of**, **reasoning behind**, and **planning for** teaching a particular **topic** in a particular **way** for a particular **purpose** to particular **students** for enhanced **student outcomes** (Reflection **on** Action, Explicit).*
- *Personal PCK&S is the **act** of teaching a particular **topic** in a particular **way** for a particular **purpose** to particular **students** for enhanced **student outcomes** (Reflection **in** Action, Tacit or Explicit). (Gess-Newsome 2015: 36)*

The definitions have allowed for the **analytical** separating out of the necessary related knowledge used for teaching, and the skill involved in the enactment of teaching as teachers apply this knowledge within their classroom contexts. The definitions also refer to the use of PCK at different times – first in the planning for teaching and second in the act of teaching. In planning for teaching, PCK is applied in the form of 'reflection *on* action' (Schön 1983), during which knowledge for teaching a particular topic, and reasoning for choices made with regard to how to teach it, are brought together from past experiences (Park & Oliver 2008). Personal PCK can thus be made explicit through the planning process. The act of teaching requires personal PCK&S and tends to be far more tacit as teachers 'think on their feet' and make decisions in split seconds – the 'why' of which are very hard to capture after the fact (Gess-Newsome 2015).

Another result of the PCK Summit was the Summit Consensus Model of teacher professional knowledge and skill, a section of which is shown in Figure 1. The model is used to clarify and develop the conceptualisation of teachers' PCK in terms of its relationship to other teacher professional knowledges. The top level of the model draws on Shulman (1986), to present a set of five teacher professional knowledge bases that collectively represent generalised teacher professional knowledge. These knowledge bases include knowledge of assessment, pedagogy, content, learners and curriculum.

Separated out from the generic knowledge bases are the knowledges that can be applied to the teaching of a particular topic at a specific grade level. These are listed as 'knowledge of instructional strategies, content representations, student understandings, science practices and habits of mind' (Gess-Newsome 2015: 31). Both teacher professional knowledge bases and topic-specific professional knowledge are canonical knowledges held by the teaching community, and it is from these knowledges that personal PCK and PCK&S emerge through specific people in specific circumstances.

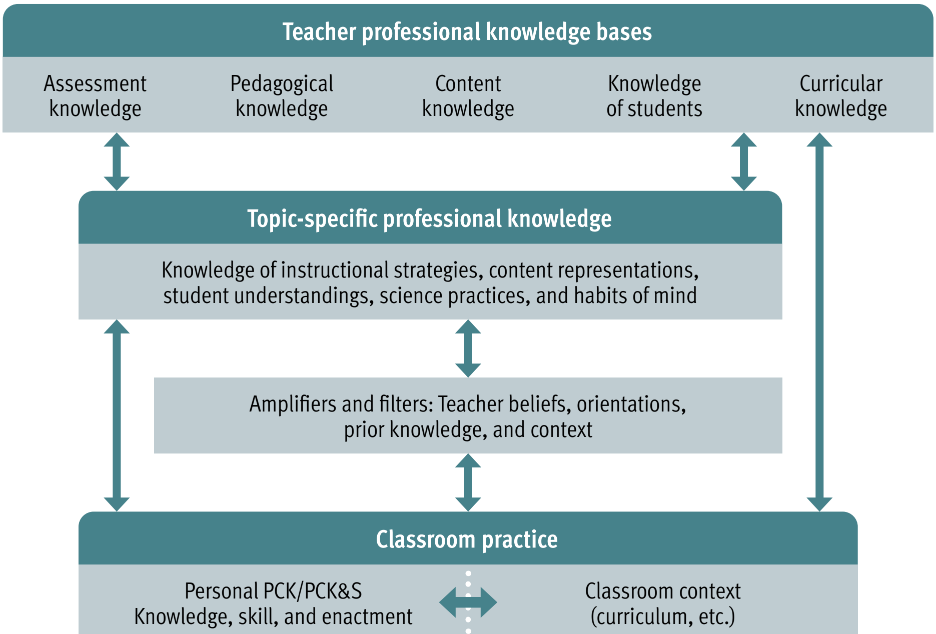

Figure 1. Selected section of the Summit Consensus Model of teacher professional knowledge and skill (Gess-Newsome 2015: 31)

Separated out from the generic knowledge bases, but shown in Figure 1 as informed by and informing them, are the knowledges that can be applied to the teaching of a particular topic at a specific grade level. Both teacher professional knowledge bases and topic-specific professional knowledge are canonical knowledges held by the teaching community, and it is from these knowledges that personal PCK and PCK&S emerge through specific people in specific circumstances.

Consideration of specific people in specific circumstances is captured in the Summit Consensus Model through the inclusion of the filtering or amplifying powers of teacher beliefs, attitudes, orientations, prior knowledge and context. These filters and amplifiers affect teacher personal PCK and PCK&S as well as their classroom practice (Luft & Roerhig 2007; Opfer & Pedder 2011; Gess-Newsome 2015). The implication is that amplifiers and filters cause teachers to 'pick and choose' from knowledge presented during professional development programmes, according to their perceived context, instructional orientation, learners, beliefs, and so on, as they evaluate the new information. The existence of amplifiers and filters in the Summit Consensus Model provides a means of understanding why the PCK of individual teachers can be varied despite the same input from teacher training and professional development programmes. Although the Summit Consensus Model flags teacher beliefs, orientations, prior knowledge and context as potential amplifiers or filters of teachers' personal PCK, aspects of teachers' context emerged as dominating themes in this research and will occupy the focus of this chapter.

The teacher within a professional development system

The Summit Consensus Model provides thinking tools for describing knowledge, its professional basis, and its transformation as it is reconstructed and put into practice by individual teachers. Contextual factors such as 'access to high-quality professional development … as well as the nature of the professional development' can impact on 'what a teacher knows and how knowledge may or may not be used' (Gess-Newsome 2015: 35). The model shows the influence of context on the teacher in two sites: as amplifying or filtering teachers' knowledge, skill and enactment; and as classroom context, included in the classroom practice level in the Summit Consensus Model.

Developing the element of context even further, Grangeat and Hudson (2015) draw on the Summit Consensus Model and identify three types of teacher contexts as mediating teacher professional knowledge:

- **Social context**, comprising the habits and repertoire of the actions of the teacher group, orientations, culture and habits of mind of the teacher group, and the type of leadership and organisation of the collective work.
- **Classroom context**, comprising classroom practice and student outcomes.
- **Instrumental context**, including teaching resources and in-service education materials. (Grangeat & Hudson 2015: 210)

All of these contexts will be engaged with in this chapter as the case study is introduced and examples are given to illustrate how the amplifiers and filters have been understood within the broader context in which the teacher professional development happened.

Methodology

The objective of this research was primarily to describe an iteration of a Fundisa for Change teacher professional development course and the context in which it occurred. To achieve this, a descriptive case study research design was used to describe and examine in detail the development and construction of environmental PCK in this course. The course took the form of five three-hour sessions focused on the content, pedagogy and assessment of environmental topics within the Grades 4–6 'Life and Living' knowledge strand of the Natural Sciences curriculum. The activities making up the course were designed to model various active learning teaching strategies.

Participating teachers

The seventeen teachers attending the Fundisa for Change course were all in the process of completing a two-year part-time in-service Advanced Certificate in Teaching (ACT): Senior Phase Natural Science at the University of Cape Town (UCT). All of the teachers participating in this study were teaching at public schools, with one of those being a special needs school. The ACT entails commitment to travelling to attend lectures, often twice a week, for three hours, from 4.00 to 7.00 p.m., after school. The Fundisa for Change Teaching Life and Living Course was taught as part of the ACT lectures at venues located on the UCT campus. The teachers' ages ranged from twenties to fifties, with varying years of experience and pre-service training. For the data presentation that follows, alphabetical letters are used to represent the anonymous feedback from the questionnaires and pseudonyms are used to protect the identities of the teachers that were interviewed.

Data generation processes

The amplifiers and filters described below arose as themes from the data and were recorded in analytic memos during the analysis. The themes were compiled by drawing on the following data sources:

- teacher contextual profile questionnaires,
- session transcripts capturing the facilitator transactions,
- transcripts of the group discussions,
- group outputs during the course activities, and
- teacher reflections on the activities – taken from the course reflection and evaluation forms.

Role of context as mediating transformation of professional knowledge into PCK

The influence of the teaching contexts was analysed in terms of the five teacher professional knowledge bases of PCK that were identified in Figure 1: assessment, pedagogy, content, learners, and curriculum. The contexts investigated included the social context, classroom context, and the instrumental context of the teachers. Within each of these contexts, descriptions of the evidence of filtering and amplifying on the pedagogical reasoning and emergent PCK for the five PCK knowledge bases is now presented and discussed.

The mediating role of the social context

The social context of the teachers refers to the broader professional culture of the school community, its leadership and expectations. Research has shown that 'the social context in which teachers are embedded influences their PCK growth' (Grangeat & Hudson 2015: 208). Professional practices such as professional collaboration and being part of a learning community at school are seen as opportunities for teachers informally to develop their PCK and further their professional learning (OECD 2014).

Teacher contextual profile questionnaires revealed that the more frequent professional community behaviours engaged in by this group of teachers were: exchanging of pre-prepared teaching materials with colleagues; engaging in discussions about learning development of individual learners; and collaboration around common assessments. Less frequent behaviours were: observing other teachers teaching and co-teaching. Attendance of team meetings appeared to vary, as did taking part in collaborative professional learning.

Within the Fundisa for Change course, the most significant aspect in terms of ability to promote teacher environmental PCK appeared to be the opportunities for collaborative group work. Also of importance was the atmosphere of trust and mutual respect among the teachers on the course and between teachers and facilitators.

Each of the five sessions that comprised the course were between two and half and three hours long. Altogether, during the course, teachers spent 55% of the time in focused discussion. In reflections on an activity where groups planned conceptual progression for the teaching of an environmental topic, ten of the fifteen teachers referred to the advantages of doing the activity in a group. Teachers were also exposed to collaborative lesson planning that related to content, conceptual progression, pedagogy and assessment of an environmental 'big idea'. In their reflections on this activity, half of the teachers referred to specific aspects of their own learning about the lesson-planning process that had been developed in some way. Teacher B stated that the process 'Gave me a better understanding of the concepts that need to be present in an ecology lesson'; Teacher I commented that 'It makes me think carefully of what is my aim for this lesson, what do I want my learners to achieve' while Teacher L's learning was to 'accommodate all levels of understanding when you plan the lesson. Involve a variety of teaching aids'.

A further quarter of teachers' reflections on their learning, related their learning back to the group work that had preceded the lesson planning, making comments such as:

> 'This was very useful. I could learn from others and gain new ideas. Also, everyone had their own ideas to bring to the table and we brought it together very well.' (Teacher F)

> 'The group planning was good in that it led to ideas coming together then being perfected. It is different from individual planning where one just looks at one's ideas and develops that.' (Teacher K)

> 'This promotes team teaching as teachers plan together the same topic. Learners in different classes can be taught using the same lesson plan.' (Teacher O)

In addition, in the evaluation form, four of the fifteen teachers commented that the best aspect of the course facilitation was the group work and planning for teaching. This was supported with comments appreciating interactive engagement with topics, group planning and group presentation. Opportunities for active and collaborative learning appeared to be an amplifier for the transformation of professional knowledge into personal PCK for teachers on the course and acted in a general way across PCK knowledge bases.

The mediating role of the classroom context

'The way classroom practices unfold and students perform, directly interacts with teacher professional knowledge' (Grangeat & Hudson 2015: 210). This observation was evident in the study, where a number of aspects of the classroom contexts of teachers participating in the course had the potential to have an amplifying or filtering effect on how they selected knowledge and actions for the classroom.

Influence of class size and discipline on teachers' pedagogical choices

Four of the teachers mentioned discipline and behaviour-related issues as specific challenges, with two of these teachers linking discipline problems to overcrowding in the classroom. Nine of the teachers had class sizes of between 27 and 40 learners. Seven had classes of 40 or more learners, with the largest class size being 51. One teacher, teaching in a special needs school, had a class size of 14. In one of the sessions, while giving group feedback on an activity regarding different teaching strategies, Phumza, a Group 2 teacher, commented: 'I think these methods would be good but for our number of learners in our classes it's going to be too hard.' Her group indicated agreement. In another instance, Viwe, a Group 1 teacher, commented on the practicalities of showing a short movie in class:

> 'Ja, ja. But being realistic, yes some of us do it in smart schools and do have the capabilities already to show movies like this. But the sad reality perhaps, is that most of us are faced with classes that reach 50 learners, so how … are you going to keep it constructive in a scenario like this?'

Influence of language level of learners on teachers' assessment and pedagogical choices

In questionnaires, just over half of the teachers reported that their classes had more than 75% of learners with their first language different from the language of instruction. Asked about specific challenges they have with their target group of learners, three teachers mentioned learners' lack of reading and/or writing skills as specific challenges, with one of these teachers observing that the learners actually resist reading and writing activities. Another teacher mentioned language of instruction as a challenge. This teacher also noted in particular the scientific terms used in the environmental topics as needing a lot of explanation time. Of the teachers mentioned above, three have close to 100% of learners in their class having their first language different from the language of instruction. Some of the ways in which the teachers adapted their practices to accommodate these challenges are illustrated by the comments below. The first comment by Lindiwe from Group 2 describes a formative assessment strategy (see Mgoqi and Schudel, Chapter 3) the teacher uses to know if learners have understood text:

> **Lindiwe from Group 2:** 'So we go through it like, Question 1 what is your answer? One person. And then did anyone have another answer? Okay, that one. And then we say okay that was *the* answer. Why is that the answer do you think? Just ten minutes. Not more than ten minutes and then I'm done. And then that for me, I found that that also kind of consolidates that they understood what was happening in the notes and also how to apply the notes to the questions in the activity … I found that using that ten minutes kind of strengthens their understanding, the strong ones … we always have those ones that lag behind. But, like, the strong ones, they do get it after a while … they do get what you are trying [to do] and they become more responsive.'

A number of teachers felt that the language level of learners impacted on the way in which they structured their assessments. One teacher felt that his desire for learners to pass made him avoid questions with higher cognitive demand. Another teacher explained that he avoids questions requiring lengthy writing but rather asks learners to provide point-form factual answers. However, this strategy would mostly result in a lowering of the cognitive demand of questions. Another teacher suggested providing a framework to make the meanings of the action verbs, such as 'describe' and 'explain', explicit. This strategy was acknowledged as providing scaffolding to learners. Thus, teachers' time pressure and understanding of learners' language ability were seen as impacting on both the form and cognitive demand of assessment tasks.

In another activity, teachers recognised discussion of word definitions as a useful generic teaching strategy for supporting language and vocabulary development. Language and science terminology in particular were mentioned by teachers both in the contextual profile questionnaire and during the course as important but time-consuming to teach, due to many classes having high percentages of learners with their first language different from the language of instruction. One of the ways in which the teachers adapted their practices to accommodate the language challenge is illustrated by the comments from Group 1 below, made during a discussion on learners' responses to the words 'Explain' or 'Describe' being used in an assessment:

> **Daluxolo:** With most of them [the learners] you find that there is a language barrier. They start explaining and they start writing something else totally. So what I try to do is 'identify your main facts and then write

them in point form'. So, I don't know, is that good? Is it bad? Because when they start explaining, I tell you it's …

Nomvuyo: You have to give them a framework. It's good then if they write in full sentences. You teach them.

Daluxolo: Yes, during classwork I do that, but then when it comes to examinations I try to limit them from writing because they really go way out of the topic. They fail to get the whole idea.

The mediating role of the instrumental context

The instrumental context includes teaching resources such as textbooks, materials from teacher professional development courses and the curriculum document as well as classroom furniture such as tables, whiteboards and data projectors (Grangeat & Hudson 2015: 210).

Themes emerging that related to instrumental contexts were the effect of teachers' perceptions of the curriculum and the availability of resources. These themes appeared to impact on the pedagogical and assessment knowledge bases of the teachers' PCK.

Influences of curriculum time allocation on assessment knowledge

The development of assessment knowledge in the Fundisa for Change course was skills-based at a general, subject and topic-specific level. Findings showed that the teachers appeared to have improved their understanding of how formative assessment strategies such as feedback can be used in their classrooms to further their learners' cognitive development and seemed to have a more defined idea of what actions they needed to take to implement these strategies. Teachers did, however, express that they felt constrained by the time allocations given to topics in CAPS in their performance of the formative assessment strategy of giving feedback. In this extract from a group feedback conversation about formative assessment in the fourth session, the teachers explain:

Thenjiwe: The problem is time allocated to CAPS … It's working through the content. There's no time allocated for feedback. When you give them a test, you mark it at your own time because you are rushing to teach them something new again. We don't have time to really look at the assessment and discuss it. We would like to do that, but we don't have time. Really.

Sonwabo: I agree with Thenjiwe about time because … you are teaching to assess, to cover what the CAPS document wants you to cover, not what you want the kids to understand.

The course included an activity of how to use the revised Bloom's Taxonomy (Krathwohl 2002) to identify the cognitive demand of questions and, through the use of appropriate verbs, develop higher order thinking skills in their learners as per the Curriculum and Assessment Policy Statement directives. Discussions gave teachers the opportunity to collaboratively create an understanding of the knowledge and cognitive dimensions of the revised Bloom's Taxonomy. Feedback given by the teachers at the end of the session appeared to reflect an increased awareness of the amount of thinking about questions required in setting up assessments, with regards to the cognitive demand of the questions. The process of checking the cognitive levels of questions was, however, seen as time-consuming. Thus, time pressure was seen as a filter to the use of these aspects of assessment knowledge.

Influences of curriculum time allocation on pedagogical choices

In another activity, to develop the link between teaching strategies and educational purpose, teachers were first asked to read brief descriptions of a variety of generic teaching methods and to consider the relevance of the methods to their subject. The purpose was to remind teachers of the variety of strategies that exist, as 'a broader range of different kinds of methods generally helps us to address a broader spectrum of environmental learning outcomes' (Rosenberg, O'Donoghue & Olvitt 2013: 3). In the feedback immediately after the session, one group of teachers argued that the assessment focus of the curriculum was the reason why they did not use a variety of methods. On the reflection and evaluation form, the majority of teachers' reflections acknowledged that different methods served different purposes and that some could be used to make lessons more interactive and help them to plan with purpose and coherence. In the second part of the activity, teachers were tasked to make the link between teaching methods and the different purposes they serve, explicit. This part focused on general teaching strategies, thereby developing knowledge of instructional strategies at a general level. Teacher learning from this activity indicated an understanding that learning goals can be achieved using different teaching methods. Comments arising during the class feedback varied from seeing the potential of using a variety of teaching methods to keep the interest of learners, to anticipating problems with implementation due to class size.

Another problem raised during group discussions was that there was not enough time allocated for practical work, despite practical work being recognised as motivating for learners. In the teacher contextual profile questionnaire, four teachers mentioned motivation of learners as a specific challenge to their teaching. One of the teachers wrote that learners with social issues 'lack motivation and vision for the future'. This same teacher also saw motivating learners as part of his role as a teacher and a way of maximising learning in his class. He stated that he knows that learning is occurring in his class 'when learners are motivated to face a new challenge'. Motivation was also linked to opportunities to do practical work in class, with one teacher commenting that 'they get so interested and show eager[ness] to work when given practical work', and another observing that 'they enjoy it a lot because they are in most cases working in groups'. Practical work also has the potential to be an opportunity for learner self-regulation and this was mentioned by two of the teachers as the reason why learners enjoy it. Other reasons given were that learners performed well in practical work 'because they get involved in the lesson and are responsible for their own learning' and 'because they are doing the project themselves step by step and they could see the results'.

Influence of perceived relevance on pedagogical knowledge

The course developed pedagogical knowledge in three activities. The first of these involved the creation of a situation of purposeful listening through making the teaching goals and expectations explicit before watching a short movie. As part of the activity, teachers discussed the impact that knowing the structure and requirements of the activity had on their learning. They reported that their attention became more focused on the task as they knew what was expected of them. In addition, on the course evaluation and reflection form, a third of the teachers reflected that the 'listening with intent' strategy would motivate their learners to listen actively and enable them to respond better to assessment questions. Teachers amplified the learning in this activity by recognising the relevance and transferability of the strategy. This was evident in the reflection and evaluation form indicating that they could apply 'listening with intent' as a strategy to other topics and subjects.

A further two activities exposed teachers to different content representation strategies for both general and environmental topics. These activities involved the translation of environmental content from one form into another: that is, from text to mind-map, and from cyclical diagram to text and then into a different diagrammatic form. In the reflections, mind-mapping was mentioned as a useful tool for scaffolding conceptual development and for checking that learners had summarised concepts correctly for a section of content. In their reflections on translating the cyclical diagram to text and then into a different diagrammatic form, one teacher commented on how the use of a different content representation caused confusion initially, while others noticed how their thinking had been stimulated and challenged through the strategy of changing the content representation from one form to another.

Influence of access to resources on pedagogical knowledge

Another potential filter to the use of different teaching strategies mentioned by the teachers was a lack of resources. Access to resources was raised as an issue by various teachers in a number of conversations throughout the course. During the first session in the recorded discussion of Group 1, four teachers were talking about the possibility of being able to show a video to their class. One of them indicated that they had access to a whiteboard (although it was broken); one had a working whiteboard but used a data projector and laptop; and the other two had no access to either forms of technology.

Only one teacher mentioned lack of resources in the form of stationery and apparatus as a specific challenge in the contextual profile questionnaire. In the reflection and evaluation form two teachers mentioned a lack of resources at their school, with Teacher E commenting: 'Teachers need resources. Most of the schools don't have resources, hence it's difficult to apply most aspects in real-life situations.' The presence or absence of resources appeared to have an amplifying or filtering effect, respectively, on the types of teaching strategies available to the teachers from a practical point of view. The statement by a teacher in the first session that if 'you don't have resources in your class you have to improvise', indicated how teachers adapt their teaching according to availability of resources.

Summary and recommendations

Methodologically, this chapter has offered a framework for how teachers' social, classroom and instrumental contexts can cause them to filter or amplify aspects of the teacher professional knowledge presented in courses, thereby impacting on the development of their personal PCK. The findings covered a range of themes that can provide insight into course planning and further PLC work, with implications for conceptual development of learners, role modelling of teaching strategies, and better teaching methods and assessment strategies. These are summarised below and their implications considered.

The study findings showed that the predominant characteristic of the course that amplified teacher PCK development was the opportunity for collaborative learning, especially around teachers' own conceptual development and lesson planning. This was further amplified by the culture of trust and mutual respect among participating teachers. One recommendation would therefore be that the establishment of an atmosphere of trust and respect for differing points of view needs to be prioritised by the facilitators. This is particularly pertinent where groups of teachers who do not necessarily know each other are brought together for the purpose of professional development. The value that collaborative work has for PLCs is clearly indicated. Also highlighted is a potential gap to be filled: namely, the inclusion of peer observation in collaborative work.

In considering how the environmental content of the course could be adapted in classrooms to aid conceptual development among learners, teachers raised a number of concerns regarding ways in which content might be filtered, because of large classrooms and associated discipline problems, lack of reading and writing skills among learners, and even the extreme of resistance to reading and writing. A further filter regarding conceptual development of learners was a difficulty with scientific concepts, especially for English second-language learners. Amplifiers to teachers' capacity to bring the environmental content of the Fundisa for Change course to their learners included an acknowledgement that formative feedback and varying the teaching methods can strengthen learner motivation.

Further PCK developed in the course was role-modelling of a number of teaching methods and strategies. Teachers acknowledged the value of a variety of teaching methods and strategies that were modelled for them (including the methods of mind-mapping and showing movies, and the strategies of 'listening with intent' and transferring representation strategies between text and diagram). One of the filters that will affect how they are able to apply this in classroom contexts was the perception of an assessment-driven curriculum and the large amount of content that teachers are expected to cover during the year. This is seen to limit use of innovative methods which may take more time in developing concepts among learners. Practical work was one of the methods particularly noted as being valuable for learner motivation but needing more time for execution.

In developing the teachers' PCK around assessment, the course introduced the new Bloom's Taxonomy for thinking about developing assessments with higher cognitive demands. Again, the pressure of curriculum volume was listed as a reason for teachers not feeling they had the time for careful construction of tasks balanced between low, medium and high-order cognitive skills. This filter, with the additional contextual filter of learners' difficulties with scientific concepts as well as with language, led some teachers to explain that they intentionally chose assessment tasks with lower cognitive demand as they are worried about learners' performance ratings. Also, teachers noted that they prefer to work with point responses as learners struggle to write full sentences and comprehensive texts. This is of big concern, especially considering the findings by Mkhabela and Schudel (Chapter 13) in which difficulties with higher order thinking are being noted in the sciences in higher grades – an indication that this problem has roots in lower grades and continues until the final year of schooling. While the issue of time constraints is a continual challenge for teachers involved in teacher professional development, it still may be worth developing strategies to share with teachers for developing logic and line of argument in longer paragraph and essay-type tasks.

Future research needs to consider how to design and implement TPD in such a way as to limit filtering and promote amplifying of professional knowledge. For instance, what sort of opportunities for teachers to share and develop constructive strategies to mitigate challenges within their contexts could be provided within the supportive space of TPD programmes? And how might we, as teacher educators, provide more sustained and contextualised TPD engagement?

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CHAPTER 19

A Realist Approach to Evaluating the Fundisa for Change Training Programme

Zintle Songqwaru

Introduction

A significant change in the South African education system in the post-apartheid era was the recognition of the importance of integrating environmental education (also defined as education for sustainable development and/or environment and sustainability education in South Africa) into the national school curriculum. Educators (both office and classroom based) are viewed as change agents who can deliver the educational responses needed to achieve Sustainable Development Goals (Unesco 2017), and as such it is imperative that teacher education programmes that aim to prepare educators to implement Education for Sustainable Development be evaluated.

This chapter focuses on the use of a theory-based approach to programme evaluation, in order to surface assumptions that underpin the Fundisa for Change Teacher Education training programme. An interrogation of unexamined assumptions embedded in teacher education programmes through a theory-based approach to evaluation provides insights, first, into how programme objectives are operationalised to achieve desired programme outcomes. Second, it provides an explanation of how, why and for whom programme outcomes were achieved, or not. Results from a theory-based evaluation process can enable a critique of professional development programmes with the aim of improving their conceptualisation, implementation and evaluation.

If a programme is successful, an evaluation of the programme should identify which elements are critical for widespread replication in other contexts. Even if a programme fails to achieve its intended outcomes, an evaluation should be able to determine whether non-achievement is due to inadequate implementation; whether the context is unsuited to operate the mechanisms by which outcomes are expected to occur; or whether failure can be attributed to the programme theory itself (Coryn, Noakes, Westine & Schröter 2011).

Mason and Barnes (2007) argued that programme theories are refined as they are being explored. What was intended to happen, what does actually happen in implementation and delivery, and the identification of the factors that lead to outcomes, are only visible through research that seeks to understand how the programme works in context.

Context and background

Chapter 1 of this book has given a broad overview of the Fundisa for Change Teacher Education Programme. This chapter is therefore focusing only on the capacity development objective of the programme, with a particular focus on building the capacity of educators who are expected either to implement or support the implementation of environment and sustainability education in the schooling system. The programme developed a monitoring and evaluation system in two impact areas, one of which focused on educators' content knowledge and practice. This component of the monitoring and evaluation assesses the extent to which the Fundisa for Change programme influences and/or improves educators' knowledge and practice. It addresses the following questions:

- How (if at all) is the Fundisa for Change training programme improving educators' knowledge and practice?
- What contextual factors influence educators' engagement and success in the Fundisa for Change training programme?

The study responded to this impact area by asking the following research questions:

1. What theory of change shaped the Fundisa for Change professional development training programme?
2. What is the Fundisa for Change training programme's implementation theory?
3. What is the Fundisa for Change training programme's programme theory?
    - For whom did the programme theory work and why?
    - In what contexts did the programme theory work and why?
    - What mechanisms enabled the programme theory to work?
    - What outcomes were achieved?

A theory-based approach to evaluation

A theory-based approach to evaluation makes it possible to determine a programme's intended outcomes, the activities that will be implemented to achieve those outcomes, and the contextual factors that may influence the implementation of the activities and thus the programme outcomes.

The aim of using this approach to evaluate the Fundisa for Change training programme was to identify the context and mechanisms that enable the achievement of the stated training programme outcomes. A realist Context-Mechanisms-Outcomes (CMO) configuration framework was used in the study to unpack the programme theory of the professional development course in the Fundisa for Change programme. The table below shows an elaborated CMO configuration adapted from Pawson and Tilley (1997) and De Souza (2013).

Table 1. Elaborated CMO configuration adapted from De Souza (2013)

	Mechanisms		
Context	***Resources*** (material, cognitive, social & emotional)	***Reasoning***	**Outcomes**
Structure: internally related objectives and practices	Roles, positions, practices, processes, resources	Preferences, beliefs, norms, values	Transformation or invariance or reproduction
Culture: ideas that influence the actions of individuals, thus determining certain outcomes	Ideas, propositions, theories, arguments about structure, culture, agency and relations	Preferences, beliefs, norms, values	Transformation or invariance or reproduction
Agency: intentional engagement in action or non-action influenced by cultural or structural conditions	Motivation	Preferences, beliefs, norms and values for action or non- action	Transformation or invariance or reproduction
Relations: interaction between related entities	Duties, responsibilities, powers and rights	Preferences, beliefs, norms, values	Transformation or invariance or reproduction

Cheyne, Abhyankar and McCourt (2013) stated that the context in which a programme is implemented shapes the mechanisms and outcomes. Hence a programme evolves when introduced into different contexts as context tends to influence what people do and how they will act. When a programme is implemented in another context, there are inevitably differences in infrastructure, institutions, stakeholders and participants. Consequently, some critical causal configurations on which programme success depends might be broken by the shift. A programme can still obtain the same objectives in different sites but by different means (Pawson 2001). Pawson and Tilley (1997) argued that all programmes are conceptualised and implemented into pre-existing social contexts. Context has an influence on the success or failure of a programme.

The Fundisa for Change programme was adapted in different contexts (provincially) and for different participants (teachers and senior education specialists) by the facilitators who implemented the programme. The complexity had to be monitored during site evaluation of the programme. Contextualising a programme brings complexity, as adapting a programme into a local setting has implications for both programme theory and design (Sridharan & Nakaima 2012). Riché (n.d.) believed that programmes should be contextualised as programme outcomes are influenced by social, institutional, cultural, economic, geographical and political factors embedded in local environments. Understanding a programme's theory within a specific context and how it interacts with factors external to the programme is important in capturing the 'how' and 'why' of programme outcomes. Programme outcomes are thus critically dependent on the choices made by participants and programme resources offered by programme implementers (Pawson & Tilley 1997).

Mechanisms in realist evaluation, according to Pawson and Tilley (1997), are a combination of resources offered by a programme and participants' reasoning in response to the resources offered. Programme resources, that is mechanisms, may be material, cognitive, social and/or emotional. Programmes work when these resources resonate with programme participants (Pawson 2003). According to Westhorp (2012), participant reasoning includes preferences, norms and beliefs and these underpin decisions that lead to particular actions, which in turn enable or constrain outcomes. Partly, the success or failure of programmes is due to the reasoning and personal choices of different participants (Pawson et al. 2005).

Mechanisms are identified in order to determine potential causal powers, for example, what the intervention does that can produce the expected outcome in the conditions in which it is introduced.

The stated outcomes of the Fundisa for Change professional development training programme were:

- *Subject Knowledge and Learning (Theory):* Show improved understanding of environment and sustainability subject knowledge in the context of a specific subject and phase [content knowledge].
- *Pedagogical Knowledge and Learning (Theory & Practice):* Show ability to use appropriate teaching methods and assessment approaches for specified subject knowledge, skills and values.
- *Situated Knowledge and Learning (Context):* Relate subject-specific environment and sustainability content knowledge to broader issues and contexts.
- *Practical Knowledge and Experience (Work Experience):* Design, develop, implement and reflectively review a lesson plan/sequence of lesson plans relevant to an environmental and sustainability content focus in a particular subject and phase/grade.

Data generation

In order to determine the training programme's programme theory as well as for whom the programme worked and under what conditions, a CMO configuration was generated from document analysis (Fundisa for Change documents), interview data (key Fundisa for Change partners and facilitators), questionnaires (participant post-training evaluations) and observation (on-site training implementation). Conclusions drawn from each site produced cumulative knowledge that was used to generate a general programme theory for the Fundisa for Change professional development course.

The thematic training focus in three of the five sites was on teaching the theme of water in Social Sciences. Participants in the three sites were senior education specialists in the intermediate and senior phase who support Social Sciences teachers. The other two sites focused on climate change in Geography and Natural Sciences. Participants were Geography teachers in one site and Natural Sciences teachers in the other. The researcher observed actions, reactions and interactions (Gummesson 2000) between participants; between participants and facilitators; and between participants, facilitator and training settings.

Data analysis

Surfacing the programme theory of the Fundisa for Change training programme required a detailed, rich and textured description of what was observed at each site. A CMO configuration was used to show what outcomes were achieved and what mechanisms enabled the outcomes to be achieved under what circumstances. Figure 1 shows a visual representation of the CMO configuration.

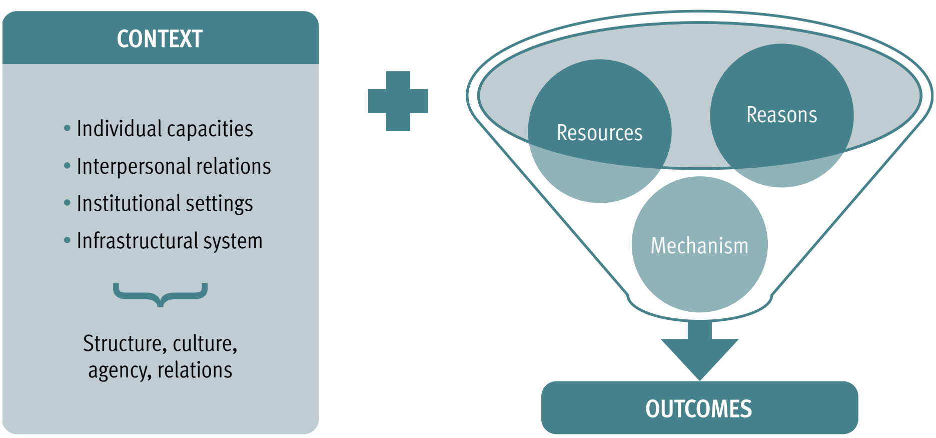

Figure 1. CMO configuration

A cross-analysis of observation data from the five sites was done to develop a CMO configuration of the Fundisa for Change training programme. According to Yin (2009:

156), 'cross-case analysis is the process of comparing and contrasting across case study analysis'. This was done to determine what was common to all the sites as an indicator of the necessary conditions for achievement of training objectives. Table 2 provides a Fundisa for Change professional development programme CMO configuration.

Table 2. CMO configuration for Fundisa for Change professional development training programme

<table>
<tr><th rowspan="2">Context
(internal to Fundisa for Change programme)</th><th colspan="2">Mechanisms</th><th rowspan="2">Outcomes
(professional development course)</th></tr>
<tr><th>Resources
(material, cognitive, social & emotional)</th><th>Reasoning</th></tr>
<tr><td rowspan="3">Structure:
• Multiple partners facilitating training from diverse sectors (environment, government and universities)
• Participants and facilitators familiar with the schooling system and curriculum
• Participants were target group in terms of their work and content covered
• Department of Basic Education involved in choosing theme of training and participants to be trained
Culture:
• Facilitators value collaboration in implementing training
• Participants value collaboration, learning with and from each other (group work activities and peer assessment)
Agency:
• Facilitators have flexibility to use own expertise to adapt training programme
• Participants attend voluntarily and actively participate
Relations:
• Facilitators commit to implement training with colleagues
• Participants belong to same professional learning community</td><td>• Redefining roles
• Introduction to new knowledge and resources
• On-course tasks and assessments
• Content knowledge presentations by facilitators</td><td>Discussions, questions, reflections, as well as how activities were mediated, enabled participants to learn new content knowledge and see value and relevance in what they currently do and are expected to do.</td><td>Participants have an improved understanding of environment and sustainability subject knowledge in a specific subject and phase.</td></tr>
<tr><td>• Introduced to ESD teaching strategies through modelling
• Teaching method resource book
• Presentation on assessment
• On-course task to set assessment task
• Field work and hands-on activities</td><td>Discussions on teaching practice and assessment to influence participants to reflect on current practice. Modelled teaching strategies encouraged reflection on current practice and motivated adoption of new teaching strategies. Critique of assessment practice enabled reflection and opportunities for change of assessment of practice.</td><td>Participants are able to use appropriate teaching methods and assessment approaches for specific subject knowledge, skills and values.</td></tr>
<tr><td>• Contextualising training content to local environment</td><td>Group discussions on topic and its relevance for everyday life and the curriculum enabled participants to understand other perspectives on the topic.</td><td>Participants are able to relate subject-specific environment and sustainability content knowledge to broader issues and contexts.</td></tr>
</table>

Context (internal to Fundisa for Change programme)	**Mechanisms** *Resources* (material, cognitive, social & emotional)	**Mechanisms** *Reasoning*	**Outcomes** (professional development course)
	• Developing capacity of participants to be able to perform redefined duties and responsibilities, as they plan to implement at work • Peer assessment	Perceived relevance of on-course activities and portfolio of evidence tasks to their everyday work.	Participants are able to design, develop, implement and reflectively review a learning programme relevant to a particular subject, phase and/or grade.
	• Field work and hands-on activities	Discussions and reflections on personal values and choices.	Change-orientated learning.

Findings of the evaluation showed that the achievement of the stated Fundisa for Change training course objectives was influenced by structure, culture, agency and relations, both internal and external, to the training programme. The structure of the Fundisa for Change training programme adopts a multi-stakeholder model where training course facilitators from different sectors (government, NGOs and institutions of higher education) work together to implement the professional development training course. This meant that different facilitators, due to their professional backgrounds, experiences and expertise, brought various mechanisms (materials, cognitive, social and emotional) that influenced participants' reasoning in relation to their own practice, thus giving participants opportunities to redefine their roles. Facilitators embraced working collaboratively, as evidenced by voluntarily becoming partners in the Fundisa for Change Teacher Education programme and working with other partners to plan training sessions. Some of the partners have a history of having worked together in the past.

Additionally, in three of the study sites, participants were already a professional cluster as they were used to attending Department of Basic Education workshops together. They were therefore used to working together, sharing experiences and giving each other peer feedback.

Although the Fundisa for Change training programme has a course structure, the variable access to training facilities and the uneven conditions under which participants are trained made it necessary to build in contextual factors when designing the course. Facilitators used their agency to adapt the training so that it was responsive to the context in which they were implementing the training. Different facilitators also used different facilitation skills, which ranged from the teaching of new content knowledge, to discussions and modelling of various teaching strategies. On-course tasks required participants to work both individually and in groups to reflect on their practice and present their work for input from peers and facilitators.

The choice of training resource materials used during the training covered the subject content knowledge that participants were teaching or supported others to teach. Additionally, the resources were contextualised to the participants' local environment: for example, a focus on the health of a river would use a river found in the province where participants were based. Field-based activities took participants to local places where they could explore concepts in practice, for example, visiting a local water purification plant to understand the purification process. Field work provided participants with 'learning in context', enabling them to see the relationship between theory (content specified in curriculum documents and textbooks) and practice (water purification plant).

An additional outcome that was achieved by participants, although not made explicit in the training objectives, was change-orientated learning. How on-course tasks were mediated challenged participants to think deeply about the values they hold, and how these relate to their actions and choices (Rosenberg et al. 2008: 21). Participants shared how they would do things differently in their personal lives, demonstrating that what is valued influences actions. Participants shared what and how they learned; this created opportunities for transformative learning, which is significant for a programme like Fundisa for Change that is aimed at enhancing transformative environmental learning through teacher education (Fundisa for Change Programme 2013).

The following Fundisa for Change training programme outcomes were achieved:

- Participants' understanding of environment and sustainability subject knowledge in a specific subject and phase improved.
- Participants were able to use appropriate teaching methods and assessment approaches for specific environment and sustainability subject knowledge, skills and values.
- Participants were able to relate subject-specific environment and sustainability content knowledge to broader issues and contexts.
- Participants were able to design, and develop, a learning programme relevant to a particular subject, phase and/or grade, and to reflectively review both their own and their colleagues' learning programmes.
- Participants demonstrated change-orientated learning.

Due to the diverse facilitation skills and mechanisms introduced by the facilitators during training, the achievement of the above-stated training programme outcomes was at varying degrees for different participants. This speaks to the realist approach to evaluation that asks the question, '*For whom does the programme work, under what conditions*?'

An improved understanding of environment and sustainability subject knowledge in a specific subject and phase was evident in sites where additional knowledge resource materials, besides school textbooks, were brought on site. It was also evident in sites where participants recognised that concepts discussed, even though they went beyond content specified in the curriculum documents, were part of the school curriculum.

In sites where participants engaged in field work and hands-on activities, there was evidence of an ability to contextualise subject content knowledge to the local environment. Additionally, participants were able to reflect on current lifestyle choices in order to make sustainable lifestyle choices.

An explicit discussion on teaching strategies for environmental teaching and learning, as well as the modelling and critiquing of teaching strategies, supported the acquisition of new teaching methods. Assessment practices were enhanced in sites where participants were given opportunities to set and analyse assessment tasks, and also analyse those set by colleagues. Feedback sessions on the analysis of assessment tasks enabled participants to get feedback from facilitators and colleagues and to learn from the discussions.

Participants designed and developed refined learning programmes in instances where they had brainstormed ideas with colleagues before they adapted their learning programmes to accommodate their own contexts. This was even more evident in sites where the learning programmes were reviewed by colleagues and participants received feedback from colleagues and facilitators.

Implications and recommendations for teacher professional development in environment and sustainability programmes

Programme success can be achieved if what needs to be changed is identified and steps to address it are clearly defined. In the Fundisa for Change case, research on environmental education in the schooling system informed programme stakeholders on the gaps in the system, for example, lack of adequate environment and sustainability content knowledge and insufficient skills to teach and assess that content, as well as insufficient resources for teaching the content. The critical components of what is at the core of a professional development programme must be made explicit to all programme stakeholders. This will enable a flexible adaptation and contextualisation of the programme in diverse contexts.

Moreover, programme implementers need to share how they have implemented and adapted the programme to address local needs. How programme mechanisms are enacted in the various contexts should be shared and reflected upon. Programme adaptation in different contexts needs to be explained and justified. This will lead to an accumulation of knowledge about a programme's theory of change and how it needs to be refined for future training in diverse contexts.

Although a programme has a structure and predetermined objectives, it must be flexible enough to take into account the context and needs of the participants, as each context has its own enabling and constraining factors that have an influence on programme outcomes for programme participants.

Participants should be challenged to think critically about their roles and whether or not their capacity matches the roles and responsibility of their work contexts. Additionally, facilitators need to model the teaching strategies and assessment skills that they want participants to acquire. This allows participants to see how the strategies work in practice and it gives them an opportunity to reflect on how the methods modelled and the assessment tasks can be used in their own contexts.

Subject- and phase-specific professional development programmes increase chances of the programme being applied by participants in their work contexts. Professional development programmes have a better chance of being successful when they resonate with the urgent changes that teachers need to implement in their teaching practice. Moreover, if the development of professionals is to be sustained, teacher professional development programmes need to be supported by education policies. Programme stakeholders should position the programme in the policy context in order to facilitate participant buy-in. How participants and facilitators understand policy documents is also important as different policy interpretations may lead to different policy enactments.

Governments, funders, accrediting bodies and professional bodies should be required to support teacher professional development programmes and provide the necessary funding and resources needed to implement those programmes. More importantly, professional development programmes must be institutionalised within professional development directorates so that funding can be made available for the delivery of the programmes on a more sustainable basis.

Conclusion

Even with an explicit theory of change, Danermark, Ekström, Jakobsen and Karlsson argued that

> we will never be able to predict accurately concrete social events, for example exactly how people are going to act in a particular situation neither can we anticipate situations. This does not mean, however, that social scientific knowledge is useless for social planning. If we have knowledge of the mechanisms of social structures, we can identify the driving forces behind the events we are observing. Doing so we can also in a more qualified manner estimate the possibilities, deficiencies and limitations of the actions we plan. Without this kind of knowledge, the analysis of a phenomenon will always be superficial or even incorrect. (2002: 187–188)

Programme outcomes for participants will vary based on their beliefs, personal concerns, and degree of commitment in the face of structural hindrances. Additionally, they will vary according to participants' readiness to avail themselves of enablements provided by programmes. Programmes should therefore respond adequately by addressing participants' subjectivities. Participants' personal liabilities and powers need to be acknowledged, in particular, their power of reflexivity to think about themselves in relation to their contexts, so that they are able to make programmes work for them (Archer 2010).

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Like many national curricula around the world, South Africa's curriculum is rich in environment and sustainability content. Despite this, environmental teaching and learning can be challenging for educators. This comes at a time when Sustainable Development Goal 4 via Target 4.7 requires governments to integrate Education for Sustainable Development into national education systems.

Teaching and Learning for Change is an exploration of how teachers and teacher educators engage environment and sustainability content knowledge, methods, and assessment practices in ways that support a call for quality education in support of ecological and social justice and sustainability.

The chapters evolve from a ten-year research programme led out of the DSI/NRF SARChI Chair in Global Change and Social Learning Systems working with national partners in the Fundisa for Change programme and the UNESCO Sustainability Starts with Teachers programme. They show the integration of education for sustainable development in teacher professional development and curricula in schools in South Africa. They reveal how university-based researchers, teachers and teacher educators have made theoretically and contextually reasoned choices about their lives and their teaching in response to calls for a more sustainable world in which education must play a role.

Teaching and Learning for Change will be of interest to education policymakers in government, advisors and educators in educational and environmental departments, NGOs and other institutions. It will also be of interest to teacher educators, teachers and researchers in education more generally, and environment and sustainability education specifically.

fundisa for change

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