Katrin Vohland · Anne Land-Zandstra
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Editors

The Science of Citizen Science

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Editorial: The Science of Citizen Science Evolves

Katrin Vohland, Anne Land-Zandstra, Luigi Ceccaroni, Rob Lemmens, Josep Perelló, Marisa Ponti, Roeland Samson, and Katherin Wagenknecht

What Is Citizen Science?

Citizen science broadly refers to the active engagement of the general public in scientific research tasks. Citizen science is a growing practice in which scientists and citizens collaborate to produce new knowledge for science and society. Although

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citizen science has been around for centuries, the term citizen science was coined in the 1990s and has gained popularity since then. Recognition of citizen science is growing in the fields of science, policy, and education and in wider society. It is establishing itself as a field of research and a field of practice, increasing the need for overarching insights, standards, vocabulary, and guidelines.

In the process reflecting citizen science and its practices, many questions arise. How old is citizen science? What is the difference, if any, between citizen science, participatory science, post-normal science, civic science, and crowd science? Is citizen science just a new political term in order to obtain funding? Some critics view citizen science as a renewed neoliberal approach to exploit citizens by making them work for free when data is a key asset of our century. These questions may not be fully answerable, but they surely deserve considered debate. These questions are a prime example of the need to maintain a lively discourse around citizen science, with as many practitioners as possible, and then bring together in a single book all these perspectives. Therefore, the present volume aims to offer to those who are new to the field of citizen science an overview of the different aspects of citizen science and the current developments and discussions in the field. The large number of chapters is an illustration of how diverse the citizen science world is and how many different aspects need to be considered when delving into the field.

This book attempts to handle in a holistic manner all dimensions of citizen science, starting with a detailed understanding of the concepts, of science, research, and knowledge. The ambition of this book is to provide a complete picture of citizen science, including the always important ethical aspects, as well as its controversial links with commercialisation and social outcomes as well as the application of different definitions as outlined by Haklay et al. in chapter 2. Cultural differences are also at stake, as seen in the Europe-wide understanding of citizen science, described by Vohland et al. in chapter 3.

The European Citizen Science Association (ECSA) has characterised citizen science (Haklay et al. 2020) based on the *ECSA 10 Principles of Citizen Science* for good practice (Robinson et al. 2018). This work provided the reference to build the different chapters in this book, addressing questions of power relations, data ownership, and political impact. The book aims to contribute to the good practice of citizen science in order to develop citizen science as an acknowledged and broadly practiced approach in universities, other research institutes, and civil society organisations. The scientific and epistemological benefits of citizen science for different disciplines are also addressed and critically reflected upon, mainly in the first part of the book. The second part of the book focuses on the societal impact of citizen science, with regard to policy, learning, and triggering (social) innovation. The tools and instruments that are appropriate to support and mainstream citizen science are elaborated in the third part of the book.

The Emergence of the COST Action Research Network

The present volume largely incorporates the research network of the COST (Cooperation in Science and Technology) Action CA15212 *Citizen Science to Promote Creativity, Scientific Literacy, and Innovation throughout Europe* and includes additional authors in order to provide a complete and coherent scholarly book on citizen science.

A European Union (EU)[1] programme, COST includes tools for networking to improve scientific excellence and scientific integration in Europe. It started in 1971 and has supported the development of the European Research Era (ERA) in two key areas: (1) scientific excellence and innovative power and (2) inclusiveness. COST has 38 member countries, and Israel is a cooperating partner (Fig. 1.1).

The main tool in COST are Actions, which are networks that are supported by funding for travel costs for workshops and training schools, and also scientific exchanges which are called Short Term Scientific Missions (STSM). The member countries nominate the members of each Management Committee (MC) – the key decision-making body of each Action. The vision of COST is to support innovative,

Fig. 1.1 European Union member countries during the key phase of COST Action CA15212 (the UK left the EU on 1 February 2020) and member countries of COST. Except for Moldova and Iceland, all COST countries are members of CA15212. Country data: World Bank Official Boundaries; COST data from www.cost.eu

[1] https://www.cost.eu/

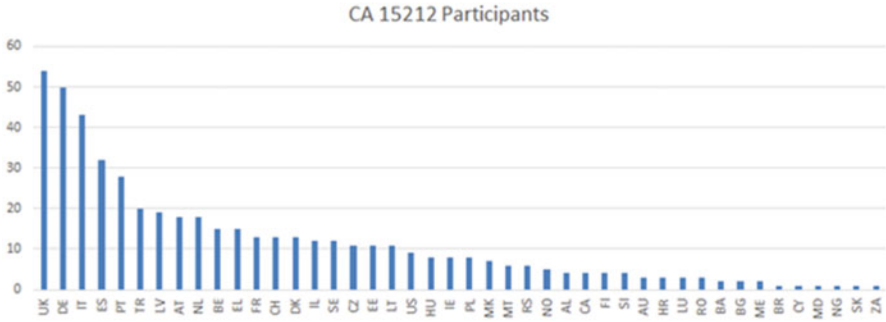

Fig. 1.2 Number of participants in the COST Action CA15212, ordered by country affiliation (internal administrative data – E-Cost, 14 February 2020)

interdisciplinary, and new topics, which might be high risk because they are not yet established in the scientific mainstream (COST 2016). COST Actions can be a valuable tool to increase and deepen networks and, through enhanced knowledge flow, support innovations (Morone et al. 2019).

Therefore, a COST Action seemed an appropriate tool to advance the reflections on the different dimensions of citizen science which emerged in the ECSA working groups. Subsequently, driven by Marisa Ponti, Claudia Göbel, and Katrin Vohland, a proposal was developed that resulted in the COST Action CA15212.[2] This COST Action addresses the relationship between citizen science and topics such as policy, education, research quality, and data standards. COST, as an instrument of the European Commission (EC) to support European excellence and coherence, has its own dynamics.

A recent study revealed an important function of COST: allowing especially women, young researchers, and researchers from so-called Inclusiveness Target Countries (ITC; see Box 1.1), to join new networks (Knecht et al. 2019). This is reflected in our COST Action. While the development of CA15212 was based on members of ECSA and its working groups, finally, participants from 43 countries contributed (Fig. 1.2). Within the last few years, the network has expanded into the Baltic states, as well as into Eastern and southern Europe, as described in more detail in chapter 3.

Box 1.1: Inclusiveness Target Countries (ITC)
ITCs, or *widening countries*, are those countries whose performance in science and technology was below 70% of the European average (EC 2019), based on a 2013 pan-European comparison of indicators. They included *research and development intensity*, measured as a percentage of expenditure of the gross

(continued)

[2] https://cs-eu.net/

Box 1.1 (continued)
domestic product (GDP); economic impact of innovation, for instance, measured by the number of patents; and *research excellence*, as indicated by highly cited publications using Scopus data and the number of top scientific universities and other organisations (EC 2013). Within the framework of the COST Action, ITCs receive tailored support and have certain privileges, for instance, funding to attend conferences (ITC Conference Grants).

This network also led to the pan-European capacity building platform EU-Citizen.Science, which emerged in response to an EC call to understand citizen science, its functions, preconditions, and quality criteria.

Part I: Citizen Science as Science

Until recently, citizen science has been recognised mainly in the natural sciences and local history. The contributions of citizens to science often remained hidden, as citizen scientists were seldom (co)authors or appeared in the methods or acknowledgements; only their data was visible (see Cooper et al. 2014). With a strong tradition of academia in Western societies, the increasing accessibility of digital tools and data, and the growing visibility of citizen scientists, the number of publications increased. A search of the ISI Web of Knowledge revealed 2625 publications of which 1028 could be attributed to European first authors (Fig. 1.3). The UK had the earliest citizen science publications and the highest number of publications. This may be due to the fact that citizen science is an English term and does not need to be translated, but also to the UK's long tradition of learned associations and other forms of citizen science.

The expansion of citizen science has resulted in debate about the scientific qualities of the contribution of citizens. This does not pertain only to data quality, but is linked to the scientific idea itself. In the majority of cases, citizens contribute data to an established research question, which leads to statements from scientists such as 'you don't get eureka moments' (Riesch and Potter 2014, p. 8). In fact, science does not only mean contributing to a specific question, but a deep knowledge of the whole field, its methods, its history, its literature, its discourses. This takes time, for which scientists are paid, and citizen scientists are not.

Therefore, the first part of this book addresses how citizen science has become a part of modern science and considers the issues around integrating its methods, models, and results into conventional ways of thinking in the different branches of scientific practice.

Chapter 4 is about the philosophy of citizen science and how it facilitates the generation of knowledge by those who have an interest in the topic, but are not

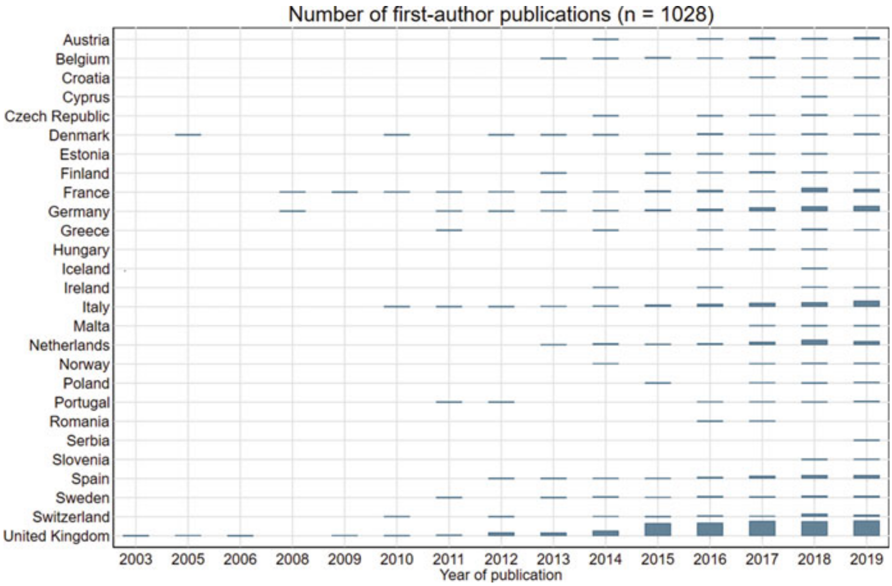

Fig. 1.3 Records for the topic 'citizen science' with a European first author; (n = 1028), retrieved from ISI Web of Knowledge, 8 November 2019

necessarily professional scientists. This leads to several issues in governing science, especially when *knowledge as a commons* is seen as a public good.

The first part of the book also highlights the different aspects of the natural sciences, the humanities, and the social sciences. In chapter 5, citizen science is viewed against the background of the natural sciences: observing and understanding phenomena, testing hypotheses, and performing experiments. Different research approaches and *citizen engagement* are described in terms of their challenges. Chapter 6 introduces the role of citizen science in the humanities as *citizen humanities*, in which citizens are involved in the activities of cultural heritage institutions and tapping local knowledge. Here the challenges are participant retention and the adaptation of new digital technologies. Chapter 7 notes that the underlying approaches in citizen science are already present in the social sciences and introduces the term *citizen social science*, elaborating on its epistemic foundations and its key issues.

Technology also plays an important role in the advancement of citizen science as a science. It advances the way data is collected and how it is processed, analysed, and integrated with other data. The first part of the book, therefore, introduces a selection of techniques relevant for citizen science and highlights key issues that play a role in the interaction of human users with technology and citizen-generated information. Chapter 8 discusses how data quality is perceived amongst different stakeholders and participants and explains how the validity and reliability of citizen-generated data can be ensured, thus providing recommendations for project implementers. In chapter 9, a conceptual model is proposed to achieve a common understanding and representation for citizen science projects, their participants, and their outcomes. Based on international standards of data interoperability, this model is designed for information sharing amongst citizen science projects. Chapter 10 provides an overview of *machine learning* techniques that can be deployed to support citizens in analysing big data by classifying data and predicting results. The chapter raises issues around trusting these methods and how to acknowledge citizens who provide input to the machine learning process.

When it comes to scientific collaboration in citizen science, there is a variety of participatory methods and stakeholder objectives that do not necessarily align with those in conventional scientific collaboration. Chapter 11 presents, with the help of four case studies, the concept of *co-creation* and posits that the citizen science process should be flexible and adaptive throughout a project. For this, an infrastructure is needed that supports communication, tooling, and decision-making. More cross-disciplinary science is discussed in chapter 12, in which citizen science, health, and environmental justice intersect in both observational and interventional studies. Considering environmental justice aspects in citizen science activities can result in disagreements, which bring the need to reconcile discrepant project aims, data-sharing conditions, and the involvement of commercial activities. The authors place citizen science in the context of neoliberalism, and the degree of accountability of individuals, as they discuss the challenges of different participation models.

Part II: Citizen Science in Society

Citizen science is not just a participatory way to contribute to scientific knowledge, but also an effective way to address a wide collection of societal challenges. The explicit commitment of societal actors marks a significant difference between citizen science and most of the standard approaches in scientific research practices. Therefore, citizen science represents a collective endeavour that, in some cases, improves *science, technology, engineering, and mathematics* (STEM) formal and informal learning, while, in others, it can harness and better connect scientific evidence to policymaking, social innovation, and even social activism. Efforts to connect science to society require a flexible and adaptive set of methodologies and perspectives, which need to be deeper explored and constantly revisited.

Citizen science fosters an open and participatory approach to science, reducing the distance between science and society, and contributing to the goal of an inclusive society. Together with public and private actors, citizen scientists can play a role in developing society, improving communities, and promoting public participation. Therefore, when considering the full potential of citizen science, we should focus not only on answering scientific questions and generating valid data but also on the possible pressures, drivers, and effects on society and social innovation. Citizen science needs to continue to engage as many segments and actors in society as possible.

The second part of the book includes eight chapters that address the societal role of citizen science and its current limitations in terms of inclusion and equal participation. It also highlights which social and technological changes impact citizen science. Some of the chapters in this part of the book examine the role of citizen science in four societal realms: policy, education or learning, social innovation, and non-governmental organisations (NGOs). The rest of the chapters focus on ethics, inclusiveness, and participation, which are three fundamental democratic values on which any citizen science initiative must be based.

Chapter 13 focuses on the always challenging concept of participation by recognising the importance of considering the perspectives and experiences of citizen science participants. It discusses the gap separating researchers from citizens, where the former do not always use the data collected by the latter. The chapter also provides guidelines and recommendations for project leaders before they begin new citizen science initiatives. Chapter 14 broadens the perspective to inclusiveness. It discusses how diversity can be enhanced, with a special emphasis on the gender perspective. Since citizen science projects offer participants the opportunity to play a role in a scientific investigation, they also offer opportunities for learning about science. Citizen science provides a variety of contexts in which science learning can occur. In chapter 15, Kloetzer et al. chart forms of learning through citizen science in six *territories*, according to where learning might take place, ranging from schools to zoos and botanic gardens. While they present opportunities, they also highlight key tensions arising from citizen science projects in educational settings and look at training different stakeholders as a potential strategy to overcome some of these tensions.

As learning goes beyond personal learning, the involvement of citizens with the broad concept of social innovation is examined in chapter 16. Here, Butkeviciene et al. use three analytical dimensions – content, process, and empowerment – to examine the relationship between citizen science and social innovation in five case studies in different countries. As a result of their analysis, the authors identify opportunities and challenges for citizen science to stimulate social innovation through a specific list of projects. Citizen science can be a tool for community change by involving citizens in various forms of participatory research together with different social actors, in addition to universities and research centres.

However, in chapter 17, Göbel et al. lament the prevalent depiction of citizen science as mainly involving researchers and volunteers while neglecting the role of civil society organisations (CSOs) and failing to consider the breadth and diversity of participatory research activities citizen science includes. The authors present two case studies to illustrate how CSOs can be involved in participatory research, making it possible to transform scientific knowledge and empower social groups. Issues of the legitimacy of research conducted by CSOs and power asymmetries between CSOs and research institutions are also discussed in the chapter. There are also power asymmetries between citizens and professional researchers.

The complex relationship between citizen science and policy needs interrogating, and this is described by Schade et al. in chapter 18. The authors focus on pressing challenges concerning the relationships between citizen science and policy in the current European policy landscape, characterised by geographical, social, and political diversity. The chapter provides a set of recommendations for possible actions to build and sustain existing relationships. Chapter 19 identifies six key pathways to environmental impact: environmental management; evidence for policy; behaviour change; social network championing; political advocacy; and community action. The attributes of projects that generate impact through the pathways are explored, and, subsequently, these impact pathways are aligned with target audiences.

Chapter 20, the last chapter in this part of the book, links to Part III and provides a critical debate on how ethical challenges should be tackled in citizen science projects. The importance lies in keeping equitable social balances and power relations between participants and citizen science project leaders. Tauginiene et al. start this challenging discussion on theory and practice by exploring dynamic informed consent, which is capable of adapting to the emergent issues during citizen science project evolution.

Part III: Citizen Science in Practice

The third section of the book addresses the question of what is needed to initiate, develop, and successfully implement citizen science projects. The chapters discuss different tools and instruments, which in various ways contribute to the success of a citizen science project.

The heterogeneity of citizen science is particularly evident in its practical activities. If one looks at the projects and what is negotiated in them, one gets an impression of the diversity that, contrary to expectations, enriches citizen science as a method. At the same time, citizen science calls for inclusivity, which must be continuously demanded and achieved with regard to practices, content, and methodological procedures. Against this background, there are particular demands on the tools and instruments that serve the practical implementation of citizen science: guidelines, tools, platforms, and apps. Specific challenges also arise around communication – an integral part of citizen science – and the evaluation of research. Communication in the field of citizen science inevitably means more than just publishing results; if motivating potential participating citizens fails, there will be no citizen science project. If one understands citizen science as a strategy of science communication, new possibilities and horizons for discussion and dissemination open up. Addressing many and different target groups is a unique challenge for practitioners. The same is true for evaluation, which requires new methods to account for participatory approaches.

An increasing number of institutions, including government agencies and research funders, are showing an interest in the field of citizen science. This interest is often driven by a desire for positive impact, and the expectation that citizen science projects can deliver this. There is indeed a rich literature of citizen science case studies that have led to change by raising awareness and influencing management practices and policy. However, many projects have delivered limited impact (despite often ambitious project aims) due to the lack of public uptake, lack of stakeholder interest, or insufficient data quality.

Chapter 21, on guidelines, proposes a categorisation: general guidelines and specific guidelines. Examples are assigned to this basic categorisation. Especially interesting is the practical example about the process of defining criteria for categorising citizen science resourcing. This example turns the approach around and presents a qualitative description of guidelines. Chapter 22 focuses on different kinds of citizen science platforms. The platforms addressed are those which display citizen science data and information; provide practical examples and toolkits; collect relevant scientific outcomes; and are accessible to different stakeholders, ranging from interested citizens to scientific institutions, authorities, politicians, and public media. Mobile and web apps have become mainstream in information provision. In chapter 23, the authors highlight the added value of mobile and web apps for citizen science. An overview of app types and their functionalities is provided to facilitate potential users in selecting apps based on their needs.

Chapter 24 discusses the need for successful communication and public relations in citizen science projects. For the authors, excellent communication means that people have listened, understood the content, and acted accordingly. The authors discuss examples, such as storytelling and vlogs, and address the challenges of communication. In the same way that communication has to be continuously adapted to the project content and the target groups, the evaluation of the projects has to be rethought. In chapter 25, the authors discuss a participatory approach to evaluation, which takes into account citizen science as participatory practice.

Conclusion

Citizen science adds value to many scientific activities and links epistemic outputs with societal values – ranging from personal growth and learning to social innovation and policy impact. However, there are some scientific areas where citizen science may provide fewer options for citizens to participate. Also, citizen science practices should not be seen as a way to save money in scientific research efforts, such as (environmental) data collection (Lave 2017).

Generally, though, citizen science provides – and increases its potential to provide – a wealth of untapped options for science: to increase its knowledge foundation, to increase its self-reflexivity, and to tackle sustainability challenges. This book can be used as a tool to enhance the value of citizen science, providing not only scholarly insights but also practical tools for capacity building; technical aspects; ethical issues; and relevant communication, inclusion, and evaluation matters. These capacities are necessary to elevate the quality of citizen science so that it is acknowledged in the scientific, social, and political arenas. In a concluding chapter, final thoughts are offered on the trends and the futures of citizen science to support the further development of citizen science participatory practices.

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Chapter 2
What Is Citizen Science? The Challenges of Definition

Mordechai (Muki) Haklay, Daniel Dörler, Florian Heigl, Marina Manzoni, Susanne Hecker, and Katrin Vohland

Abstract In this chapter, we address the perennial question of *what is citizen science?* by asking the related question, *why is it challenging to define citizen science?* Over the past decade and a half, we have seen the emergence of typologies, definitions, and criteria for qualifying citizen science. Yet, citizen science as a field seems somewhat resistant to obeying a limited set of definitions and instead attracts discussions about what type of activities and practices should be included in it. We explore how citizen science has been defined differently, depending on the context. We do that from a particularly European perspective, where the variety of national and subnational structures has also led to a diversity of practices. Based on this background, we track trade-offs linked to the prioritisation of these different objectives and aims of citizen science. Understanding these differences and their origin is important for practitioners and policymakers. We pay attention to the need for definitions and criteria for specific contexts and how people in different roles can approach the issue of what is included in a specific interpretation of citizen science.

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Keywords Citizen science terminology · Quality criteria · Cultural differences · Policy applications

Introduction

The first recorded use of the term citizen science in the form that we currently use can be traced to three decades ago, according to the researchers of the *Oxford English Dictionary* (OED). The term appeared in an issue of the *MIT Technology Review* from January 1989. The article 'Lab for the Environment' covers three examples: community-based laboratories that explore environmental hazards, laboratory work by Greenpeace, and Audubon's recruitment of volunteers in a 'citizen science' programme. With regard to the latter, it states: '"Speed is also crucial to the Audubon Society's acid-rain campaign. Government studies sometimes withhold data for years", says Audubon vice president Robert San George. Audubon involves 225 society members from all 50 states in a "citizen science" program that gets information out within five weeks. Volunteers collect rain samples, test their acidity levels, and report the results to Audubon headquarters, which releases a monthly national map of acid-rain levels. The information is used to lobby Congress' (Kerson 1989, p. 12).

This origin story provides an indication of what citizen science is: it includes the generation of scientific data (through the testing of the acidity of rainwater), engages volunteers over a large area (the continental USA), and addresses a politically relevant issue (acid rain and the lobbying process to reduce it). Yet, as we look through a table of definitions of citizen science – which were taken from influential actors and documents (Table 2.1) – a pattern starts to emerge. While all these definitions have things in common – in particular, a notion of a public that participates in an activity called scientific research – most of them are imprecise and open to interpretation. We will come back to look at these definitions, but, as a starting point, we should recognise that there is an inherent challenge in providing an exhaustive definition of citizen science encompassing the many different purposes and approaches applied to even more diversified contexts. It is important for practitioners and policymakers to understand these differences so that they can navigate and support the full breadth of opportunities available in and through citizen science.

From the collection in Table 2.1, it is clear that a definition of citizen science includes an instrumental side: it must reflect the objectives of the actors and the extent of the engagement of citizens in the different processes generating scientific knowledge. This means that citizen science (and its definitions) needs to encompass and promote an open and broad understanding of manifold research practices and participatory activities that can take place when people, who are not tasked with carrying out research as part of their paid work, get involved in research. This multiplicity of definitions is essential to the development of citizen science – its enabling frameworks and mechanisms and the different needs of specific fields of application. For example, when applying for European Union (EU) funding for a citizen science project, the *White Paper on Citizen Science for Europe* (Serrano Sanz et al. 2014) definition might be the best one to use. Alternatively, when addressing

Table 2.1 Selected definitions of citizen science

1	*Oxford English Dictionary* (2014)	Scientific work undertaken by members of the general public often in collaboration with or under the direction of professional scientists and scientific institutions
2	Wikipedia (2005)	A project (or ongoing program of work) which aims to make scientific discoveries or verify scientific hypotheses
3	Wikipedia (2019)	Scientific research conducted, in whole or in part, by amateur (or nonprofessional) scientists
4	*National Geographic Encyclopedia*	Citizen science is the practice of public participation and collaboration in scientific research to increase scientific knowledge. Through citizen science, people share and contribute to data monitoring and collection programs
5	Australian Citizen Science Association	Citizen science involves public participation and collaboration in scientific research with the aim to increase scientific knowledge. It's a great way to harness community skills and passion to fuel the capacity of science to answer our questions about the world and how it works
6	European Citizen Science Association	Citizen Science – the participation of the general public in scientific processes... an open and inclusive approach, for example, by supporting and being part of the exploration, shaping, and development of the different aspects of the citizen science movement, its better understanding, and use for the benefit of decision-making
7	European Citizen Science Association	Citizen science projects actively involve citizens in scientific endeavour that generates new knowledge or understanding
8	Citizen Science Association (US)	Citizen science is the involvement of the public in scientific research, whether community-driven research or global investigations
9	Group on Earth Observations Citizen Science Working Group	Citizen science encompasses a range of methodologies that encourage and support the contributions of the public to the advancement of scientific and engineering research and monitoring in ways that may include co-identifying research questions; co-designing/conducting investigations; co-designing/building/testing low-cost sensors; co-collecting and analysing data; co-developing data applications; and collaboratively solving complex problems
10	United Nations Environmental Programme (UNEP) (2019)	Citizen science entails the engagement of volunteers in science and research. Volunteers are commonly involved in data collection but can also be involved in initiating questions, designing projects, disseminating results, and interpreting data

(continued)

Table 2.1 (continued)

11	UNESCO (2013)	The participation of a range of non-scientific stakeholders in the scientific process. At its most inclusive and most innovative, citizen science involves citizen volunteers as partners in the entire scientific process, including determining research themes, questions, methodologies, and means of disseminating results
12	US *Crowdsourcing and Citizen Science Act* (15 USC 3724) (2016)	The term citizen science means a form of open collaboration in which individuals or organizations participate in the scientific process in various ways, including (A) enabling the formulation of research questions; (B) creating and refining project design; (C) conducting scientific experiments; (D) collecting and analysing data; (E) interpreting the results of data; (E) interpreting the results of data; (F) developing technologies and applications; (G) making discoveries; and (H) solving problems
13	Citizenscience.gov (US)	In citizen science, the public participates voluntarily in the scientific process, addressing real-world problems in ways that may include formulating research questions, conducting scientific experiments, collecting and analysing data, interpreting results, making new discoveries, developing technologies and applications, and solving complex problems
14	US National Institutes of Health	Citizen science efforts are driven by community concerns. These community-led projects may involve a partnership with an academic or research institution, where both parties work together to collect and share data. The goal is to address a community concern through collaborative research and to translate the research findings into public health action that benefits the community
15	US Environmental Protection Agency (EPA) (2018)	Citizen science is a form of open collaboration in which individuals or organizations participate voluntarily in the scientific process in various ways, including collecting and analysing data. Citizen science provides a way for members of the public to participate and support EPA programs
16	The US National Aeronautics and Space Administration (NASA)	Citizen science is defined as a form of open collaboration in which individuals or organizations participate voluntarily in the scientific process in various ways. This policy defines citizen science projects as science projects that rely on volunteers
17	US National Oceanic and Atmospheric Administration (NOAA)	Citizen science is defined as a form of open collaboration where members of the public participate in the scientific process to address real-world problems in ways that include identifying research questions, collecting and analysing data, interpreting results, making new discoveries, developing technologies and applications, and solving complex problems

(continued)

Table 2.1 (continued)

18	The US National Academies of Science (2018)	The involvement of the broader public in the research enterprise
19	EC Environment (2013)	Citizen science encompasses many different ways in which citizens are involved in science. This may include mass participation schemes in which citizens use smartphone apps to submit wildlife monitoring data as well as smaller-scale activities
20	Socientize (2014)	Citizen science refers to the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources
21	EU (2016)	Inclusion of non-institutional participants, in other words the general public, in the scientific process
22	EU (2017)	Citizen science – where citizens become providers and users of data. This will reinforce and give new meaning to the policy of open access to publications and data; this openness should enable citizens and citizen groups to participate in evidence-based policy and decision-making
23	EU (2019)	More and more Europeans hold higher education degrees. Enabled by digitalisation and knowledge, citizens are today prosumers capable of shaping the innovation process and bypassing restrictive practices of established sectors and governments. This goes well beyond citizen science and covers the entire research and innovation process
24	OSPP (2018)	Broadly defined, citizen science is 'scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions'. Citizen science is an already very diverse practice, encompassing various forms, depths, and aims of collaboration between academic and citizen researchers and a broad range of scientific disciplines. Civic participation in research can range from short-term data collection to intensive involvement in the research process, from technical contribution to genuine research, and from collaboration to co-creation of knowledge. Yet, there is still a need to define and establish citizen science as a genuine, open research approach
25	G7 Science Academies (2019)	... Two categories of citizen science. The first one, which is predominant, is participatory research done by citizens who have not necessarily received training in scientific research. It was this activity that has been historically named 'citizen science'... A second and more recent category of citizen science involves scientifically trained individuals working in isolation, or in virtual communities, to develop

(continued)

Table 2.1 (continued)

		projects outside established controlled environments (university, government, or industry research system)
26	OECD (2017)	At the heart of the scientific process, it can be more narrowly understood as people, who are not professional scientists, taking part in research, i.e. co-producing scientific knowledge. This involves collaborations between the public and researchers/institutes but also engages governments and funding agencies
27	Science Europe (2018)	The practice of citizens performing science and of scientists working together with citizens
28	LERU (2016)	Citizen science, the active involvement of nonprofessional scientists in research... The boundaries of what can rightly be termed citizen science are debatable, but there is broad consensus that projects should involve voluntary and active public engagement with research
29	RAND Corporation (2017)	Citizen science takes open science activities beyond the purview of professional scientist circles by exploring the involvement of citizens in scientific research and the implications of these activities on and within society
30	*Green Paper Citizen Science Strategy 2020 for Germany* (2016)	Citizen science describes the process of generating knowledge through various participatory formats. Participation can range from the short-term collection of data to the intensive use of leisure time to delve deeper into a research topic together with scientists and/or other volunteers, to ask questions, and to get involved in some or all phases of the research process
31	UK Parliamentary Office of Science and Technology (POST) (2014)	Environmental citizen science – the involvement of volunteers in environmental monitoring
32	UK Environmental Observation Framework (2012)	Citizen science, broadly defined as the involvement of volunteers in research
33	Nesta (2019)	Citizen science is any process where scientists and the public process scientific data or observations. Citizen science (usually unpaid) volunteers work together to collect or unlock new resources for research, experimentation, and analysis by opening the process to everyone
34	*Environmental Science & Technology* journal (2007)	According to Wikipedia, the term citizen science refers to a program in which a network of volunteers, many of whom have little or no specific scientific training, perform or manage research-related tasks, such as observation, measurement, or computation

For the sources of these definitions, please see the information on GitHub (Haklay et al. 2019) engagement in policy, the definition developed by the Open Science Policy Platform (OSPP – see Table 2.1) in 2018 could provide a good example. In short, fitness for purpose is an important aspect when choosing a definition to be used in a given context.

At the same time, the definitions also provide descriptive elements, outlining certain features of the research collaboration, which is especially clear in the case of the *Oxford English Dictionary* (2014), where the aim is to provide an explanation of the term, as well as in the case of Wikipedia. Finally, all the definitions also have a normative aspect. The normative aspect of the definitions lies in setting the expectations of the different actors within a citizen science project, for example, alignment with matters of concern (Liu and Kobernus 2017; Balestrini et al. 2015), legal alignment (Rogers 2010) and normative pressure (Venkatesh et al. 2003), and alignment to social norms (Venkatesh and Davis 2000; Fishbein and Ajzen 1975) and social factors (Thompson et al. 1991).

Our aim in this chapter is to explore the ambiguity of citizen science definitions, and, instead of narrowing it down by providing a set of criteria to frame citizen science, we want to explore what it tells us about the field and how it is articulated in different contexts under different conditions. This has important implications for those involved in doing citizen science. On the one hand, the lack of a concrete definition is a problem for people who are interested in learning about the field, providing policy support, or creating funding programmes. On the other hand, because the activities of citizen science cover a wide range of academic research fields – each with its own objectives, worldview, and approach to the construction of knowledge (what is known as epistemology), methodologies, and classification of the world (known as ontology) – a single or narrow definition would risk the exclusion of a variety of activities from citizen science. This is a concrete problem, since with the increasing availability of funding for citizen science projects, excluding an activity through a given definition can cause its exclusion from funding. Those applying for citizen science funding need to be aware of these differences for their applications to be successful. This can also create antagonism between different practitioners when engaging the public in research, therefore reducing the growth of citizen science in new areas of activities (amongst other things).

We also need to emphasise, from the start, the best practice principles that were established by the European Citizen Science Association (ECSA) to provide guidance on the fundamental principles and elements expected of a good citizen science project – these are widely known as the *ECSA 10 Principles of Citizen Science*. As Robinson et al. (2018) point out, there are many caveats to these principles, and they are not a replacement for a clearer articulation of citizen science in a form that fits into specific contexts and needs. We are therefore not aiming to replace or challenge these principles, rather to extend the discussion about the nuance which we need to consider when applying them.

This discussion, and the mapping approach, proposed later in this chapter, could also support the integration and, hopefully, mainstreaming of citizen science concepts and practices within the implementation of European and national research and innovation programmes. Furthermore, discussion and mapping could contribute to

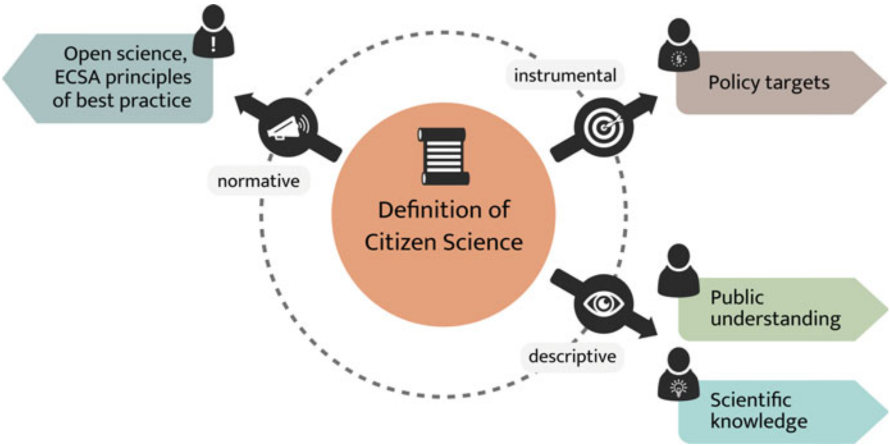

Fig. 2.1 Dimensions of definitions

deeper research in this field, enriching the evolution of citizen science understandings, definitions, and practices over the next decade in Europe.

We therefore try to demonstrate the complexities of defining citizen science while, at the same time, providing some directions and useful information that could help practitioners, scientists, and policymakers to make sense of the multiple approaches in citizen science and the factors that affect its relevant and effective application to the given contexts.

To achieve this, the chapter will cover four aspects. Since the origins and earlier examples of citizen science dated to the mid-1990s have been well rehearsed (e.g. Cooper and Lewenstein 2016), we turn to the challenges of definitions. Using the set of definitions presented in Table 2.1, we highlight some of the challenges and inconsistencies that these definitions reveal, as well as their instrumental, descriptive, and normative aspects (Fig. 2.1). Next, we show the variety of understandings of citizen science in various European countries and then pay special attention to the development of quality criteria for listing a project on the Austrian citizen science platform *Österreich forscht* as one of the first examples of articulating criteria for citizen science projects. In addition, the development of the criteria led to a noteworthy discussion within the citizen science practitioners' community. With these examples and context, we move to the final part of the chapter, in which we try to reconcile these apparent contradictions and challenges in a discussion that maps the roles and constraints of different actors and the way that they have developed (and will develop) criteria and definitions that are fit for their specific context, culture, and practice.

The Challenges and Dimensions of Definitions

The overview of nearly 35 definitions in Table 2.1 – collected from multiple sources and originating from the efforts of Auerbach et al. (2019) – presents the range of definitions within the field of citizen science (see Haklay et al. 2019 for further details). The compilation is not a systematic collection of definitions, rather a curated list that covers different areas of the world, areas of policy, and a variety of sources – most of them have either policy or practice impacts. They include definitions that were created by practitioner associations, within laws and regulations, in official reports that are aimed at policy impact, and in widely used references in the research field.

Our aim is not to carry out a full content analysis of the definitions – such an analysis of the term *citizen science* can be found in Hecker et al. (2019) – but to use this collection to examine some of the issues that emerge from even a cursory analysis of it. In particular, we will look at the descriptive, instrumental, and normative aspects of the different definitions. Following this examination, we look at what such aspects tell us about epistemology, methodology, and social practice and possible impacts on the given context of application.

The set of definitions is organised as follows: 1–4 are taken from reference sources; 5–8 are from citizen science associations; 9–11 are from global multinational organisations; 12–18 are from the USA where the *Crowdsourcing and Citizen Science Act of 2016* (12) has impacted federal agencies (13–18); 19–24 are from the European Commission and its related bodies; 25–29 are from science-focused bodies; 30–32 provide national examples from Germany and the UK; and the list closes with Nesta, the influential UK innovation charity, and an early example of citizen science in an academic journal editorial in 2007.

All the definitions have a descriptive element – they are trying to describe the type of activity that is termed ‘citizen science’. This is in particular the case for dictionaries and encyclopaedias (1–4). Note, for example, the more generic approach in definitions 1–3, where the participation is in ‘scientific work’ (whatever that is), in comparison to the more environmentally focused definition from the *National Geographic*, where the work is ‘data monitoring and collection’. This descriptive tension can also be noted across other definitions, such as the EU (19 and 22) definitions that focus on data collection practices, in comparison to the generic definitions in 21 and 24. Overall, the more generic and open definitions seem to be more common.

The definitions also have an instrumentalist aspect, which especially stands out in the case of US agencies’ definitions (12–18) where the agencies adopt a version that matches their goals and objectives – notice how the US National Institutes of Health definition (14) is clearly linked to community-based participatory research, a long-standing focus of the US National Institute of Environmental Health Science. Another instrumentalist focus is about the expectations of the definition’s writer(s) from citizen science – for example, the EU Lamy report (22) sees the value in participation in evidence-based policy and decision-making.

Finally, across the definitions there are normative aspects of citizen science that are included – for example, the expectation that the participants are volunteers, which is noted in 11 definitions (10, 11, 13, 15, 16, 28, 30, 31, 32, 33, and 34). However, the assumption about volunteering, in the sense of an unremunerated activity, as a prerequisite to participation is problematic when working with marginalised and socially disadvantaged groups, who might need to be compensated for the time that they are dedicating to the project, or when the project is community led and executed to support community aims. Indeed, the community-oriented definition of the US National Institutes of Health (14) does not mention volunteering. Another normative aspect is the role of citizen science within *open science*, such as in the RAND Corporation (29), where it is taking science beyond the control of professional scientists or opening science – which is also recognised by the G7 science academies (25). The G7 definition mentions that citizen science works outside the 'established controlled environment' of universities and research institutions. Thus, both the RAND and G7 definitions and documents point to the benefits but also the risks of research activities that are happening outside regular actors in the research process. There is also an indication of different levels of engagement – for example, the UNESCO definition (11) points to citizen science's potential as a most inclusive and innovative form of participating in science and is thus clearly elevating the value of such a deep engagement.

Beyond their descriptive, instrumental, and normative elements, the definitions also help demonstrate the deeper challenges of defining citizen science – these go to the heart of the philosophy of science. The practices that fall under the term citizen science cross many disciplinary boundaries in academia. While the world of research and science is divided between humanities, social sciences, and science, the participants might have multiple interests – a variety that is represented by the diversity of citizen science platforms. Thus, on the Zooniverse platform, we can find projects in all these areas. Indeed, when we look within scientific disciplines, we can find citizen science projects in physics, life science, medicine, ecology, biology, and many other fields. The modern research enterprise is structured around disciplines – from university departments to funders and to academic journals – all are geared towards specialisation in disciplines and subdisciplines, and activities that cross multiple disciplines (interdisciplinary activities) continue to require special support. This clash – between well-established academic structures and the practice of citizen science across research areas – is the source of a challenge in the definitions.

We can start by looking at the epistemological challenge. Citizen science is an activity that engages with the creation of new knowledge, and here the meaning of 'science' is significant. In some definitions, it is the natural and life sciences that are included, while in others this is a reference to modern academic research in all its varieties – including social sciences and the humanities. For example, the Wikipedia definition from 2005 (2) expresses an expectation that the project should lead to scientific discoveries or verify a hypothesis – the hallmark of the natural and life sciences. The use of science (without the wider concept of research) also appears in all the definitions that are used by citizen science associations (5–8). An alternative emphasis is offered by the US National Academies (18) which talk about a generic 'research enterprise', as well as LERU's (28) use of 'research'.

On the methodological side, there is the question of what activities we can expect the participants to carry out. Here, some definitions are geared more towards the dominant ecological observational understanding of citizen science as mostly a data collection activity – for example, definition 31 from the UK Parliamentary Office for Science and Technology. Similarly, the definition from an editorial in the *Environmental Science & Technology* journal (34) also emphasises specific tasks – observation, measurement, and computation. Other definitions are aimed at a wider range of activities – here the Group on Earth Observations (9) and the *Crowdsourcing and Citizen Science Act* (12) are especially comprehensive in the list of tasks and activities – including collaborative solving of complex problems.

Finally, there is a social practice. When we looked at the normative aspect, we have noted the assumption that citizen science is a leisure activity and an expectation that the participants do not get any financial benefit from participation. Therefore, volunteerism is central to the understanding of citizen science. Other examples of social practices appear in definitions – for example, the linkage between citizen science and the research and innovation process. Definition 23, which comes from an EU document developing ideas for future research and innovation, suggests that there is a need to 'bypass restrictive practices of established sectors and governments'. Notice that this definition suggests that participation in the entire research and innovation process is 'beyond citizen science', thus revealing a restrictive conceptualisation of citizen science by the document authors as working within the boundaries of the established research system.

There are, of course, many other disagreements and inconsistencies within these definitions and beyond them, which the reader can use as a personal exercise (e.g. identifying ontological disagreements), but this is not the purpose of the analysis here. What we aimed to demonstrate is that defining citizen science is difficult, and it reveals as much of the author's or authors' perspectives, as it does about citizen science. We can now turn to look at the specific ways in which citizen science is understood across Europe.

Different Interpretations of Citizen Science in Europe

When we go beyond the collection of definitions, we can also observe different perceptions and foci, according to cultural differences and diversified contexts, in referring to and applying citizen science approaches, leading to the simultaneous use of different definitions.

For example, in Europe, according to the outcomes from a recent pan-European survey of citizen science strategies and practices in COST countries[1] (carried out as

[1]More details in Vohland et al., this volume, Chap. 1

part of COST Action CA15212 *Citizen Science to Promote Creativity, Scientific Literacy, and Innovation throughout Europe*, under Working Group 3 – Improve Society–Science–Policy Interface), the following definitions are de facto used or represent a starting point for the development of definitions in different European countries:

- ***Austria*** – refers mostly to the definition provided by the *White Paper on Citizen Science for Europe*, as a starting point for the development of citizen science practices applied to specific contexts (the Austrian case is discussed in detail below).
- ***Bosnia and Herzegovina*** – opted for the development of *dedicated* definitions, according to focus areas of applications like agriculture, urban management, energy consumption, and disciplines, e.g. social science.
- ***Czech Republic*** – uses the *ECSA 10 Principles of Citizen Science* as a starting point, especially when applying for EU funding, as these are widely acknowledged by the international community and funding bodies.
- ***Germany*** – framed citizen science in a strategic national process, as 'scientific activities including or initiated by persons not employed in the scientific system for that purpose'.
- ***Poland*** – uses a *descriptive* definition rather than a *normative* one, according to Arnstein's 'Ladder of Citizen Participation' (1969) and depending on the different focus activities, e.g. open education, creative commons, open access, and related actors like research and innovation funding, higher and general education institutions, et cetera.
- ***Slovenia*** – understands citizen science as the application of participatory approaches into research activities with a focus on policymaking. This implies the active involvement and empowerment of stakeholder communities (scientists, policymakers, and citizens), in the direct development of solutions, projects, policy strategies, and processes of common concern.
- ***Spain*** – uses the *White Paper on Citizen Science for Europe* as a basis, further complemented by specific definitions according to the focus areas or disciplines addressed, e.g. social science.
- ***Turkey*** – carries out citizen science as *contributory science*, whereby citizen science projects are designed by research scientists alone and the members of the public contribute (only) with very specific data.
- ***United Kingdom*** – in general, citizen science is seen as a participatory/engagement project, whereby the driver is the resulting benefit to be gained by the participants, both the scientists or the public. As noted in the definition table, in the UK there is a focus on environmental applications, with the UK Environmental Observation Framework leading with its own definition. The main science funder is developing its own strategy for supporting citizen science as part of a wider public engagement strategy.

These examples indicate that there is not a single definition or framework that is used for all cases. We can see that there are different starting points, and a number of criteria for defining citizen science across Europe, each with its own focus according to different contexts and objectives. We can expect that these multiple processes will mature over the coming decade, and we will then be able to analyse how these different trajectories influence the practices of citizen science and their impact on different stakeholder communities and their hosting ecosystems.

Even when citizen science is carefully framed, it still can be interpreted in many different ways. To better understand national and cultural differences in interpreting citizen science, we can have a look at an initiative in Austria to identify and define citizen science.

Österreich forscht, the platform for citizen science projects in Austria, was launched in 2014. From the beginning, the platform was committed to guaranteeing the quality of listed projects for the general public. Additionally, project leaders asked for transparent criteria to develop a common baseline for listing citizen science projects. When launching *Österreich forscht*, the platform coordinators evaluated projects for scientific and participatory aspects. However, these evaluations were not documented in a transparent manner. Therefore, in 2017 the selection process for projects listed on the platform had to be reconsidered.

From 2017 to 2018, so-called Quality Criteria for Citizen Science Projects on *Österreich forscht* (Heigl et al. 2018) were developed by the Austrian citizen science community in an inter- and transdisciplinary effort to secure the high quality of the projects that are presented on the platform. The process of developing criteria was designed in an open and transparent way. Representatives of 17 institutions collaborated in several personal and online meetings. Feedback loops for project leaders and the general public were conducted. Additionally, the international community was consulted via a workshop at the 2nd International ECSA Conference, held in 2018 in Geneva. This *co-creative* approach ensured the commitment of the Austrian citizen science community to implementing the criteria in their projects. To support the implementation process, guidelines and tutorial workshops were installed. The 1-year process led to a set of 20 criteria containing sections on scientific rigour, communication, cooperation, open science, transparency, and ethics.

The experiences during the process of developing the criteria motivated working group members to call for a similar process on an international level to strive for an internationally accepted definition of citizen science. This call was published deliberately as opinion in the *Proceedings of the National Academy of Sciences of the United States of America* (*PNAS*) in April 2019 (Heigl et al. 2019a). The publication of this opinion caused intensive debates within the international citizen science community on whether or not citizen science needs a definition at a general level and if the Austrian criteria are exclusionary and narrow or enable different forms of citizen science to be included. On a more specific level, this debate showcased how different conceptions and interpretations of citizen science can lead to serious misunderstandings, but also to new insights and positive reactions (Auerbach et al. 2019; Heigl et al. 2019b).

In particular, the topic that was most debated was the exclusionary nature of criteria, which reflected the different backgrounds of the participants in the discussion (and was eventually the catalyst for the development of the definitions in Table 2.1). While some argued that the Austrian criteria were too narrow and excluded many projects, others felt that the criteria were very open to different forms of citizen science coming from a wide variety of backgrounds with various goals. Furthermore, the perspectives and positions of the people who take part in citizen science projects were another topic of discussion – whereas some fear that institutional research will take over and define citizen science to the disadvantage of citizen- or community-led research, others want to ensure the scientific integrity of citizen science to build up trust in citizen scientists as well as funders and policies. A consequence of the process in Austria is that the listing of a project on *Österreich forscht* is perceived as a sign of quality by the Austrian citizen science community and also by the general public. This case shows how different contexts and backgrounds (e.g. country, discipline, non-institutional/institutional) can lead to very different interpretations of citizen science in general and the quality of assessment in particular. The publication of the quality criteria and the opinion piece started a discussion on what citizen science is and who should make this decision at an international level. Such a self-reflective process is very complex and is associated with extensive discussions on the characteristics of citizen science. However, this process is paramount for establishing a robust and approved scientific method that contributes to further increase in scientific knowledge. An emerging outcome of this discussion is the work that is being carried out within the ECSA Working Group on Citizen Science Networks. In this working group, citizen science platform coordinators are collaboratively designing an approach to find common criteria which should be the basis for their respective platforms to decide whether or not to list a project.

In summary, the publication of the criteria for citizen science projects provided an important impetus to intensively address the question of what constitutes a citizen science project and who must/can/is allowed to make this decision. This is an important step towards further developing citizen science and bringing the community closer together.

Definitions in Practice

So far, we have shown that the discussion about definitions of citizen science demonstrates the importance of reflecting on the boundaries of citizen science and makes it even more obvious that actors in citizen science – including policymakers, funding agencies, scientific communities, and practitioners – need to make transparent what they mean when talking about citizen science.

Definitions in Different Contexts

Definitions can have different functions, and they need to take into account the respective roles of those who provide a definition and the objectives in establishing the definition. The Austrian example showed the necessity of defining quality criteria in the operationalisation of citizen science as a starting point for further discussion. From this example, we have learned that definitions can be perceived as boundaries that are exclusive. Yet, they can also empower actors to create an identity within these boundaries, just as the Austrian citizen science community has done. Additionally, boundaries can also help to formulate transitions. Without definitions or characteristics, citizen science risks becoming an arbitrary term. Actors with an implicitly different understanding or conceptualisation of citizen science might fail in communication and collaboration due to misunderstandings. Ultimately, the citizen science community – including citizen science practitioners, researchers on citizen science, and funding bodies – risks becoming assailable in their work if the term citizen science is not characterised.

When developing, implementing, or adopting citizen science initiatives, a common understanding developed amongst the relevant stakeholders would be enough to identify the influencing factors and preconditions that facilitate the development of citizen science practices in given contexts, even if to reach such common understanding different definitions are used. It is with this spirit that a mapping of definitions against intended objectives, actors, and contexts could help practitioners in identifying and agreeing up front on a common understanding of the initiative to be carried out collectively and the pathway to follow for its development.

More recently, Manzoni et al. (2019) have conveyed the need to investigate opportunities and barriers concerning upscaling and spreading citizen science projects. Along these lines, recent research studies commissioned by the Joint Research Centre of the European Commission (Ideas for a Change, forthcoming[2]) identify a few important drivers when developing citizen science initiatives that are even more fundamental when talking about *spreading* in different contexts and *scaling* them at different geographical levels. These are, namely, demonstrating the usefulness, value, and benefits with respect to the matter of concern addressed by the initiative, its alignment to legal norms and social values, the ease of being understood, knowledge and resource sharing, and, last but not least, the narrative behind it and the communication material used to promote it.

All in all, we observe that even the definitions used by different European countries are not exclusive but rather complementary. These definitions are a mixture – starting with a more general and open defnition, which are complemented by more specific ones, when contextualisation is needed. From this example, we can take that there are no standalone definitions, but rather multiple combinations depending on the scale of contextualisation needed. The higher the contextualisation, the higher the mixture of definitions and criteria, in order to come to a dedicated one serving that specific context.

Table 2.2 attempts to map the different definitions identified in Table 2.1, by using a matrix based on a stepwise approach: first by grouping the definitions according to the different contexts – political, scientific, societal. These are then

[2]https://ec.europa.eu/jrc/communities/en/ecas?destination=node/4341

Table 2.2 Matrix of the function of definitions of citizen science, for different stakeholders and their hosting scientific-socio-economic ecosystems, alongside context objectives

Context	Objectives of the citizen science definition	Main actors	Who is expected to be influenced?	Examples (numbers refer to Table 2.1)
Political		Policy institutions, policymakers and officers, international organisations, NGOs	Policymakers and officers, and, indirectly, society at large	
	Awareness of policymakers and consensus building			ECSA definition (7), German green paper (30), Socientize 2014 (20)
	Criteria and legitimation for funding and specific fundraising schemes			*ECSA 10 Principles of Citizen Science* (7), ACSA (5), EU 2019 (23), OECD 2017 (26), US Act (12)
	Strategic positioning and steering of citizen science development			Citizen Science Association (8), US Citizenscience.gov (13), EU 2016 (21), *ES & TJ* (34)
Scientific		RTD institutions, universities/academies, individual researchers, and amateurs	Scientific communities and citizen scientists	
	Scientific and technical advances, knowledge and academic production			US NAS (15), Nesta (33)
	Definition of research field and area of application			UNESCO (10), GEO (9), US NOAA (16), UK POST (31)
	Self-identification as part of a (research) community			*National Geographic* (4), Science Europe (27), SCU (19), OED (1), Wikipedia (3)
Societal		Local communities, communities of practices, local administrators/	Citizens, local communities, their administrators, producers/suppliers/	

(continued)

Table 2.2 (continued)

Context	Objectives of the citizen science definition	Main actors	Who is expected to be influenced?	Examples (numbers refer to Table 2.1)
		policymakers, local agencies (cadastres, energy suppliers, etc.)	actors in the local ecosystem	
	Address specific community challenges			US NIH (14)
	Awareness and fundraising processes			US NASA (16), US EPA (15), EU 2017 (22)
	Increase of individuals' knowledge and communities' collective intelligence			RAND 2017 (29), UNEP GEO6 (10)
	Framing communication supports and alliances, networking with other actors			LERU (28), Wikipedia 2005 (2), G7 Science Academies (25), UKEOF (32)

used to identify a second level, which is around what the definition is used for (e.g. fundraising, policymaking, awareness, scientific advances, community challenges). We also identify who is expected to be impacted by each group of definitions.

Through this mapping exercise, we can see the types of definitions that can be used according to different objectives, depending on the roles of the different stakeholders that the definition is aimed at and those who are creating it.

The mapping, of course, depends very much on deciding what is the centre of gravity in each definition and matching it with the focus of the specific contexts. As this process is subjective, other interpretations are possible. In addition, the same definition can be mapped against different contexts and objectives, depending on the openness of the definition itself (although here they are linked to one context for the sake of clarity).

Through this initial mapping, we argue that even a limited subset of existing definitions covers all three identified contexts quite well, their descriptions address the objectives of the intended actions within the contexts, and the different stakeholders can identify themselves in terms of roles and values.

Learning from the Plurality of Definitions

In this chapter, we have explored the complexity of defining what citizen science is. We have done so by drawing out differences between organisations, countries, understandings, and stages of development of citizen science in a given place.

The diversified use of citizen science definitions clearly indicates that there is not a single definition that is used for all cases. We can see that there are different starting points and a number of criteria for defining citizen science around Europe, each with their own focus according to different contexts and objectives.

In this context, the COST survey mentioned above represents a snapshot of different practice developments in European countries. In some countries, citizen science is already a well-known concept, and more or less concrete understandings of citizen science have been developed (e.g. Germany, Austria); in other countries the community is starting to organise and exploring, adjusting, and implementing existing concepts of citizen science in their respective understandings (e.g. Lithuania, Denmark). This can be seen also with the *ECSA 10 Principles of Citizen Science*, which the Australian Citizen Science Association adjusted for their own needs. Some countries follow a top-down approach, where projects are defined by scientific communities or government agencies; other countries follow bottom-up, co-created approaches when a common challenge needs to be addressed by local communities. Also, sometimes the ownership, production, and use of data are the focal points for reaching a common understanding of what citizen science is. Consequently, the definition of citizen science varies from country to country and from community to community.

The development of definitions has no endpoint, and throughout the activities of the COST Action, we observed the continuous development of understandings and definitions. These definitions are instrumental to the purpose of the action and reflect the culture underpinning the specificity of the different contexts in which they are applied. Nevertheless, equally importantly, all of them try to address 'how' and 'to what extent' citizens are involved and participate in science.

It is also important to note that, currently, at international policy level – both in the United Nations system and in the European Commission – citizen science is seen as being part of a wider process called citizen-generated data processes and practices, thereby opening up the possibility of a much wider definition with respect to citizen science going forward. Also, great economic value is being attributed to this emerging source of data, in addition to scientific and social values, as a result of a collective intelligence effort. This development and the higher awareness of the role of information and the precious contribution from society pave the way for the increasing importance of a stronger and more relevant evidence-based policy formulation and implementation.

Conclusion

In this chapter, on the background of existing definitions of citizen science, we addressed the question *why is it difficult to define citizen science?* using theoretical, geographical, practical, and societal approaches. Since citizen science is currently developing so rapidly and the discussions about definitions and criteria are so lively, we have avoided narrowing this down to a single definition. We do not want to anticipate or disrupt the decision-making of the citizen science community with hypothetical recommendations while that community considers whether and how citizen science should be defined. Our hope is that we have invited readers of this chapter and book to reflect on the question of definitions of citizen science from their specific point of view and to recognise the possible intentions, challenges, and potentials of the current situation. However, we would like to emphasise that we expect the discussions to continue in an open, collegial, and fact-based manner, as they have done so far. Having an awareness of the current broad set of definitions in use in citizen science can also help practitioners and policymakers to navigate and support its diversity, as it continues to increase in its scope and scale.

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Chapter 3
Citizen Science in Europe

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Abstract In this chapter, we explore the landscape of citizen science across Europe, how networks have developed, and how the science of citizen science has evolved. In addition to carrying out a literature review, we analysed publicly available data from the European Commission's Community Research and Development Information

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Service (Cordis). We also extracted information from a pilot survey on citizen science strategies throughout Europe, carried out within the framework of the COST Action CA15212. Our findings are complemented by case studies from COST member countries. Finally, we offer some insights, considerations, and recommendations on developing networks, utilising the COST Action and EU-Citizen.Science as capacity building platforms.

Keywords European regions · Policy support · Institutionalisation · Research funding · ECSA · Community of practice (CoP) · Responsible research and innovation (RRI)

The Rise of Citizen Science in Europe

In Europe, the emergence of (citizen) science is strongly linked to the endeavours of a number of well-known individuals to explore the world during the Renaissance before the broader institutionalisation of science began. Leonardo da Vinci, for instance, experimented with scientifically innovative questions while making his living as an artist. Likewise, Sibylla Merian sold her drawings to raise the necessary funds for travelling to Suriname and studying insect metamorphosis. The disciplinary differentiation of research, together with the establishment of laboratory research in the twentieth century, increased the gap between institutionalised science and other parts of society, including what may be called *citizen science* (Strasser et al. 2019).

While the practices themselves are much older, citizen science as a term evolved in the 1990s. Alan Irwin (1995) claimed that science should serve the needs of society and empower citizens. Rick Bonney and colleagues also realised the value of data hidden in amateur naturalists' desks and developed strategies to make them usable for research (Brossard et al. 2005). However, it was not until 2012 that the term became renowned globally, thanks to a steep rise in the number of publications, projects, and funding schemes. Several networks of practitioners evolved worldwide (Göbel et al. 2016; Storksdieck et al. 2016). In Europe notably, early examples emerged in Austria, Germany, and Spain (Liu et al., this volume, Chap. 22); all developed alongside the cross-national European Citizen Science Association (ECSA). Moreover, the COST Action CA15212 *Citizen Science to Promote Creativity, Scientific Literacy, and Innovation throughout Europe* connected over 500 researchers and supported them in establishing a *science of citizen science*.

A Diverse Citizen Science Landscape

European countries and regions differ in many ways, the most obvious being the 24 official languages spoken across Europe. However, related to citizen science practice, additional differences can be identified: socio-geographical differences, such as the degree of individualism versus collectivity espoused; political

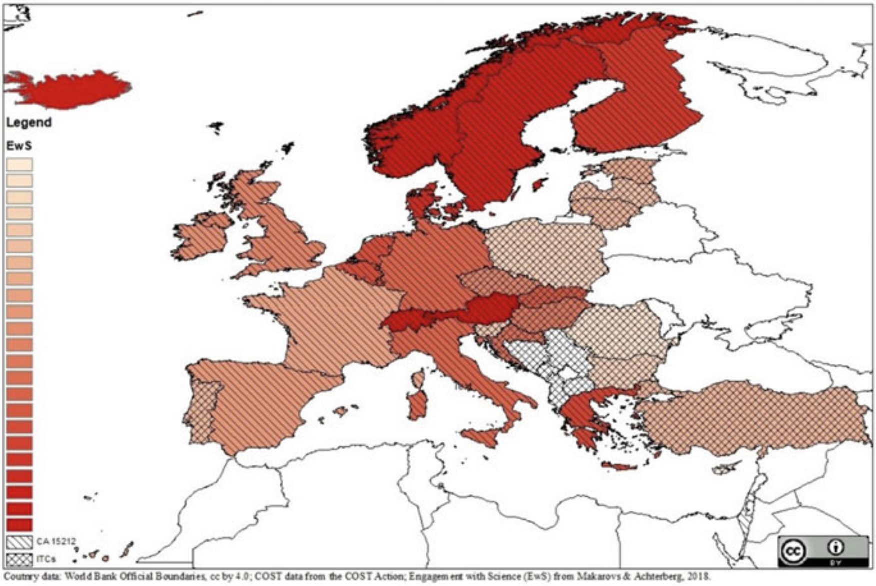

Fig. 3.1 Engagement with Science (EwS) in Europe indicator, based on data from Table 2 (p. 36) in Makarovs and Achterberg (2018). The higher the score (indicated by a darker red), the more engaged the public is in science. The figure also shows the countries who are members of the COST Action CA15212. Within its funding scheme, the COST programme specifically supports the so-called Inclusiveness Target Countries (ITCs). Country data: World Bank Official Boundaries; COST data from www.cost.eu

differences regarding the level of democracy expressed; and cultural differences, such as the roles assigned to science and engagement in societal issues. Looking more closely at these factors can provide a starting point to gain deeper understanding of the diversity of the citizen science landscape in Europe. For instance, the link between democracy and public participation in research is especially salient: the analysis of data gathered within the framework of a Special Eurobarometer survey showed that countries with higher democracy indices[1] have higher rates of engagement with scientific activities (Makarovs and Achterberg 2018; Fig. 3.1).[2]

[1]The democracy index, as measured by the assessment of 60 items ranging from the election system and government's function to personal rights and engagement, revealed differences worldwide but also in Europe (EIU 2018). Most countries in Western Europe were identified as 'full democracies', albeit some countries, such as France, Belgium, and Italy, were tagged as 'flawed democracies' with some deficits in political culture and low levels of political participation. In Eastern Europe, most countries fell into that class, even if they were labelled 'hybrid regimes'. This means inter alia that 'elections have substantial irregularities that often prevent them from being both free and fair' (EIU 2018, Appendix).

[2]The indicator is based on interview data from the Special Eurobarometer survey from 2010 on Science and Technology. https://data.europa.eu/euodp/de/data/dataset/S806_73_1_EBS340

In 2016, the first large-scale online explorative survey of European citizen science was conducted. It focused on five topics: types of citizen science projects, their perceived impact, added value and challenges, current funding schemes for citizen science, and project outcomes (Hecker et al. 2018). In all, 174 citizen science project coordinators responded, mainly from Central, Western, and northern Europe (136 projects), including Austria, Belgium, Denmark, France, Germany, Ireland, Luxembourg, the Netherlands, Norway, Sweden, Switzerland, and the United Kingdom. Only 32 projects (approx. 18%) were in southern and Eastern Europe, including the Czech Republic, Greece, Italy, Lithuania, Portugal, Slovakia, Slovenia, and Spain. A regional analysis showed no significant variation in the frequency of citizen science projects in terms of different degrees of public engagement or scientific discipline. Projects across Europe predominantly contributed to the life sciences.

A second survey conducted by the European Commission, focusing on environmental policy, showed a similar pattern (Bio Innovation Service 2018): a gradient in project numbers from west to east, with the vast majority of projects linked to biodiversity research. These results were confirmed by a more recent survey carried out in 2019. It targeted mainly members of the Management Committee of the COST Action CA15212 from 31 European countries and aimed to identify citizen science strategies and initiatives in Europe (Manzoni et al. 2019). Again, this survey revealed that most citizen science activities take place in the life and environmental sciences compared to the humanities or social sciences. The presence of institutional strategies at the national level was limited to few countries, while initiators of projects were mainly scientific institutions, followed by NGOs and self-regulated communities. Funding came mainly from public administrations bodies, while the terminology used to describe these projects differed widely among the countries represented (see also Haklay et al., this volume, Chap. 2).

An increasing number of country-level reports further complement the overall picture, mostly in Western Europe, for instance, in the United Kingdom (Tweddle et al. 2012), Switzerland (science\cité 2015, Strasser and Haklay 2018), France (Houllier and Merilhou-Goudard 2016), Spain (Serrano et al. 2017), Germany, and Austria (Pettibone et al. 2017), as well as a massive citizen science biodiversity project in Portugal (Tiago et al. 2017). There are also reports for some Central and Eastern European countries, such as Latvia (Prūse and Dātava 2017) and the Czech Republic (Duží et al. 2019).

Besides realising that citizen science activities and strategies in Europe are context dependent, the above survey from Manzoni et al. (2019) also revealed several features of current European citizen science practice. It is through *communities of practice* (CoPs), networks, and shared platforms that most citizen science activities are supported. Project impact is identified, to different extents, in all segments of the hosting ecosystem, namely, at policy, scientific, economic, and social levels. The presence of dedicated plans supported by funding for long-term sustainability is a crucial influencing factor. Mutual trust and interest in common challenges proved to be core enabling conditions.

In sum, despite the different understandings and definitions assigned to citizen science initiatives, the prevalence of citizen science practices seems to be increasing both at European and national levels. This is due to several supporting factors, such as the acknowledgment of the assets stemming from the use of citizen-generated data; the perceived impact of citizen science on social innovation; and, most importantly, the mutual benefits of technology developments and citizen science practices. Nevertheless, many challenges and opportunities arise from the diversity characterising the European scene with regard to science cultures, historical differences in science and societal relations, and *research and innovation* (R&I) policy approaches.

Citizen Science in Western and Northern Europe

In countries such as Austria, Germany, and the United Kingdom, the tradition of *learned associations*, which arose in the eighteenth century, is still present today. Typically, persons who are employed in museums and research institutes meet regularly with amateur experts to organise excursions or talks and map or determine species. This tradition is still visible in current approaches. For instance, Sweden developed *Artportalen*, a platform which systematically integrates citizen science in national biodiversity reporting. Aided by European funding and emerging networks, citizens increasingly contribute to gathering localised data which can be used for geographic applications (Trojan et al. 2019).

In Germany and Austria, governments see citizen science as a means to involve the general public in science to increase scientific literacy as well as to foster innovation (BMBF 2019; Box 3.1). For instance, in Germany, the Federal Ministry for Education and Research (BMBF) supported citizen science by funding a 2-year national strategic process and a citizen science capacity building programme, in 2014–2016, to assess the opportunities and challenges of citizen science. Citizens, civil society organisations, scientific institutions, and researchers from all fields contributed to the enhancement of citizen science in a programme that built on dialogue and participation. This resulted in a national strategy for citizen science, community building, and the platform *Bürger schaffen Wissen* (CitizensCreateKnowledge) which hosts more than 100 projects from diverse disciplines (Pettibone et al. 2017). In the context of these developments, the Federal Ministry also initiated a funding programme for citizen science projects with two calls for supporting citizen science projects (in 2017 and 2019). Key challenges also lay in the structures and incentives of the scientific system. In Germany, especially, non-university research institutes, such as members of the Leibniz and Helmholtz Associations, run citizen science projects. Some universities adopted the citizen science approach as a tool to fulfil requirements for knowledge transfer or the so-called Third Mission. Austria has a comparable national citizen science platform, *Österreich forscht*, and also provides government funding; however it is more associated with educational activities (Box 3.1).

Box 3.1: Sparkling Science in Austria
The Austrian Federal Ministry of Education, Science and Research (BMBWF) initiated a funding programme called Sparkling Science to support projects where pupils at all education levels work together with scientists in the research process. The project started in 2007 and will end in 2020. Since 2007, 299 projects have been funded at a total cost of about 35 million Euros. The projects covered various research areas (natural sciences 30%, social sciences 20%, technology 12%, teaching and learning research 12%, informatics 11%, humanities 9%, medicine and health 6%) and directly involved 198 research institutions, 28,935 pupils, and 1947 teachers (Sparkling Science 2018). The programme selects projects that take into account the state of the art in science and in which pupils work with researchers towards the achievement of the project's specific research goals. Moreover, pupils' contributions are embedded in a way that the project results comply with scientific quality standards.

Citizen Science in Central and Eastern Europe

Compared to north-western or south-western European countries, Central and Eastern European regions followed different historical trajectories in the relationship between science and society (Mejlgaard et al. 2019). This is reflected in science's general role and responsibilities in society (see, e.g. the MASIS project) in Central and Eastern European (CEE) countries and their shared experience of belonging to, or depending on, the Soviet Union for several decades. This heritage is also illustrated in the organisation of the scientific system with core disciplinary foci gathering around physics and chemistry rather than sociology or environmental issues, or in the low level of outreach activities (Kozlowski et al. 1999).

Citizen science practices emerged as a novelty from the West, but volunteerism has quite a long tradition, and many amateur or professional initiatives contain socially innovative elements that could be seen as prefigurations of citizen science (see also Butkevičienė et al., this volume, Chap. 16) and involve citizens and crowdsourcing in semi-scientific or civic projects. Typically, people join, as volunteers, initiatives in biodiversity monitoring, nature protection (e.g. Box 3.2), and ornithology. However, there are also small-scale civic or public institution-led initiatives in mapping geography, soil science, water quality, and air pollution.

Although there appears to be less evidence of citizen science projects in the CEE region, this may be due to unequal knowledge production in several aspects. For example, language barriers may cause lower representation of non-English citizen science projects (Bio Innovation Service 2018); or monitoring of internal and international activity might be less frequent, as indicated by Hecker et al. (2018).

Citizen science in CEE countries can be characterised as a 'hidden citizen science landscape' (Duží et al. 2019, p. 243): engagement in individually led or participatory research is given recognition or defined as citizen science. The relatively undervalued role of citizen science within the R&I sector is another aspect. Recently, however, international cooperation is developing, thanks to scientific projects, and membership in international citizen science associations (ECSA, CA15212, and others) is leading to increased knowledge about citizen science in CEE countries.

For example, in the Czech Republic, citizen science (*občanská věda*) has made progress, including a higher rate of cooperation between academia and NGOs, a greater popularisation of the practice, and the amplification of citizen science projects, primarily via the Czech Academy of Sciences and NGOs (e.g. Czech Ornithological Society; Duží et al. 2019). Moreover, citizen science is now part of one university's curriculum. However, despite a flourishing environment for citizen science (predominantly in the natural sciences, nature protection, and ornithology) and civic participation projects in general, there was no corresponding response at government and political levels (as represented in official documents, individual grant schema, etc.). Current developments indicate that positive progress will continue, including an increased level of international cooperation at European level (e.g. ECSA, COST Actions).

In Lithuania, citizen science as a term (*piliečių mokslas*) emerged in the public discourse only recently, although it is still not well established. Even though the social media and news bulletins present stories and experiences of citizen scientists from other countries, at the policy level, citizen science lacks recognition. Nevertheless, there are several projects in Lithuania that can be classified as citizen science, for example, *Rūšių ralis* (Species Rally), aimed at both natural science professionals and nature lovers, and *Bronės Pajiedaitės takais* ('On Brone Pajiedaite's path'), a project on Bryozoan biodiversity monitoring.

Box 3.2: Wilderness Ranger in Hungary

In Hungary, 10 years ago, a biodiversity monitoring citizen science project began under the auspices of the Agricultural Ministry's nature conservation department. Their programme called *Vadonleső* (Wilderness Ranger) invites citizens to participate in protected species conservation, conservation-oriented data gathering, and practical nature conservation. Within this period, 12,000 people have participated in gathering data about 18 protected species. However, no strategies or policy documents have been created based on this initiative to further support citizen science practice. Citizen science remains largely unacknowledged by research funding. However, small-scale projects are available in academic institutions and NGOs.

Citizen Science in Southern Europe and the Balkans

The economic development of countries in southern Europe and the Balkans was somewhat delayed compared to most northern and Western European countries. Political stability and democratic institutions were undermined by varying periods of dictatorship over the course of the twentieth century, and they have all faced some kind of financial crisis at the beginning of the twenty-first.

An exploratory desktop survey conducted for the needs of this report allows us to make some preliminary remarks on the rapidly growing trends of citizen science in southern Europe. One of them reveals a greater emphasis of most projects on public participation through sensing and monitoring projects, mainly with a focus on biodiversity topics. Citizens are asked to participate through making observations and collecting data with the use of different apps. While most of the projects are active mainly on a local or national scale, a great number of them are part of wider European EC-funded initiatives. The majority of the activities address the general public. A few of them target more specialised groups, such as school communities (teachers and students) or particular audiences (e.g. hunters, divers, etc.). Citizen science projects are organised and coordinated either by university organisations and research centres or by other types of organisations, such as foundations, associations, and NGOs.

Spain is one noticeable southern European country where citizen science has been flourishing in the last decade. Spain can compete on equal terms with some of the leading northern and Western European countries in the field. The trend is towards a growing development of citizen science in a decentralised manner, with multiple educational, social, and economic impacts. Spain stands out as one of the countries with numerous diverse citizen science initiatives, many of them with an international perspective (e.g. Box 3.3). A significant endeavour has begun recently under Fundación Ibercivis to create a Citizen Science Observatory (*Ciencia Ciudadana en España*) and to map all related activities in an online repository. It comprises almost 200 Spanish citizen science projects and actors distributed throughout the country and covering a range of topics and scientific fields. A total of 23.8% of all initiatives are centred on biodiversity and environmental issues, 18.5% on ICT challenges, 16.9% on health and biotechnology topics, and 11.5% on the social sciences and the humanities (Serrano et al. 2017). Almost half of the registered activities are linked to international and European projects, while one-fourth of them are national, and far fewer have a local scope. More than 25% of the reported activities are research based.

Box 3.3: Natusfera and the European Open Science Cloud
One example of the current citizen science activity in Spain is *Natusfera*, a citizen science platform created by the Ecological and Forestry Applications Research Centre (CREAF) and coordinated by the Spanish branch of the

(continued)

Box 3.3 (continued)
Global Biodiversity Information Facility (GBIF) under the Spanish National Research Council (CSIC). It consists of a web portal and an app for mobile devices, allowing any citizen who is interested in creating and sharing nature-based observations, meeting other naturalists, or learning about biodiversity species to sign up, download the app, and start creating their own projects or virtual field notebooks. *Natusfera* is the first platform supported by ECSA to become available to any European group wanting to run and engage in biodiversity projects for and with citizens. To this end, it will be translated into as many European languages as possible. So far, more than 12,000 users have engaged with the platform, and more than 234,000 observations have been recorded on almost 12,000 species, mainly throughout Spain but also in other European countries. *Natusfera* is also among the European Biodiversity Citizen Science Observatories that participate in COS4CLOUD – an EC-funded project, involving 14 European partners (and 1 South American) to design services that address *open science* challenges and integrate citizen science data in the European Open Science Cloud (EOSC). The project's aim is to make European citizen science practices related to biodiversity and environmental quality monitoring more user oriented; to engage a wider range of stakeholders in society, government, industry, academia, agencies, and research; and to develop new citizen science projects and approaches by engaging new audiences, especially youths and school students, in research procedures.

In contrast to Spain, Greece is a southern European country where citizen science is in its infancy and hard to define. The first groups of citizens and Greek-based NGOs who were involved in citizen science projects date back to 2008. However, the outbreak of economic crisis in Greece the same year was decisive in shaping future trends in the field. The financial recession and the accompanying austerity measures triggered a host of dire changes in Greek society, including a considerable decrease in GDP and a high rate of unemployment, especially among young people. Public participation in the civil society and formal volunteering actions in the post-dictatorial period have been rather weak, due to the dominant role of the state. The onset of the Greek crisis brought about a significant shift in responsibility and action, mainly directed towards social welfare and assistance to the most vulnerable social groups. Public participation and citizens volunteering for other causes (e.g. for fulfilling personal learning interests) would not come first in a row of more pressing priorities. However, even in this ambiguous context, citizen science found fertile soil to grow in Greece.

Out of the 21 Greek citizen science projects that have been tracked, 7 form part of larger European projects (the Scent project, LIFE Euroturtles, Marine LitterWatch, GROW Observatory, the PLUGGY project, iNaturalist, and Project Noah), while the rest have been initiated on a national or local scale. Almost half of the projects are run by Greek-based NGOs with a longstanding tradition in the organisation of science-focused and/or culture-oriented activities, while the rest have been established and operate under national research institutions and scientific associations. There is only one case of an international citizen science project supported and coordinated by a large private company (the Sea Hero Quest project by Cosmote). More than half of the projects and initiatives are linked to biodiversity topics (i.e. marine biodiversity, alien species, fauna, and ornithology).

The Balkans form a distinct European region with a strategic geopolitical position. Extending from the Adriatic to the Mediterranean Sea and from the Marmara to the Black Sea, they stand at a crossroads through Europe and from Europe to Asia. Balkan countries share historical–political roots and cultural features, long-lasting ethnic conflicts, and some more recent severe outbreaks of war. None of them participated directly in the big sociopolitical and economic transformations that took place in Western Europe in the nineteenth and twentieth centuries. For most Balkan countries, state identities and democratic functioning have been greatly affected by long-time communist regimes. Only a few of them are official members of the EU.

Although there are some national projects, almost one third of the identified projects are linked to larger European or global projects. These include Co-PLAN (Box 3.4) and BioNNA in Albania, the Bulgarian Society for the Protection of Birds (BSPB) and BirdLife International in Bulgaria, Association BIOM in Croatia, EwA and iNaturalist in Romania, and LIFE ARTEMIS in Slovenia. Participation in these projects targets the general public or students and is mainly for ‘monitoring’: citizens contribute with observations and the collection of data through the use of apps. Environmental topics, issues, and causes are the most frequent foci of interest, especially those having to do with biodiversity conservation, alien species reporting, and air pollution.

Box 3.4: Building Citizen Science Monitoring Infrastructure and Methodology in Albania

Co-PLAN is an Albanian (non-profit) organisation based in Tirana, which aims to promote ‘tangible social transformation’ through community participation and policymaking related to sustainable development, environmental quality, and good urban and regional governance. It works with people and institutions on both national and western Balkan regional levels but also builds collaboration in a European context. Co-PLAN focuses on exploring ways to advance citizen engagement in local governance. Through participation in the EC-funded project ‘Green Lungs for our cities’, it seeks to create a bottom-up monitoring platform for air quality, noise pollution, and urban greenery at the local level, in the cities of Tirana, Durrës, Elbasan, and Shkodër.

European-Level Support for Citizen Science

In addition to developments in individual European countries and regions, citizen science has received major support for the development of activities and networks at the cross-national level. The EU has played a central role, through dedicated funding for research and development of citizen science projects and capacity building activities. As an umbrella organisation of European citizen science practitioners, the ECSA functions as a community of practice, undertakes advocacy work, and links to other international networks. The COST Action CA15212 complements this picture by supporting networking for researchers working on citizen science.

EU Funding for Citizen Science

Since 2011 several citizen science projects have been supported by the EU's Seventh Framework Programme (FP7) as well as under Horizon 2020 (Table 3.1). Currently, about 234 million Euros has been allocated to projects which are somehow linked to citizen science.[3]

The highest proportion of EC funds went to Research and Innovation Actions (RIAs), while Cooperation and Support Actions (CSAs) had the second highest share. This indicates the dual nature of the institutionalisation of citizen science: on

Table 3.1 Funding of projects by the EC, assigned to the year of project start

Year of project start	Number of released projects	Amount of money invested (in €)
2011	2	14,984,790
2012	2	4,109,999
2014	4	2,161,605
2015	14	69,924,599
2016	22	62,573,965
2017	6	16,286,683
2018	19	28,618,133
2019	10	27,906,833
2020	1	7,174,252[a]
Totals	**80**	**233,740,859**

Source: Cordis database
[a]On date of retrieval, not the complete year

[3]However, these data need to be regarded with a careful eye since citizen science is a young, fuzzy, and overhyped subject. This might lead to both over- and underreporting. For instance, the project ENVRIplus (Finland) receives over 14 million Euros, but does not have 'citizen science' in its description or on its webpage and only one deliverable deals with tools for citizen science (http://www.envriplus.eu/wp-content/uploads/2015/08/D14.6.pdf). On the other hand, PANELFIT is not listed although ECSA is one of the beneficiaries.

the one hand, it is driven bottom-up, from within the scientific system by project consortia requesting funds for projects to apply (and develop) citizen science for the generation of scientific knowledge. On the other hand, there is a top-down component represented by funding that goes into projects promoting citizen science to various audiences, such as policymakers, researchers, and the public. The United Kingdom, the Netherlands, and Spain started the most projects and received the highest share of funding.

This is in accordance with Hecker et al. (2018), whose survey showed that 28% of the 32 southern and Eastern European and approximately 10% of the Western, Central, and northern European projects (a quarter of the responding projects) 'receive either no funding or less than €10,000 funding. Many projects (43%) receive between €10.000 and €250,000, while approximately a third of them (31.8%) substantial funding of over €250.000, and 14% more than €1,000,000' (Hecker et al. 2018, pp. 194–195). Project coordinators stated that this funding mostly comes from national and EU research funds, while NGOs and projects often have several sources of funding. Less than half of the project coordinators thought that the initial funding was appropriate, while only 15% viewed the long-term funding as appropriate.

Emerging European Citizen Science Networks

The European Citizen Science Association

The idea of founding ECSA as the European umbrella organisation for citizen science was largely inspired by the Open Air Laboratories (OPAL) project in the United Kingdom (Davies et al. 2011). Supported by the Big Lottery Fund UK and several other institutions, education and learning about nature was combined with the gathering of scientific data by the public. In contrast to a loose network, a legal entity (like ECSA) would allow bidding for (European) funds and provide a legitimised voice to advocate for citizen science in the political arena at the European level. Therefore, in 2012, ECSA was officially registered as an association under German law, with seven members, and based at the Museum für Naturkunde in Berlin, which still hosts it. The association grew quickly and integrated individual as well as institutional members (59 and 84, respectively, in 2019) and 10 employees together with part-time officers and students (ECSA, personal communication). To support work on citizen science projects played a major role. One of the first and most important funding sources for developing the association and citizen science in Europe was the Horizon 2020 Doing it Together Science (DITOs) project, coordinated by University College London (UCL). Later, the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria, invited ECSA to join successful EU project proposals, such as the LandSense and the WeObserve projects. In 2019, ECSA was a partner in seven projects, sustained by several organisations throughout Europe, including the capacity building platform EU-Citizen.

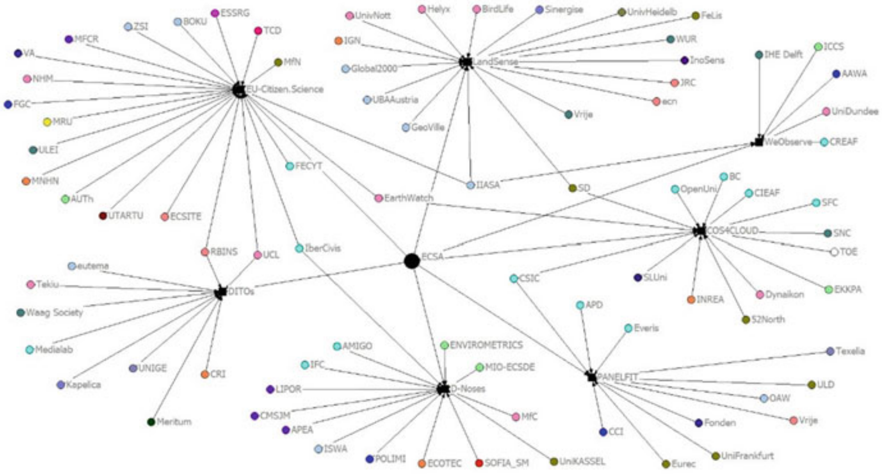

Fig. 3.2 EC projects with ECSA as beneficiary; partners from the same country are in the same colour. Source: database: https://cordis.europa.eu, date of retrieval 23 October 2019, acronyms used; Software: Ucinet (Borgatti et al. 2002)

Science (Fig. 3.2). ECSA's role varies in these projects, but includes core task such as communication, exchange between practitioners, and sharing of best practice.

Doing It Together Science (DITOs) Project

DITOs was one of first pan-European projects structuring citizen science. Its main purpose was to organise public engagement events dealing with citizen science in do-it-yourself (DIY) biology and environmental sustainability. ECSA was responsible for *policy engagement*, engaging decision-makers[4] at local, national, and EU levels to raise awareness of citizen science, to stimulate personal encounters, and to develop institutions. This work provided the opportunity to strengthen citizen science in various respects:

1. **Advancing the development of ECSA.** ECSA profited from DITOs primarily through funding for personnel at the secretariat and networking events. Beyond this, ECSA used DITOs to refine structures and community management processes in more open ways in order to be a more credible agent of integration for European citizen science communities. This approach was based on working together with practitioners from citizen science, community-based research, and

[4]Decision-makers were persons with the ability to effect change regarding citizen science and DIY science, e.g. politicians, staff of funding agencies, scientific institutions, civil society organisations, and others.

DIY science. Several round tables explored questions of inclusiveness, and ECSA launched the working group Empowerment, Inclusiveness and Equity in cooperation with the Living Knowledge Network (e.g. Göbel et al. 2019). However, building and maintaining cultures of working more openly is challenging. Such work usually takes more time than operating in less participatory and less transparent ways, staff need to be trained, and strategic commitment needs to remain a priority throughout changing leadership.

2. **Building capacity for national citizen science networks.** Through DITOs, ECSA managed to strengthen emerging national initiatives, such as the Italian citizen science community. A series of round table events were organised in 2017 and 2018 which resulted in guidelines for how to support citizen science in different sectors and at various governance levels (DITOs Consortium 2019). Cooperation with local partners, including the Italian National Academy of Sciences and the Maremma Natural History Museum, was essential. ECSA also supported national networks in Germany, the United Kingdom, France, and Spain through DITOs. If and to what extent such networks are successful in stimulating (ex)change and achieving political and financial support also depends on policy priorities – like the current push for participatory science communication in Germany (BMBF 2019).
3. **Anchoring citizen science in EU research policy.** ECSA's advocacy work in DITOs mainly addressed the Responsible Research and Innovation (RRI) and Open Science agendas. The ECSA Working Group Citizen Science and Open Science gathered good practice and recommendations, while ECSA leadership engaged with the Open Science Policy Platform, a high-level policy forum. As a result, participation and research have been better conceptualised and carried out in more significant ways. A pluralistic concept of citizen sciences, like the escalator models used in DITOs (Haklay 2018), as well as ensuring diversity of speakers and perspectives, was essential. How these activities of positioning citizen science as a relevant approach to research and science communication fit in with larger restructurings in the EU research policy agenda that is downsizing funding for public engagement (cf. Gerber 2018) is to be assessed in the future.

Challenges and Opportunities

Citizen science opens up many scientific and societal opportunities for Europe as a whole. The engagement of citizens in scientific endeavours and their contributions to scientific knowledge boost learning and personal development. Communities of citizen scientists can learn from each other and jointly strengthen the field by building networks (such as ECSA). As demonstrated in this chapter – and the rest of the present volume – each European national case is unique (i.e. in terms of its history, culture, and governance structure), and no one-size-fits-all solution appears plausible for citizen science practice. At the same time, rich and diverse possibilities are offered for the public to become engaged and make a difference – in science, the governance of social, economic, and environmental challenges, and society at large.

However, an imbalance with regard to funding programmes and infrastructures still exists in Europe. In addition to this, countries with more engaged citizens and funded projects have the power to shape the discourse around citizen science and do advocacy work (cf. Haklay et al., this volume, Chap. 2), which strongly impacts on the understanding and future infrastructures of citizen science generally. However, it is essential to provide all European citizens with equal opportunities to participate in citizen science activities. The COST Action is such an empowering tool to address current socio-economic inequalities within and across countries. Discussions over the different terminology and disciplines as well as the history and current societal and political functions have been fostered to enrich the field, as demonstrated by the large number of reports and papers.

Recommendations for Future Developments

Today, citizen science is a growing and flourishing practice in Europe and across the world. To take advantage of this momentum, a strategic and multiscale approach is necessary. This approach rests on three pillars:

1. **Spread best practice from projects:**
   - Expand citizen science initiatives across European countries and regions, including networking, translating, and making available methodologies and tools. This way, existing solutions can be systemically adapted to culturally different settings and applied at larger geographical scales.
   - Share good practices and examples (e.g. on EU-Citizen.Science). Develop actionable toolboxes, which offer a multitude of resources directly applicable and adaptable to different contexts and needs. Increase knowledge and understanding of the pitfalls and failures to initiate learning in the field.
   - Base more structured methodologies on theory development.
2. **Link with strategic partners:**
   - Increase support for local initiatives from both existing communities of participatory research and new bottom-up and independent activities.
   - Cooperate with civil society organisations, since they are key agents for generating genuinely transformative research (see Göbel et al., this volume, Chap. 17).
   - Combine both top-down and bottom-up dimensions to strategically address the multiple geographical, cultural, political, and social factors required to realise the transformative potentials of citizen science.

3. **Anchor the citizen in research and development:**
   - Develop and apply appropriate reputational mechanisms.
   - Use overarching conceptual framings, such as the positioning of citizen science inside European policy priorities (e.g. Green Deal or mission-oriented research, cf. Mazzucato 2018; see also Schade et al., this volume, Chap. 18), or the global agenda of the Sustainable Development Goals (SDGs).
   - Ensure capacity for training specific stakeholder groups (e.g. public authorities), and make it accessible to the different CoPs (e.g. via EU-Citizen. Science).
   - Encourage knowledge transfer and innovation, including changing underlying business models, for instance, by using regional and structural funds to support currently underrepresented areas.

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Part I
Citizen Science as Science

Chapter 4
Science as a Commons: Improving the Governance of Knowledge Through Citizen Science

Maite Pelacho, Hannot Rodríguez, Fernando Broncano, Renata Kubus, Francisco Sanz García, Beatriz Gavete, and Antonio Lafuente

Abstract In recent decades, problems related to the accessibility and sustainability of science have increased, both in terms of the acquisition and dissemination of knowledge and its generation. Policymakers, academics, and, increasingly, citizens themselves have developed various approaches to this issue. Among them, citizen science is distinguished by making possible the generation of scientific knowledge by anyone with an interest in doing so. However, participation alone does not guarantee knowledge generation, which represents an epistemological challenge for citizen science. Simultaneously, economic and socio-institutional difficulties in science governance and maintenance have grown. To solve those problems, several market elements have been introduced, a solution rejected by those who consider science as a public good that states must guarantee. Alternatively, research and work on the commons are growing worldwide, the concept being extended from natural

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resources to knowledge resources. In this chapter, we propose science as a commons, underlining the essential role of citizen science. Difficulties also apply to citizen science itself, but the increasing development of a multitude of projects based on cooperation favours the conditions required for its sustainability and quality.

Our philosophical proposal is based on empirical knowledge about citizen science coupled with socio-economic concepts, according to a sociopolitical epistemology.

Keywords Science governance · Open science · Political epistemology · Social epistemology · Knowledge commons

Introduction

In recent decades, problems and questions related to the *governance of science*, particularly to its sustainability and accessibility, have multiplied not only with regard to the acquisition and dissemination of knowledge but also its generation and co-production.

We can consider the case of communities affected by environmental, health, and broader societal issues, whose interests are not prioritised by those in power. Let us also consider the appropriation, by certain industries, of the knowledge of traditional and local communities, in such a way that they are excluded from access to knowledge that they themselves have generated. Or the circumstance, also paradoxical, produced by the increase in the price of scientific journals to which universities and research centres have been subjected to in order to be able to access the knowledge that, once again, they themselves have generated. Another major area of tension related to the sustainability of science is how to address intellectual property management in a way that is compatible with the open science model. Dealing with growing data sets involves serious ethical and legal privacy issues. The funding of scientific institutions and research programmes is an issue of ongoing concern and debate that requires research.

Before continuing, it is necessary to clarify that talking about science and scientific knowledge requires at least three aspects: the generation of knowledge itself, the means for this generation, and the communication of results.

In recent decades, all the above-mentioned issues, along with many others, have been posed in relation to the evolution of legislation and technology, as well as the underlying culture. Other questions include what does excellent science mean; how should funding for science be managed; what kind of knowledge can be patented; and, what is meant by open science. These pragmatic questions are associated with ongoing philosophical research (e.g. epistemological and ethical) that explores the differences between various types of knowledge: how they are generated; how they are validated and by whom; who owns them; where, and how, is science undertaken and why.

Citizen science, as a cross-cutting and continuously evolving methodology, can offer compelling answers to these questions. The development of a multitude of collaborative projects, in different areas, scopes, subjects, etc., that favour the sustainability, accessibility, and quality of scientific knowledge, must be considered to achieve the optimal governance of science.

The aim of this chapter is to provide an answer to the question of how to achieve an improved governance of science through citizen science. We propose to understand and manage science as a commons. This proposal is based on analyses that overcome the public-private dichotomy, where the sole respective actors are the state and the market, to achieve an improved governance of science through citizen science.

The role of citizen science is crucial to this proposal, as it involves a research practice in which every citizen, entity, and community can find their place and share responsibility. Our philosophical proposal is based on our empirical knowledge of citizen science and on the growing studies, both theoretical and empirical, on the commons.

The term 'commons' refers to a form of community management of a shared resource. *Good governance* of the commons implies that the communities who share access and/or use of a resource manage their behaviour through a self-established set of rules (Ostrom 1990; Madison et al. 2019). The commons results from a collaborative, open, and experimental process that necessarily involves the *community of practice*. Each community not only produces the commons but is simultaneously produced in the common acting (Dardot and Laval 2019).

Justifying our thesis requires philosophical argument in different fields. We will start with a first approximation to the relationship between citizen science and the commons. The chapter continues with a philosophical consideration of the nature of science, underlining its social structure. Then, it addresses key features of the methodologies of citizen science. On this basis, we will develop our proposal, explaining the central *commons* and *knowledge common*s concepts, and conclude that citizen science should also be considered a commons. Finally, we summarise the main challenges in this field alongside recommendations for citizen science projects and for wider society.

Citizen Science and the Commons: Old and Entangled Concepts

Different conceptions of science and its environments have co-evolved alongside new forms of *knowledge co-production* (Jasanoff 2003). In this sense, various approaches have been proposed regarding science, in the more general context of *co-production* (Ostrom and Ostrom 1977) and the *participatory turn* (Jasanoff 2003). These approaches include, among others, the *extended peer community* (Funtowicz and Ravetz 1997), a *new social contract between science and society* (Gibbons 1999), *public engagement with science* (Leshner 2003), *socially robust science* (Nowotny et al. 2005), *citizen science* (Irwin 1995; Bonney 1996), *well-ordered science* (Kitcher 2001), and, more recently, *open science* (e.g. Moedas

2015). All these approaches share the underlying idea of giving voice to anyone concerned about scientific and technological issues that affect them (Fischer 2000).

Regarding citizen science, it should be noted that it does not only consist of such relevant issues as establishing a greater multidirectional dialogue between all parties involved; attending to citizens' demands for decision-making on scientific-technological and risk issues, and providing complementary socio-ethical approaches to scientific-technological ones. These approaches are, indeed, necessary and lead to meaningful participation in the deliberation and influencing of political pathways (Fischer 2000). But, citizen science practices also represent a substantial step forward in the democratisation of science, by making possible generation of knowledge by supposedly non-expert agents in all stages of the scientific process. In doing so, diverse capacities to undertake science are recognised and built (Leach et al. 2005). In addition, citizen science is not a new practice; there exist impressive examples throughout history related to active citizen participation, not only in the environmental field but also in diverse areas such as meteorology, astronomy, and oceanographic science (see Sanz et al., Chap. 21, this volume).

Nevertheless, how to reconcile the contribution of a large number of non-professional agents in knowledge generation with the quality of this knowledge is a complex issue. Even so, there is a growing body of literature showing the relevance of citizen science for academic research.

Besides that, closely related to the already mentioned issues, society faces difficulties in the governance and maintenance of the scientific-technological system, with consequences that go beyond the purely economic. Thus, there is a complex intertwining between epistemic issues (which question the validity of knowledge) and sociopolitical issues (which question who can be considered legitimate and responsible agents of its production) (Broncano 2006). As a supposed solution to this tension, there has been an increase in the incorporation of market elements in science management (Radder 2010; Vermeir 2013), such as intellectual property rights and modes of patenting and licensing. At the same time, such commercialisation has been frequently objected to, highlighting the nature of science as a *public good* (Callon 1994; Nowotny et al. 2005; Mirowski 2018), with various arguments to prevent or stop its privatisation.

As an alternative solution to the conflicts – particularly in science –surrounding the public-private dichotomy, in the last decades, work and research on commons governance and collective action (Ostrom 1990) has developed in academia and in activism, law, and politics (see a complete set of references in Dardot and Laval 2019). In particular, Dardot and Laval, in their work *Common* (2019), explain the various meanings of the commons concept and its historical evolution.

Moreover, the commons concept has expanded from natural resources (fisheries, pastures, etc.) to the knowledge commons (Hess and Ostrom 2007) since the beginning of the twenty-first century, specifically, to scientific knowledge (Vermeir 2013; Irzik 2013). This includes collaborative methodologies, for example, data production in citizen science projects (Weber et al. 2019) and data analysis in online citizen science projects (Madison 2014).

Science and Knowledge: Networks of Cooperation

In this section, we first carry out a brief analysis of the current systems of scientific knowledge dissemination, as well as its generation, from the viewpoints of social epistemology (Goldman 1999) and political epistemology (Broncano 2006). Next, we introduce the diverse methodologies in citizen science projects which contribute to improved development and governance both of physical resources and scientific systems.

Citizen Science Highlighting the Social Structure of Science

Willard V.O. Quine was one of the most influential twentieth-century philosophers of science, chiefly due to his image of science as a vast *network of beliefs* whose periphery connects with reality, while the interior is populated with theoretical hypotheses (Quine and Ullian 1970). From Quine's perspective, science is not fragmented into separate fields. Thus, an empirical result in a certain research field may influence a theoretical hypothesis in a different field.

The metaphor of the network does not only apply to the meaning of theoretical terms or to the relationship between theories and experiences but also to the construction of science as collective work. An enormous number of people obtain data, generate hypotheses, make calculations, teach other people, criticise current theories, explore ideas apparently distant from their specialty, join in discussions over coffee, and, in short, create social networks on which the network of beliefs that shapes our scientific knowledge is sustained.

Boutang (2011) proposes a metaphor to account for the way in which knowledge is produced as cognitive social work: *pollination*. In the case of the knowledge society, cognitive pollination refers to a vast network of interactions – educational, suggestive, imitative, and collaborative. Society reproduces itself through the flow of information, contributions, and small discoveries that generate the accumulation of knowledge. The globe becomes a vast campus of knowledge – where specialised professional research intersects with transdisciplinary spaces – that allows unlikely cognitive fertilisations. The image of pollination, therefore, suitably represents the situated and social nature of epistemic agency. Epistemic agency, or in other words, the ability to form true beliefs from intellectual capacities, is a faculty that has both a personal and an interdependent and collective dimension. Each researcher boosts knowledge, at least partially, by relying on epistemic resources shared with the rest of the scientific community and, beyond that, with the rest of society. Knowledge is always a situated and interdependent activity, both in the use of resources that have been donated by others and in the evaluation of the result of one's own work. This interdependence is not based on a hierarchical or pyramidal structure of authority but on a vast network of acts of sharing, criticising, legitimising, and changing epistemic resources. It is the network's shape that represents the image of pollination:

knowledge is spread in sometimes improbable and unpredictable ways because it germinates in diverse and distant spheres. This image does not completely blur the distinction between experts and laypersons; on the contrary, what it produces is an extension of the distinction. We are all experts in some domain, in that we produce reliable beliefs, and at the same time we are all laypersons regarding our cognitive dependencies on other people's work.

Participation in science is grounded in both the nature of human knowledge and cognitive activity. The idea of a network of beliefs, supported by a social network that continuously pollinates and germinates creativity, can help us to think about citizen science in less hierarchical ways; as based on the social division of labour between expert scientists and lay persons. Science, technology, and society studies (STS), developed mainly since the 1980s, show many pollination phenomena, such as activism, that point to blind spots in science and identify new avenues of research (Hess 2007; Frickel et al. 2009). Whether this ideal is realised depends on multiple factors, including educational and institutional. Sometimes, institutional design –for example, structures in which not everyone has a voice – impedes cognitive cooperation through difficulties in accessing common epistemic resources. Practices can also lead to the exclusion of others due to competitive or epistemic arrogance. In a certain sense, the original view of science as part of the public sphere that gave rise to modern science in the Enlightenment and the nineteenth century has been lost (see David 2008).

The impulse to citizen science must be part of a change in perspective on the general redesign of all our institutions of production of science and technology. That change must be focused on stimulating cooperation. At the beginning of the nineteenth century, Humboldt introduced an educational reform based on the unity of the Wissenschaft (Hohendahl 2011), in contrast to the concept of science of the Enlightenment, which was much more oriented towards the separation of areas and objects. From Humboldt's reforms emerged science as we know it. Despite its shortcomings in what could still be seen as an elitist arena, the core meaning of those reforms was and is very relevant. Those proposals can be extended to the whole of education, uniting research and teaching at all levels, and to the broader epistemic life of our societies.

Incremental innovations in all fields, from scientific theory to diverse technologies, produced the paradox of a progressive and unstoppable conversion of knowledge into a form of capital. The shape of science has been drifting towards a metric system where indicators measure research impact and researchers orient their lives towards securing good indices rather than the unpredictable task of advancing knowledge. This reorientation appears to be driving a steady decline in the motivating factors and affective bonds that sustained the epistemic communities of the twentieth century, when in a few decades there were surprising scientific and technological revolutions in all fields.

Faced with this trend, the joint actions of production and dissemination of knowledge have been progressively recognised by initiatives that understand science as a commons. In the Humboldtian model, researchers and professors are joined together. In an increasingly complex society, collaboration in the production and reproduction of knowledge involves new actors and sectors, such as students in training, research managers, innovative companies, hospitals, and public services. The epistemic cooperation of all personnel is essential, and the flow of knowledge is fundamental to institutional functionality. Beyond that, we find a growing awareness that the networking that sustains science can substantially benefit from the contribution of informal networks of citizens who draw attention to abandoned or *undone science* (Hess 2007). Their traditional knowledge can provide new lines of research, and even amateur work can produce relevant contributions. The frontiers between science and the public are blurring, opening up new ways of extending knowledge networks to wider society. Thus, citizen science is presented as a paradigm of this new configuration of borders: nowadays, many research projects in diverse areas cannot be successful without citizen participation.

The Core of Citizen Science Methodologies

The methodologies currently used in citizen science are diverse and ever evolving. We are interested in projects that provide examples of good practice in the generation of scientific knowledge, not only because of their research results but also in terms of their accessibility and their sustainability.

We group some examples of activities (see Table 4.1), together with their methodologies, according to a simple classification to illustrate our ongoing thesis about understanding science as a commons. The first type includes practices related to environmental management and the preservation of natural resources; the second type refers to projects whose aim is to achieve better epistemic results in different areas of knowledge; finally, a third type includes those activities seeking to improve citizen science itself. Our intention is not to introduce a new typology of citizen science projects, among the many existing ones. Rather, we seek to clarify, starting with empirical observation, the ways citizen science can contribute to better scientific knowledge and sustainability of the scientific system.

In this small sample, we consider contrasting activities and methodologies. For example, in *distributed computing* projects participants contribute simply by donating computer processing time (e.g. Einstein@Home), whereas other projects require the participation of members of society as a whole: policymakers, academic scientists, industry and business representatives, and local communities (e.g. SnowChange). Other examples include projects funded by European funding programmes (e.g. EU-Citizen.Science) and independent projects that are sustained purely by participants' contributions (e.g. *Biodiversidad Virtual*). We have incorporated *bottom-up* (e.g. *Biodiversidad Virtual*) and *top-down* projects in the natural sciences (e.g. Galaxy Zoo) and the humanities (e.g. Old Weather). There are also online (e.g. Debian) and offline activities (e.g. ECSA conferences), as well as those that combine both methodologies (e.g. Model Forest).

Both objectives and methodologies have been intentionally shown here as separate in an analytical way, but usually they are intermingled in many projects.

Table 4.1 Citizen science activities according to their main objective, including diverse methodologies

Main objective	Methodologies	Good practices
Type 1 Better management of natural resources	Contributing with pictures. Identifying and cataloguing them Community-based methodologies, which combine academic science with local knowledge: contributing with data, stories, local culture, etc. Promoting focus groups, interviews, co-created actions and reports, as well as local, regional, national, and international meetings	*Biodiversidad Virtual* Model Forests GAP2 SnowChange SEO/BirdLife
Type 2 Better research results	Identifying and classifying systems (galaxies, planets, cells, animals, and plants, etc.) on online platforms Transcribing handwriting texts or translating documents Serious games Distributed computing	Galaxy Zoo Old Weather Einstein@Home
Type 3 Better management of citizen science projects	Constitution of associations, observatories of citizen science, etc. Collaborative networks for supporting other projects Research and/or elaboration – ideally with citizen participation – of guidelines on communication, ethical issues, quality of data, dataset management, among other issues	ECSA conference Debian EU-Citizen. Science

Activities whose main objective is the conservation of natural resources directly involve the generation of scientific knowledge: ecological and socioecological knowledge, as well as other types of knowledge (e.g. legal, economical, socio-ethical). The projects that address producing best practice guidelines and the associations that seek to support citizen science are largely initiated by participants and/or project managers. Many of them aim to improve environmental management, ethical aspects, and/or knowledge generation. To illustrate good practices, we have chosen both projects ongoing for many decades (e.g. SEO/BirdLife) and others limited in time and already completed (e.g. GAP2). Results co-created by the diverse involved communities include scientific publications and methodologies that can be used in their respective research areas and beyond. Some of these projects are explained in more detail in Table 4.2.

Although it would be convenient to speak of *citizen sciences* (Lafuente and Estalella 2015) to account for the many existing types, citizen science is frequently understood as a scientific methodology that encompasses diverse areas of knowledge. Two points are clear: first, citizen science consists essentially of undertaking research; and, second, it is carried out by citizens, that is, people who are usually not professional scientists, although in many cases they work together. We agree with Haklay (2015, p. 11) when he states, in view of the diverse practices and definitions of citizen science, that 'what is common to these definitions is the collaboration

Table 4.2 Examples of citizen science projects constituting science as a commons

Main objective	Project	Description
Type 1 Better managing natural resources	Model Forests	The Model Forest approach was first developed by the Government of Canada in the early 1990s. It was in response to a period of intense conflict in the forest sector when forest workers, governments, environmentalists, indigenous peoples, and communities were in conflict over forest resources and how to manage them sustainably. A Model Forest promotes partnerships in a forum where a range of values and interests can be represented and partners with a common goal of sustainable development can share new ideas. Each forest is intended to be a dynamic 'model' from which others can learn and advance their sustainability goals; finding common solutions to issues such as biodiversity protection, conservation, and economic stability. (Source: International Model Forest Network n.d.)
Type 2 Better research results	Galaxy Zoo	Galaxy Zoo was founded in 2007 by astronomers at the University of Oxford to enlist volunteers to assist with data classification to better understand the evolution of galaxies. Based on the number of participants (hundreds of thousands), the amount of data processed, the speed and accuracy in completing the project, and the number of research papers produced, it has been a success. Madison (2014) explains that the key reason for its effectiveness as a commons is due to its social organisation. Its 'big community' was guided by a vision of a specific organisational solution to a specific research problem, initiated and governed by professional astronomers in close collaboration with volunteers.
Type 3 Better managing citizen science projects	Debian	The Debian Project is an association of developers and users whose common goal is to create a free operating system called Debian. About a thousand developers around the world volunteer to help create Debian. The project started in 1993, seeking to be collaboratively and carefully created, maintained, and supported. It began as a small, tightly knit group of free software hackers, and gradually grew into the large, well-organised community that continues to operate today. At Debian, people spend their free time writing software, packaging it, and then donating it; their motivations include: to help others, to learn more about computers, to avoid the inflated price of software, in return for the excellent software they receive from others, or simply for fun. In academic institutions and in citizen science projects many people create free software to facilitate their research results being used more widely. (Source: Debian n.d.)

beyond institutional boundaries, the activities that are part of the scientific process, and the cooperation between members of the public and professional scientists'. In this sense, Haklay et al. (Chap. 2, this volume) understand as restrictive certain conceptualisations of citizen science that confine it within the established research system.

We understand that cooperation – key for the constitution of a commons – is at the core of the diverse practices of citizen science. In the previous section, we considered the structures that make this cooperation possible, delving into the nature of science shaped as an open network. Further on, it will be necessary to deepen the meanings, possibilities, and implications of cooperation, particularly in science. But, before that, we need to address the proposal of knowledge as a commons.

Knowledge as a Commons for Better Governance of (Citizen) Science

At this point, we will deal with the notion of *openness* and its close relationship with citizen science. The issue of openness in science will lead us to deepen the approach of the commons. In this analysis, we will argue our proposal to consider science – and citizen science itself – as one of the knowledge commons. Throughout this section, we present examples of citizen science projects to illustrate our proposal.

Commons: Beyond Public Goods

In the section on networks of cooperation, we considered the expansion of the knowledge network system underlying the growing phenomenon of citizen science. That expansion leads to an increase both in the number of agents and in the flows of production and dissemination of knowledge. In this context, openness – as opposed to enclosure or exclusion – is key if we want knowledge to be as accessible, disseminated, and co-generated as possible. It could then be inferred – as has been widely assumed by Western culture, particularly in the second half of the twentieth century – that knowledge is a public good like the light of a coastal lighthouse or a road network. A public good is a resource open to use by all, including those who may not contribute to its existence or maintenance. Furthermore, a public good is managed by state institutions.

The mainstream view of social dilemmas (e.g. tragedy of the commons, the prisoner's dilemma, etc.) and the possibilities of collective action takes for granted the selfish and opportunistic behaviour of individuals, which leads to the deterioration or loss of shared goods through over-exploitation. This justifies the intervention of external agents to ensure the maintenance of open, shared resources. This perspective proposes a scheme of governance with only two institutional forms, the state and the market, to address collective problems.

According to the mainstream view in economics, resources are classified into two types with respect to their intrinsic properties. On the one hand, there are *private goods*. These are excludable and rivalrous. On the other hand, there are *public goods*. These are non-excludable and non-rivalrous. However, a decade later this classification was shown to be insufficient, since it does not account for the case of *club goods*. These can be used to understand the basic properties of goods, namely, excludability and rivalry (also known as *subtractability*). Consider the example of the theatre. You can access the play only if you pay for the ticket. The play is an excludable good, because not everyone can access it. Nevertheless, the fact that other people enjoy the play at the same time does not diminish your enjoyment. The play is a non-subtractable good, because the fact that others use it does not prevent you from using it too.

However, in the 1970s, Ostrom and her team proposed an alternative thesis, based on their wide empirical studies. They introduced the concept of the *common goods*, simply known as the *commons*. These are excludable resources, as public goods, but subtractable, as private goods. Pastures and forests are examples of common goods. They are excludable because in principle everyone can access them. Nevertheless, they are also subtractable to use. The grass or the wood consumed by one user cannot be consumed by another user. In addition, the introduction of the commons led to a reconceptualisation of excludability and subtractability as gradual properties. Some goods are more or less excludable/subtractable than others (see Fig. 4.1 for a diagram of the classification of goods).

It is therefore the rules, rather than the intrinsic properties of the resource, that define how it is classified. Thus, management and property approaches to resolve conflicts related to their scarcity can be addressed in alternative ways to the market and the state. The emphasis is neither on property nor accessibility, but on the rules agreed by communities of practice. The property may be state or private or communal. The management may be communal, or communal-state-private, or state-private, etc. This depends on the agreements made. Resources are considered commons when the community is the beneficiary and when it develops the rules that define the uses of the resource, including self-monitoring.

Although there are no fixed or universal rules for the constitution of a commons, their sustainability is based on reciprocity, trust, and cooperation. Ostrom's work

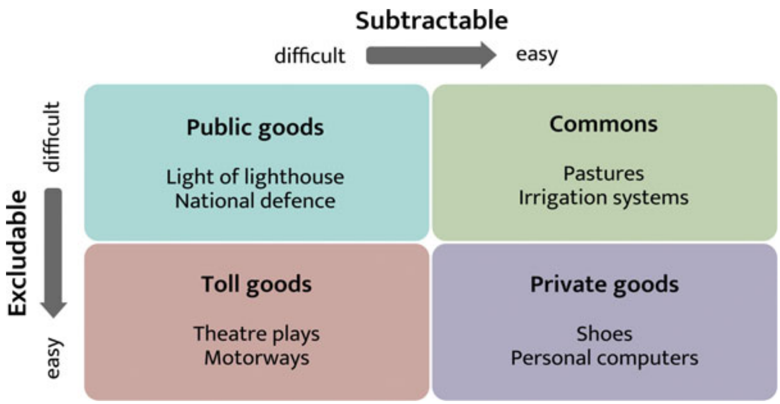

Fig. 4.1 Classification of goods including commons. (Adapted from Ostrom 2009)

shows that human beings have complex motivational structures beyond personal interest, as well as a greater capacity to solve social problems than the prevailing theories on social dilemmas. In fact, individuals in diverse communities know how to resolve their conflicts, without the intervention of external agents: through self-government, in a decentralised, or polycentric, way. In many different contexts, self-governance has reinforced the capacity to solve problems sustainably over long periods of time.

Commons had tended to be ignored in traditional economics analyses. However, the sustainability of certain commons, even over the centuries, has been demonstrated as possible through case studies around the world. It is also highly relevant to mention, albeit very briefly, the convergences of studies on commons and cooperation in different research areas. The emergence of cooperation as a key to the evolution and survival of various complex systems, from the cellular level to socioecological and social structures (Levin 2004), has prompted the research on strategies that lead to stable outcomes in the long term (see Levin 2004 on evolution theory; Axelrod 1984 and 2010 on game theory and political science; MacIntyre 2016 on ethics).

Finally, it should be noted that the classification of certain goods depends on the existing technological possibilities along with the current norms and laws. However, and above all, it depends on the will of those who have competences, responsibilities, and power for defining the resources towards one or another direction. The key question here is: should science be included among public goods as is currently often advocated to prevent its privatisation? Our proposal emphasises that science should be considered a commons in order to achieve its optimal governance.

From Natural Commons to Knowledge as a Commons

At the beginning of the twenty-first century, Elinor Ostrom, Charlotte Hess, and other researchers began to develop the notion of *knowledge as a commons* (Hess and Ostrom 2007), extending the concept from the physical to knowledge. Knowledge can be considered as a commons because of its relatively high subtractability and relatively low excludability. These authors explained that, despite various difficulties, similarity can be established because knowledge commons are collectively sustained resources whose accessibility and durability are conditioned by the rules of use.

Science can be understood as a commons mainly because it requires common action within a collaborative project – the result of deliberation and agreement on the rules – to preserve knowledge. Science as a commons is not equivalent to public science but to ‘open science or extramural science yet not merchantilized’ (Lafuente and Estalella 2015, p. 29). In this sense, open science is related to inclusiveness. Lafuente and Estalella argue that science as a commons does not consist of professional science including citizens in their design and evaluation; it is not the usual science but ‘a democratic or postmodern version’ (p. 29). Science is a commons due to the application of 'contrastive, collective and recursive cognitive practices, a historically differentiated way of producing knowledge, community and commitment' (Lafuente and Estalella 2015, p. 29).

Unlike public and private goods, science as a commons is constituted from and together with its communities, according to the rules of use they themselves establish. Achieving a kind of science that constitutes *the common* (Dardot and Laval 2019), or a *common science* (Lafuente and Estalella 2015), requires collaborative action from all those involved – with common objectives, deliberations, infrastructures, and rules of use – as well as attitudes based on trust, reciprocity, and cooperation.

However, such a proposal must be achievable in practice, while science is widely developed on a large scale. Among current good practices of common governance, we can consider some that we have included as sound practices of citizen science, for example, SnowChange, Model Forests, and *Biodiversidad Virtual* (Table 4.1). Their main shared features are the cooperative management of resources and the co-creation of scientific knowledge beyond (or together with) official institutions. These practices consist of a type of collaborative action that favours a sustainable development of natural resources, as well as the knowledge and methodologies derived from such collaborative actions (see Fig. 4.2). We can also refer to hundreds of projects around the world or to the thousands of publications and studies about socioecological systems among many other topics. Or we can reference Alan Irwin (1995, p. 10) and why he chose environmental issues as a paradigm of the citizen science phenomenon. He indicated three reasons: first, they imply areas of encounter among institutions and citizens; second, environmental risks represent very well other areas of technical and social debate; finally, sustainable development also

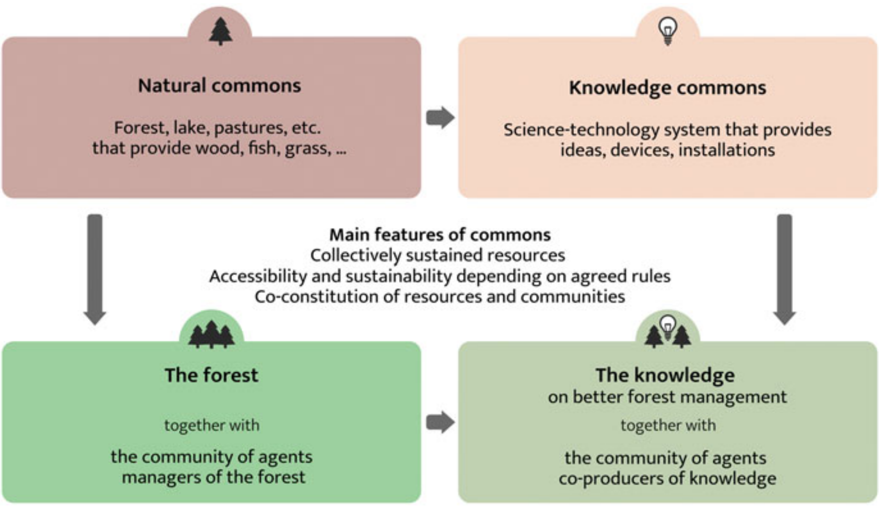

Fig. 4.2 From natural commons to knowledge commons. (Source: prepared by the authors based on the texts of (Hess and Ostrom 2007) and (Dardot and Laval 2019))

involves defining the sustainable way of managing science and expertise. Irwin's last reason reflects a central theme in this chapter, together with the concept of cooperation as a methodological foundation of citizen science. Indeed, our proposal for *the constitution of science as a commons through citizen science* is valid for any cooperative action. Citizen science is particularly powerful because it refers to the sustainability not only of natural resources but of knowledge and science itself.

Citizen science has a particularly relevant role because it (1) allows the development of a multitude of projects in diverse fields with different scopes; (2) favours the constitution of self-regulated and polycentric systems; and (3) supports the conditions of governance and the conservation of the commons.

Citizen Science as a Commons

Lafuente and Estalella (2015) present an analysis of the role of citizen science in the open science context and specifically as a common science. They understand citizen science as science conducted outside the walls of academia, in which knowledge is developed by virtuous communities. They also highlight that there is not a unique citizen science but rather many citizen sciences (with respect to the diversity of citizen science definitions and interpretations see Haklay et al., Chap. 2, this volume). A relevant comparison is to the maker movement and hacker ethics. Makers and hackers can be defined, respectively, as people who build things and software, sometimes as anti-consumerism, but often for practical reasons based on do-it-yourself (DIY) culture (Toombs et al. 2014). The *gift economy* translates into sustainable practices and protocols, promoting an open, experimental, inalienable, horizontal, and distributed culture (Lafuente and Estalella 2015). Though not all activity is science, there is a lot of science undertaken by makers and hackers. In this sense, robust citizen science projects – for example, Debian as an emblematic hacker project – help to understand the constitution of scientific knowledge as a commons. In addition, it can be better understood that projects are constituted as knowledge commons. Each one of them consists of a resource sustained by a community, and the community is constituted at the same time as the resource.

Using a different approach we can find initiatives such as Model Forests where open and collaborative science is linked to concepts such as *cognitive justice*, *situated knowledge*, and *knowledge commons*, together with those shared by European policies (inclusion, sustainability, equity). In this way, the sociopolitical aspects of scientific knowledge are understood beyond its (necessary) economic conditions and implications. A set of relevant references for this topic can be found on the Open Collaborative Science Development Network (OCSDNet) website (OCSDNet n.d.).

Understanding that citizen science is a suitable practice to *constitute the common* implies a double sense, which Dardot and Laval (2019) propose for the common in general: science (and citizen science) is configured as a commons at the same time that, through common action, co-responsible communities are created and consolidated. This proposal is illustrated with the examples in Table 4.2 and in the scheme in Fig. 4.2. We understand that citizen science, by overcoming the fictitious fracture between science and its environment, represents a fundamental element for achieving this. However, this is also dependant on the motivations of the involved agents in the governance of a true scientific-technological and sociopolitical progress.

Paraphrasing MacIntyre (2002, p. 107) on the commons concept, we note that in many situations the key question that we should ask is not 'how should *I* act' but 'how should *we* act', since the common goods of concrete communities (e.g. the work team) are at stake. These common goods are achieved and enjoyed by individuals as members of communities. An example of success in maintaining the natural commons would be the case of fishing communities. But these achievements are fragile and depend, in large part, on the characteristics that define the agents of these communities. The networks of reciprocity must be created and protected mainly through the development of virtues, including the virtue of *recognition of dependence*. This is possible through common deliberation about how to define and obtain the shared goods of each community: different but interdependent with one another.

Monitoring Cooperation

As we have seen, goods are one kind or another not so much per se but by how we *use* them. Particularly, good management of a commons is linked to cooperation and self-government including monitoring among the members of the community of practice. In this chapter, we have introduced a proposal to understand and manage science – and citizen science – as a commons, that is, as a vulnerable resource that requires rules of use and monitoring, agreed within the communities of use. Vulnerability results from the action of individuals who do not assume their responsibility in the maintenance of a shared resource. They are *free-riders* who simply consume at the expense of the work of others.

In fact, inequitable treatment of participants can take place, as many citizen science professionals have pointed out. Specifically, Vohland et al. (2019, p. 9) have warned about the need for vigilance 'against instrumentalization by economical interests or the displacement of state duties to citizens'. There are also concerns about the intentions behind its promotion either by institutional science or by policymakers, for example, with respect to possible cost outsourcing (Resnik et al. 2015). In this sense, Mirowski (2018) explicitly argues against citizen science (and open science), understanding it as a tool exclusively for fostering the economy, encouraged by European policies.

With respect to European policy, Schade et al. (Chap. 18, this volume) explain that citizen science has been explicitly placed in different science policy frameworks, in line with the overarching objectives of the Europe 2020 Strategy and in relation to specific areas such as the Digital Agenda, Science 2.0, Responsible

Research and Innovation (RRI), and Open Science, the latter being the main current framework. Indeed, the European Commission (EC) proposes citizen science as one of the priorities of open science, to 'encourage the inclusion of non-institutional participants, in other words the general public, in the scientific processes' (EC 2016, p. 53) and 're-direct research agendas towards issues of concern to citizens' (EC 2016, p. 54). In the founding document of this initiative, Carlos Moedas (2015, p. 1) states that 'we are moving into a world . . . where new knowledge is created through global collaborations involving thousands of people from across the world and from all walks of life'.

The above statements do not seem objectionable, in principle. Nevertheless, they need to be addressed in more detail as they can be limited in scope by a reductionist interpretation of open and citizen science. This requires clarifying the analysis of practices in a system whose main goal appears to be the industrial and commercial exploitation of knowledge.

In this respect, the statement 'the European Union will not remain competitive at the global level unless it promotes Open Science, and relatedly, Open Innovation' (EC 2017, p. 4) can be seen as indicative of the instrumentalisation of 'openness'. Citizens would be seen as 'users' with 'a central and transversal role to play in bringing innovation to the market' (EC 2016, p. 17) rather than as legitimate producers of knowledge.

Of course, this way of interpreting open science and citizen science is not the only one in the EC. The many citizen science projects funded through the last three Research and Innovation Framework Programmes (FPs) have involved thousands of people – including professional scientists, policymakers, companies, the third sector, and citizens in general – actively participating, aware of their co-responsibility for the generation of scientific knowledge and the maintenance and cohesion of their communities and societies. Regarding more specific ethical issues, we refer to research carried out by Tauginienė et al. (Chap. 20, this volume).

If the main feature of citizen science is cooperation (action for constituting commons), specific rules must be established in each project, so that 'its practice . . . by different actors and interest groups . . . be monitored and reflected upon carefully' (Vohland et al. 2019, p. 6). The current ambivalence of citizen science towards either strengthening or mitigating its instrumentalisation (Vohland et al. 2019) is related to its condition as a commons. Due to the gradual properties of resources, one type of resource can evolve into another quite easily. Commons are especially vulnerable as they share properties of both public and private goods. In this sense, in a neoliberal context, they face the risk of being privatised.

In short, citizen science represents an important occasion for sociopolitical and cultural-scientific change, which not only favours citizens to be more committed and co-responsible with respect to science but also to achieve better science in all its dimensions. However, it also represents a resource that we need to better understand in order to ensure its preservation.

Challenges

Citizen science faces many challenges and must correct and/or prevent bad practices. Though with its own particularities, some challenges are shared with academic science (Resnik et al. 2015). Here we outline some of the most relevant ones:

Epistemic or Cognitive Challenges The implementation of citizen science projects must guarantee the conditions for learning as well as the development of the personal and collective capacities necessary for research. Only in this way can scientific results better be obtained along with socio-cognitive benefits for the participants during the research process.

Ethical Challenges It is necessary to disseminate good examples of citizen science as well as to prevent bad practices, such as misappropriation of research results, exploitation of participants through cost outsourcing, or participation biases. Practices that promote environmental conservation, the generation of knowledge in diverse areas, together with the strengthening of the multiple communities that generate it, must be understood as constituting the commons. Moreover, these same practices must also be understood as knowledge commons. This is the main reason why they must be preserved and promoted.

Political Challenges A better understanding of the scope of cooperation for good governance, as well as of the development of stable forms of cooperation and the strengthening of communities and each one of their members, must be achieved. In that sense, practices favourable to the constitution of the commons should be promoted and preserved. This requires attention to the civic implications of research dynamics, as well as to co-responsibility dynamics in public and common spaces (*res publica*). European FPs seem to echo these political virtues by introducing the relevance of concepts such as capacity building and recognition (FP7), responsibility (FP7 and F8), and co-creation (FP8 and FP9).

In general, the above-mentioned challenges demand more reflexivity concerning ends and means, particularly in relation to science education and its current promotion through science policies. It seems increasingly necessary to promote a problem-oriented education system, willing and capable of integrating a variety of perspectives and concerns – philosophical, scientific-technical, artistic, etc. More generally, technological and sociopolitical strategies must be consolidated and developed in order to promote polycentric initiatives that are sensitive to interrelation, interdependence, and communication. Examples of these strategies are found in citizen science, such as platforms, shared resources, data repositories, citizen laboratories, and support networks that connect a growing number of projects. The management of these tools requires solid foundations – such as trust-based cooperation – that build and strengthen links for the durability of resources, as well as the flourishing of communities, societies, and their members.

Future Trends and Recommendations

Citizen science is situated in a discussion between two poles: a certain enlightened tradition of modernity, which relies on science and progress, and the postmodern relativism that questions science itself and which today is reflected in anti-scientific attitudes and pseudoscientific practices. This is a different discussion, but closely related to, that which occurs between the experts (those who know) and the allegedly lay people (who, not infrequently, also know).

The practice of citizen science presupposes a cognitive and social (pro)active involvement, so that we can truly speak of the co-creation of scientific knowledge. Many complex and/or controversial research questions – that, increasingly, cannot be fully covered by academic research – are suitable to being studied via citizen science methodologies. Thinking about an already foreseeable future, the unstoppable growth in the amount of data will increasingly lead to *machine learning* techniques, currently used also in citizen science (see Franzen et al., Chap. 10, this volume). However, the previous statements should not be understood or practised in an instrumentalist way. The proposal of the commons starts precisely from the premise – theoretical and empirical – that cooperation, with all that it involves, is the best solution for all concerned with matters of general interest. But its application is neither simple nor homogeneous and therefore requires continuous reflection and surveillance by communities.

Citizen science has been proposed in this chapter as key to the constitution of science as a commons, by allowing the development of a multitude of projects based on cooperation for the preservation of natural or knowledge commons. The corresponding network of agents and communities not only favours the conditions of governance, sustainability, and quality of knowledge, but also comes with important cultural, social, and political changes. Understanding science – and citizen science – as a commons brings to the fore a challenge inherent in the concept. The constitution of a commons requires specific conditions that must, in turn, be created and preserved.

In society in general (politics, education, art, science, sport, etc.) we need:

- A better understanding of the meaning, scope, and benefits of cooperation and, consequently, the promotion of this governance model, through research, education, and policies, whether governmental or not.
- A wide diffusion of the concept of the commons that transcends the public-private dichotomy, highlighting the protagonism of citizens themselves (including professional scientists and politicians) in the infinite possibilities of common spaces.

In each citizen science project, the following tasks are also needed:

- The establishment of rules within the communities that shape the projects.
- Careful monitoring of the projects (especially the top-down ones) so that the participants are considered not as users but as collaborators, members of the research team, each one with their own responsibilities, be they major or minor.

This monitoring translates into recognition of citizen scientists both in the development of research and in the research products derived from it.
- Monitoring also refers to action against free-riders who can be citizen scientists, professional scientists, managers, communicators, or politicians.

Citizen science is already part of the transition towards a different culture, where cooperation is the guiding principle in all shared areas, for example, in governance models, in education, health, culture, and communication. However, this will only happen if we intend to address it in the day-to-day of each project. Since many commons have existed for decades, even centuries, we know that this proposal can be achieved.

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Chapter 5
Citizen Science in the Natural Sciences

Didone Frigerio, Anett Richter, Esra Per, Baiba Pruse, and Katrin Vohland

Abstract The natural sciences include the life and physical sciences and study nature through observing and understanding phenomena, testing hypotheses, and performing experiments. Key principles such as reliability, validity, objectivity, and predictability are achieved through transparent assumptions, methods, data, and interpretations as well as multidisciplinarity.

In this chapter we present insights into the genesis of citizen science in the natural sciences and reflect on the intellectual history of the natural sciences in relation to citizen science today. Further, we consider the current scientific approaches and achievements of natural science projects, which are applying citizen science to address empirical and/or theoretical research, focusing on monitoring programmes. Presenting examples and case studies, we focus on the key characteristics of the scientific inquiries being investigated in the natural sciences through citizen science. Finally, we discuss the consequences of engagement in scientific processes in relation to the future of natural scientists in a complex world.

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Introduction

The *natural sciences* combine the *life sciences*, which involve the study of life and organisms such as microorganisms, plants, and animals including human beings, and the *physical sciences*, which are focused on non-living systems such as celestial objects and the structure and composition of matters and substances. The natural sciences are grounded in observing and understanding phenomena, testing hypotheses, and performing experiments. *Inquiry-based research* is performed across spatial and temporal scales with the application of standardised methods and protocols. The main driver in the natural sciences can be expressed by Goethe's Faust: 'So that I may perceive whatever holds / The world together in its inmost folds' (Goethe 1986). Information about the natural world is described in measurable units. Key principles such as reliability, repeatability, objectivity, and predictability ensure validity for scientific advances and are often achieved through multidisciplinary approaches. Both the life and physical sciences include several basic and applied scientific fields. Zoology, botany, genetics, neuroscience, and theoretical biology are examples of *basic research fields* in the life sciences, whereas environmental sciences and conservation biology are *applied research fields*. In turn, earth science, chemistry, physics, and astronomy are regarded as basic research fields in the physical sciences, whereas astrophysics, digital electronics, and nanotechnology are examples of applied research fields.

As a research format, *citizen science* has evolved over decades – generating knowledge, fostering scientific literacy, and enhancing learning through engagement in all scientific disciplines (Kullenberg and Kasperowski 2016). In this respect, the natural sciences offer a wide application for citizen science approaches across a range of disciplines (Follett and Strezov 2015). In the physical sciences, Galaxy Zoo is a well-known citizen science project, where the public was invited to visually inspect and classify nearly one million galaxies via the Internet. The aim of the study was to first distinguish between the two main morphological classes of massive systems in order to understand the formation and subsequent evolution of galaxies. The project achieved more than 40 million individual classifications made by hundreds of thousands of participants (Lintott et al. 2008). Sørensen et al. (2016) also launched Quantum Moves, an online project gamifying optimisation problems in quantum physics. The physicists showed that human players were able to find solutions to difficult problems associated with quantum computing. Furthermore, Barr et al. (2017) demonstrated that *non-expert volunteers* can identify the decay of long-lived particles with an efficiency and fake rate comparable to that of ATLAS algorithms, a machine learning-based analysis process.

Several examples of the successful application of citizen science can also be found in the life sciences. The project EteRNA was among the first Internet-scale citizen science games scored by high-throughput experiments. A community of 37,000 non-experts leveraged continuous remote laboratory feedback to learn new design rules that substantially improved the experimental accuracy of RNA structure design (Lee et al. 2014). Similarly, Phylo involved volunteers in investigating the multiple sequence alignment problem, used to reveal conserved DNA sequences across species (Singh et al. 2017). However, *biodiversity monitoring* projects are among the most common citizen science projects in the life sciences. For example, the North American Bird Phenology Program's Migration Observer Cards project was among the earliest citizen science activities and has contributed vital data to ornithology (Irwin 1995; see also Box 5.1). Over recent decades, communities of non-expert volunteers have been involved in numerous projects, for example, in monitoring streams and benthic macro-invertebrates (Fore et al. 2001); in mapping the distribution of the wintering areas of monarch butterflies (Howard et al. 2010); in investigating the ecology of an invasive population of Red-vented Bulbuls (Brooks 2013); and in recording damage caused by leaf-mining moths to horse chestnuts (Pocock and Evans 2014).

In this chapter we explore and present insights into the genesis of citizen science in the natural sciences and reflect on the intellectual history of the natural sciences in relation to citizen science today. Specifically, we draw a line from the amateur scientists of the past working in isolated knowledge domains to the collaboration-based scientific investigations of the future. We start with the question 'How are key characteristics of the natural sciences applied by contemporary citizen science?' moving on to 'What processes of scientific inquiry are investigated through citizen science?' Finally, we explore the more theoretical question 'What are the consequences of engagement in scientific processes?', in respect to the future of natural scientists in a complex world.

Bringing together existing research, it becomes evident that while citizen science is well established in the natural sciences, no thematic boundaries seem to exist to integrate and make use of its manifold potential. As one of the major aims of this book is to give an overview about the current discussion, understanding, and relevance of citizen science in different scientific fields including humanities (Heinisch et al., Chap. 6, this volume) and the social sciences (Albert et al., Chap. 7, this volume), we begin our reflection about citizen science in the natural sciences by paying tribute to citizen scientist pioneers who inspired many of today's citizen science enthusiasts. We introduce amateur scientists from the past as role models to learn about the key principles of citizen science in the natural sciences. We provide insights into the research approaches within projects and programmes and highlight scientific achievements as well as societal outcomes from citizen science in the natural sciences. For instance, selected case studies on biodiversity monitoring are presented to showcase practical aspects of citizen science in the natural sciences. The chapter closes with some remarks on the future.

History

The history of the natural sciences and citizen science is closely related. One of the oldest examples which can be termed citizen science is the observation of cherry tree flowering in Kyoto, Japan (Aono and Kazui 2007). Merchants, politicians, monks, and others all noted the start of the cherry bloom in their diaries, the first entry found for which was from 801 AD.

When citizen science is presented to newcomers, historical stories, people, and places that have shaped the understanding of today's natural world are often referred to.[1] Explorers and advocates for the natural sciences such as Alexander von Humboldt, Ferdinand Müller, and Maria Sibylla Merian are showcased to highlight how enthusiasm and an inherent curiosity for understanding the natural world have influenced them. They travelled around the world into unknown and unexplored areas, collected information and data in remote and untouched places, archived species and objects in boxes and books to be shipped around the world, and shared new knowledge. Many amateur scientists from the past have shaped and grounded the natural sciences and are representative of the core of citizen science – seeking understanding and gaining new knowledge, sharing and caring for the sustainability of findings and data, and enabling members of society to become scientifically literate citizens.

When German-born Ferdinand Müller arrived in Australia in the mid-eighteenth century, the science of Australian botany was born. The amateur botanist devoted his life to the inventory of the iconic flora of the Terra Australis Incognita. He revolutionised data collection by engaging local communities and establishing groups of collectors that he recruited through newspaper articles and word-of-mouth recommendations. Over 1300 people, including Indigenous Australians, women, and children, supported Müller's scientific mission and contributed to Australian botany (Finkel 2018).

In Europe, 200 years before Müller's community engagement in scientific discovery, Maria Sibylla Merian was born in Frankfurt, Germany. A young Merian pursued her inquisitiveness of the world of insects and observed, described, and painted insect development, today known as metamorphosis. Later in life, she travelled as an amateur entomologist, with no formal education, around the world to investigate relationships between insects and host plants and developed, through her research, the foundation of modern entomology. Much of today's knowledge, for example, about the distinctions between butterflies and moths and the ecological requirements for the survival of butterflies, dates to Merian's early findings. Her knowledge and discoveries were published in several books in German (not in Latin, as was common at that time) and were, therefore, accessible to other non-scientists. However, she received less scientific recognition than her academic peers. Decades later, Merian is a widely recognised and respected figure in science.

In 2019, many research institutions across the world celebrated the 250th anniversary of Alexander von Humboldt and paid tribute to the universal scholar who developed and linked the knowledge of disciplines within the natural sciences, ranging from astronomy to zoology. Humboldt was an outstanding scholar who embodied the concept of life-long learning and widely communicated about science, writing thousands of letters to both his peers and policy-makers. His open mind

[1] https://www.youtube.com/watch?v=cE1kpXLkGbo

motivated him to formulate and include new theses in his thinking about the natural world. Humboldt gained novel insights into global relationships such as the effects of human activities on climate change and the science of biogeography.

These three historical examples showcase that some of today's key principles of citizen science (Robinson et al. 2018) are not new. The genesis of new scientific knowledge often starts with an observation of a phenomenon, and, as Charles Darwin pointed out, 'It is well to remember that Naturalists value observations far more than reasoning' (Darwin 1887). Observations are necessary to formulate research questions and testable hypotheses, ideally generating theories and leading to new questions requiring further observations. Both Humboldt and Merian applied this type of process when approaching the natural world. The explorers, universal scholars, and amateur scientists outlined reflect the beginning of the so-called professionalisation of science, when 'doing science' became a profession (for more details see Haklay et al., Chap. 2, this volume). Long before a distinction between amateurs and professional scientists was made, people with various backgrounds shared an interest to make sense of the world around them through community building and partnerships with members from various knowledge domains. Much of the understanding of the natural world was and is achieved through the development of standardised methods in the natural sciences.

Research Approaches

Generally, the natural sciences can be defined as applying to 'subject matter based on the philosophy of naturalism' (Ledoux 2002), where natural events are investigated using scientific methods. In this chapter, we consider research in the domain of natural sciences to be grouped according to two major methodological domains – empirical and theoretical research. *Empirical research* can be distinguished between (1) *observations*, that is, the collection of data about objects in the natural world, and (2) *experiments*, that is, the collection of information and relations using variables and measurements that allow analysis of cause and effect relationships. Observations include the recording of patterns and processes occurring in, and being representative of, the natural world alongside various spatial and temporal dimensions, ranging from local to global phenomena and from short- to long-term observations. The observations are achieved using *senses* or *sensors*. Technical devices such as microscopes and scanners are used to further enhance the seeing, hearing, smelling, and feeling of objects in the natural world. Within experiments, the empirical approach is to collect evidence that confirms or rejects a hypothesis or assumption formulated prior to the collection of the evidence. This process allows the analysis of causal and/or correlative relationships. In contrast to the empirical domain that is data driven and focuses on testing and validating hypotheses, the theoretical domain is conceptually grounded and focuses on the collection of concepts and theses to explore and explain the natural world. For this, ideas are theorised, abstracted, and synthesised to find ways to define how the natural world and its environment interact

(Lederman 2007). A pan-European survey showed that the majority of citizen projects involve performing observations and collecting data, rather than doing experiments or brainstorming on possible research questions (Hecker et al. 2018).

Biodiversity monitoring especially profits from a citizen science approach as working with citizen scientists in monitoring biodiversity networks increases the amount of data (and therefore their reliability) and expands the temporal and spatial scales of the investigation (Chandler et al. 2017a). As over 80% of biodiversity data in Europe is recorded by citizen scientists (Schmeller et al. 2009), it is not surprising that the spatial and temporal coverage of the assessment of biodiversity depends to a large degree on volunteers' availability and ability to travel to areas of interest.

Such monitoring projects invite citizens to contribute data collection in different habitats and locations over a long period of time. Participants gain knowledge about the organisms they observe and are involved in the realisation of scientific research. Developing and implementing these projects to achieve scientific knowledge and scientific literacy requires great effort (Bonney et al. 2009); but citizen science represents a practical way to achieve the geographic scope required to document ecological patterns and address ecological questions at scales related to regional population trends and the effects of environmental processes such as the range and migration patterns of species (Sih 2013). Large-scale citizen science projects enable participants to join national and even global research and collect data in many places at the same time. The results of these studies can be used for population management decisions and even international environmental and conservation policies (Chandler et al. 2017a). Furthermore, the development of mobile applications for monitoring has brought together numerous new volunteers in nature conservation (Silvertown et al. 2013). Smartphone apps and mobile web access enable volunteers to be involved in recording observations and environmental monitoring in multiple ways (Luna et al. 2018). Also, the development of digital tools allows professionals to easily obtain large, comprehensive sets of data which would not be achievable without the contribution of volunteers.

Most biodiversity-oriented citizen science programmes aim to identify the location and abundance of species. These data are used in different studies (e.g. eBird, iNaturalist, and iSpot) to determine the population trends and range of species. For instance, more than 50% of GBIF (Global Biodiversity Information Facility) data for biodiversity monitoring is obtained from citizen scientists (Chandler et al. 2017b). The high participation rate is important in reducing data errors, as these projects generally do not require participants to have a scientific background. Other citizen science projects are carried out on specific topics by museums and local nature observation groups. *BioBlitzes* are popular in this regard and contribute to the confirmation of existing species, the discovery of new species, and knowledge about changes in the distribution of species, such as the expansion of invasive alien species (IAS) over time and space (Chandler et al. 2017b).

Considering the world is facing increasingly rapid and dramatic changes to habitats, species loss, and ecosystems due to human activity (UNGA 2015), there is an urgent need to monitor global biodiversity worldwide. Currently, there is great untapped potential for citizen science, particularly in Asia and Africa, to become a valuable tool for sustainable development (Pocock et al. 2019). Environmental citizen science is already widespread throughout North America, Australia, and Europe (Chandler et al. 2017b). For instance, the development of bird surveying in Turkey represents a valuable example for the application of citizen science in the life sciences by performing observations (Box 5.1).

Box 5.1: eKuşBank and the Turkish Breeding Bird Atlas
Bird surveys carried out in Turkey from the nineteenth century until the 1970s were usually based on faunistic checklists and the addition of new records. The Ornithological Society of Turkey decided to compose a breeding bird atlas in the mid-1970s through new research approaches. However, this attempt was unsuccessful because not enough birdwatchers were available (Kasparek 1991). Between 2000 and 2002, Turkish bird atlas studies have been conducted on a regional scale with the support of the Society for the Protection of Nature (DHKD) and the methodology adopted by the European Bird Census Council (EBCC), and their breeding codes started to be used in Turkey for the first time.

With the foundation of *eKuşBank*, in 2004, a voluntary network has been established (Özesmi and Per 2006). Its breeding codes provide up-to-date, important data about the breeding behaviour of different species. They also increase the awareness of birdwatchers and scientists.

Since the breeding codes started to be used by the Ministry of Agriculture and Forestry in 2007 and their use in the ministry's biodiversity projects was made obligatory (Nuhun Gemisi 2019), their usage has become widespread throughout the country. In addition, the data quality and the number of citizen observations are increasing (Per 2018). Since the completion of the breeding atlas project in 2019 (Boyla et al. 2019), areas that are significant in the breeding of species have come to light. *eKuşBank* data are widely and effectively used by scientists, NGOs, and decision-makers in Turkey. Following the inclusion of *eKuşBank* in the eBird infrastructure, now foreign tourists can also share their observations. Through citizen science, birdwatching has come to the fore in Turkey. The Department of Biology, Gazi University, in Ankara, is a project partner.

One of the few projects involving citizen scientists in doing experiments, that is, in contributing to testing hypotheses, is Heavy Metal City-Zen. Participants are asked to conduct a simple experiment in their urban gardens, by cultivating the same focal plant species in two different sorts of soil: the proposed variant (e.g. a mixture with compost that is provided to participants) and their own control variant (the untreated urban soil of their own garden). The project is still ongoing and aims to investigate the status of soil health in Vienna, Austria, providing data on the potential risks of heavy metal contaminants and suggesting mitigation strategies.

Similarly sparse are examples regarding the engagement of citizen scientists in theoretical projects, which are approaching and generating new research questions or discussing the relevance and potential of results. The few examples seem to focus on *crowdsourcing*, mainly used by companies which aim to include potential customers in production by conceiving new products, for instance, via the Samsung Strategy and Innovation Center – a global hub for start-ups, technology, and artificial intelligence professionals where new products are developed with input from the public.

Scientific Achievements

The examples mentioned so far with respect to citizen science and the natural sciences share the common feature of citizen science being applied as a research method aiming for scientific outputs. Volunteers are engaged in the production of scientific knowledge, and their contributions are handled through scientific standards. Accordingly, citizen science projects in the natural sciences have led to peer-reviewed publications across a range of disciplines (Kullenberg and Kasperowski 2016).

Astronomy is one of the oldest scientific areas where lay people have contributed observations. It involves a broad array of persons, physically as well as via online platforms, and results in various scientific contributions: citizen scientists contribute to the detection of objects such as planets, comets, asteroids, and supernovae. They contribute to the understanding of the meteorology of planets by documenting clouds and storms; support insights into exoplanet systems and the radiation of blazar outbursts via observations; and cluster particles, craters, and supernovae based on digital images (Marshall et al. 2015). One of the biggest projects is Galaxy Zoo, part of the Zooniverse platform (Fortson et al. 2012): scientists outsourced the basic classification of galaxies. The project grew rapidly – gaining more participants and results than ever expected. In addition, the citizen scientists interacted, discussed results, and initiated their own project ideas, thereby increasing understanding about the scientific field. Zooniverse itself hosts different projects from a variety of disciplines where lay people can add their observations or contribute to digital projects to cluster patterns and observations. The contribution of citizen scientists is judged to be successful by the academic scientists involved; in one example, a Quasar ionization echo was discovered by a citizen scientist (Lintott et al. 2009).

In recent years, the amount and complexity of data from large detectors such as the Laser Interferometer Gravitational-Wave Observatory (LIGO) have grown enormously and exceeded the time capacities of volunteers. In a search for a new computational technology, researchers who established the Gravity Spy project tested a joint workflow between citizen scientists who identified novel glitches and machine learning techniques (Coughlin et al. 2019; cf. also Franzen et al., Chap. 9, this volume).

Additional applied research questions in the natural sciences have been successfully answered by citizen science. A Swedish group of scientists asked pupils to collect mushrooms and measure their radioactivity to investigate the long-term impact of the nuclear accident in Chernobyl (Andersson-Sundén et al. 2019). By joining the project, *Strålande Jord*, the pupils gain an understanding of the methodology of measuring radioactivity and additionally contribute to updating data on the radioactive load of mushrooms. Citizen scientists also contribute to the measurement of air pollution (i.e. aerosols). Within the framework of the iSpex experiment, participants contribute to the understanding of the temporal dynamics of aerosol distribution (Snik et al. 2014). Currently, iSpex is part of the MONOCLE (Multiscale Observation Networks for Optical monitoring of Coastal waters, Lakes and Estuaries) platform which develops low-cost optical sensors for citizen science.

In some other areas, for instance, chemistry, citizen science is largely absent. Albeit alchemists can be claimed as historical citizen scientists, nowadays there is scarce literature, and science and technology studies (STS) scholars complain that 'fewer historians of technology focus on chemistry than on other sciences, for example, and virtually no social scientist covers mid- and late-20th-century chemistry' (Woodhouse et al. 2002, pp. 305–306).

A further, broad field of natural sciences involving citizens is the life sciences, especially biology. As already mentioned in the introduction, for centuries humans observed natural phenomena and contributed to the understanding of nature. They described species and observe the spatial and temporal (phenological) distribution of plants and animals. Many projects today deal with the observation and interpretation of wildlife data, often with management approaches, supported by tools for data collection and analysis (Frigerio et al. 2018).

In contrast to the data that are observed and reported by citizen scientists from conservation areas and public land (e.g. backyards, gardens, and schools), biodiversity of agricultural areas is less well documented. In Germany, for instance, over 50% of the total land area is used for conventional and organic agriculture. Most of this land is designated private land, and comprehensive statements about the state of biodiversity in agricultural landscapes are limited. Therefore, nationwide monitoring schemes for agricultural areas are currently developed and tested to allow scientifically based answers about the influence of agricultural production, land use, and agricultural structural change on biodiversity. The Federal Ministry of Food and Agriculture in Germany is financing a 5-year pilot study to develop a basis for future monitoring of biodiversity in agricultural landscapes (MonViA). The aim of this pilot is the development of standardised sampling methods and analysis routines and the implementation of feasibility studies for different monitoring approaches, including a citizen science-based monitoring approach. Actors in the agricultural landscape hold extensive local knowledge about biological diversity, management practices, and the effects of the application of supplements such as fertilisers, some of which is maintained over generations. In turn, understanding the important role of biodiversity in the agricultural landscape and the added value of biodiversity for ecosystem stability varies considerably among actors. Further, the potential of citizen science in agricultural landscapes to contribute to reporting on Sustainable Development Goals (SDGs), such as ending hunger and achieving food security, has recently gained attention (Fritz et al. 2019). Established citizen science projects with and for farmers, such as the Austrian project *Biodiversitätsmonitoring mit LandwirtInnen*, show that citizen science can develop from an educational project to a monitoring programme. This project also highlights that participation, as well as non-participation, in citizen science should not incur negative economic or social consequences. Finally, citizen science in agricultural landscapes (as elsewhere) needs human power and financial capacity.

Participants in several international projects have contributed to the knowledge and conservation of genetic diversity, especially in the area of agriculture and food science (Ryan et al. 2018). More specifically, citizen scientists monitor pests, experiment with new food items, and assess the effects of environmental schemes, for example, flower stripes on their farms.

In genetics there is a vivid and diverse citizen science community analysing genomes, but also experimenting with new genetic sequences and synthetic organisms. One example is the experimental cultivation of *Roseobacter* strains, a common bacterium in oceans which may be used as chassis for synthetic biology applications, for instance, to degrade plastic. Using simplified devices, such as the UCLHack12 open-source incubator-shaker, investigations and manipulations are open to a broader public, in this case mainly cooperation between do-it-yourself (DIY) biologists and students (Borg et al. 2016). DIY biology comprises non-professional researchers (*biohackers*) who work in their own kitchen labs according to an ethical code of safety and transparency issues. In Europe, the community is challenged by strict legal regulations of gene technology and insufficient resources (Seyfried et al. 2014).

Societal Outcomes

In general, applying citizen science in the natural sciences produces long-term societal outcomes. As participation is often not dependent on the competence or experience levels of volunteers, the research questions addressed do not usually include investigation of the short-term added value for participants (Kasperowski et al. 2017). There is empirical evidence that collaboration between education and natural science research increases motivation for out-of-school learning (Scheuch et al. 2018) and fosters the acquisition and retention of non-traditional knowledge compared to classroom-based curriculum learning (Hirschenhauser et al. 2019). Nevertheless, citizen science projects need adequate financial and temporal resources for recruiting (and often training) participants and communicating with them. The efficacy of citizen science is optimised when the tasks required can be learned quickly; and the impact of citizen science increases when citizen scientists feel responsible for and are personally involved in projects (Senabre et al., Chap. 11, this volume). Finally, the engagement of citizens in scientific processes has the potential to combine the collection of publishable data with outreach, thereby raising awareness and providing direct benefits to society without compromising scientific output.

Challenges

As science professionalised, society and science diverged into strictly separated systems. The increasing specialisation and complexity of scientific language, research, and infrastructures, such as the publication system, make it challenging for lay people to access, gain, and benefit from knowledge that is ultimately generated by public finance. On the one hand, scientists conduct research in which millions of euros are invested, the legitimacy of which is sometimes questioned by the public. On the other hand, we are challenged by pressing problems in social, economic, and ecological contexts and demand sustainable solutions, which might be optimally fostered by science and society working together in a synergistic way. However, there are discipline-related differences, in the case of environmental issues and biodiversity problems, for instance, engaging and raising awareness by citizens can support science in bringing a topic to political interest, not least because the mass participation of citizens (and potential voters) indicates its importance. As Carl Friedrich von Weizsäcker observed, when the 'socially organized search for knowledge',[2] science does not find its way into social and political space; novel forms of participation as well as new forms of teaching the natural sciences and access to scientific thinking are needed.

A key challenge is to understand and support participation in citizen science not only by citizen scientists but also by the initiators of citizen science (academics, data aggregators, policy-makers). Based on a theoretical framework on behavioural theory which differentiates between internal beliefs, social pressures, and control beliefs, Wehn and Almomani (2019) identified key incentives and barriers. For citizens, fun, interest, and recognition are supporting factors, while inadequate data use and neglect of privacy issues are hindering factors. For scientists, resources (time, staff, funding) play a key role alongside data quality (cf. Balint et al., Chap. 8, this volume). For both, management, data aggregation, and communication skills are also important. Furthermore, current science management approaches encourage short-term research projects with results applicable to decision-making processes rather than long-term commitments where the output/input ratio can be low. Good communication of the results and a well-defined data policy are important steps to enhance the impact of citizen science activities. Ganzevoort et al. (2017) report that only a minority share their data publicly and suggest viewing the citizen scientist as curator rather than as owner of the data as they care about how it is used. Here new concepts such as *dynamic informed consent* (Tauginienė et al., Chap. 20, this volume) may help.

[2]Cited in the discussion forum: Die Verantwortung der Wissenschaft in der Gesellschaft. Öffentliche Diskussionsveranstaltung am 03. Mai 2017 in der Aula der Georg-August-Universität Göttingen. https://vdw-ev.de/portfolio/die-verantwortung-der-wissenschaft-in-der-gesellschaft/

Relevance, Future Trends, and Recommendations

Citizen science has been and will continue to be highly relevant to the natural sciences. Seeking understanding of the natural world is at the core of the natural sciences as well as being a goal for citizens. For this purpose, many hours of volunteering are spent to support the vast diversity of crowdsourced projects where citizens contribute by mass observations, while they are not necessarily deeply involved epistemically. From a data scientist perspective, crowdsourcing is the only way to gather comprehensive observation data for ensuring models' accuracy. Watson and Floridi (2018) even argue that seldom or improbable events and anomalies, detected through the power of the crowd, are essential to further develop scientific theories. The integration of many (volunteer) observers increases the probability of detecting these seldom events. In addition, the 'crowd' can react quickly; for instance, the first projects to address the COVID-19 crisis emerged on the platform Foldit (McGrath 2020). In parallel, rather simple digital tasks are increasingly being replaced by machine learning and other automated systems. From a citizen's perspective, crowdsourced projects are easy to join and do not often require much preparation, while comprehensive skills, advanced tools, and materials are not prerequisites for participation. A shortcoming of such low-level engagement is the missed opportunity for more advanced and in-depth involvement in scientific processes (Fig. 5.1) – engagement often ends with the data observation, recording, and transfer to platforms or the scientific community.

In fact, a transformation in respect to opportunities for citizens to engage in natural sciences beyond data contribution is already in sight. Natural science projects currently being classified as *activist approaches* may gain relevance in the future. For instance, citizens can search for scientific methods to demonstrate the severity and distribution of air pollution or participate in environmental justice (Toos et al., Chap. 19, this volume). Other activities engage citizens in the formulation of research questions (Senabre et al., Chap. 11, this volume). The added value of such approaches is multifaceted for both citizens and the scientific community. The expansion of opportunities for citizens to engage in various phases of the scientific discovery, such as engagement in theoretical work (Fig. 5.1), will likely increase citizens' scientific literacy and understanding of the relevance and innovative power of the natural sciences in our daily and scientific lives. If planned carefully, the scientific community will see a growth of perspectives that will help to better illustrate a comprehensive view of the issues to be solved and the challenges to be addressed.

We expect that future citizen science in the natural sciences will maintain its focus on crowdsourcing activities, aiming to expand the spatial and temporal scope of traditional science. However, and this is our vision for future citizen science in the natural sciences, facilitating engagement of citizen scientists in all phases of the scientific process will contribute to a better understanding of the value of evidence-based decision-making (Herrick et al. 2018). Co-creation of knowledge with citizens has shown to have outcomes on multiple levels, particularly on the community and

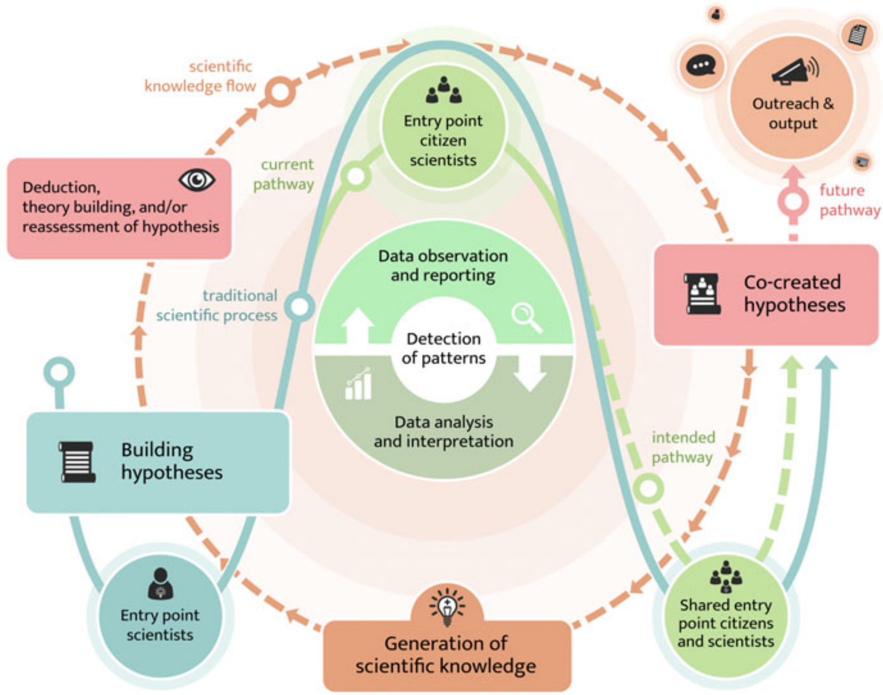

Fig. 5.1 In the natural sciences, citizen scientists typically join the scientific process via crowdsourcing or data collection (solid green line). However, there would be added value if citizens were more integrated in the theoretical work/hypothesis-driven research (green dotted line)

individual levels. Attainment of voice in decision-making, influence on management of natural resources, and the ability to access otherwise unavailable knowledge are only some of the outcomes driven by citizen science activities (Tero 2013; Bela et al. 2016). Based on the several examples mentioned as good practice in this chapter, we are confident that contemporary citizen science in the natural sciences has the untapped potential to contribute to the formulation of hypotheses and research questions. In other words, the future of citizen science in the natural sciences rests on the transition of citizen science beyond data collection (Fig. 5.1).

To enable multiple entry points to the scientific process for citizens, it is necessary to change the preconditions of the design and implementation of citizen science in the natural sciences. We recommend the following steps:

- First, establish and value flexible citizen science schemes that respond to the needs of volunteers to become more integrated participants in the whole scientific process.
- Second, provide on-going training for both volunteers and scientists, for example in scientific thinking to develop a scientifically literate mindset that leads to new research questions and theoretical thinking.

- Third, develop capacities for inter- and transdisciplinary research and communication and learn from best-practice case studies (e.g. on the platform EU-Citizen. Science; Butkevieciene et al., Chap. 16, this volume).
- Finally, value and formally acknowledge scientists who are open minded to this kind of trustworthy cooperation between scientists and citizens.

Literally shifting frontiers was part of the motivation of the past explorers of the natural world. Without confidence to sail beyond the horizon, without curiosity to enter the unknown wilderness, and without true passion for the natural world, much of our current knowledge would be fragmented and less colourful. It is now up to us to prepare and enthuse the next generation of Humboldts, Müllers, and Merians. Citizen science holds many opportunities to contribute to the natural sciences and to experience the beauty of understanding the world around us.

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Chapter 6
Citizen Humanities

Barbara Heinisch, Kristin Oswald, Maike Weißpflug, Sally Shuttleworth, and Geoffrey Belknap

Abstract Citizen humanities is the term for citizen 'science' in the humanities. It has a long tradition and, since the object of investigation is human culture, raises questions about values, cultural significance, and deeper meaning of phenomena related to human culture.

The development of digital technologies not only led to the emergence of digital humanities but also to new ways of involving citizens in the activities of cultural heritage institutions and academic research. Participants' contributions to academic research and to the preservation of cultural heritage range from uncovering treasures hidden in archives and digital environments to tapping local knowledge. Their tasks have included tagging, transcribing, or cataloguing artefacts, through which they acquire specialist knowledge and competences, while assisting scholars and researchers to gain new insights. Challenges in the citizen humanities include biases, participant training and retention, as well as the advancement of digital technologies, such as artificial intelligence.

Citizen humanities can combine topical issues in society with academic knowledge, demonstrate the relevance of the humanities for society, and establish a direct link to its members. In addition to the advancement of knowledge, the citizen humanities can unlock the potential of embedded, diverse, and culturally sensitive knowledge and play a crucial role in preserving and enriching cultural heritage.

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Introduction

Citizen humanities is the term for citizen 'science' in the humanities. While (citizen) science comprises natural sciences, such as biology, chemistry, and physics, (citizen) humanities encompass fields such as languages, literature, history, philosophy, and art. The humanities' primary object of investigation is human culture, ranging from the organisation of life in society or the state to the interpretation of the world in language, art, philosophy, and academia. In comparison to the sciences, the humanities do not (only) focus on explaining but rather understanding texts and artefacts, thus favouring methods of interpretation, critical thinking, and analysis.

While the main outputs of the humanities are texts, the digital humanities produce additional forms, such as images, platforms, and multimedia corpora. Moreover, while the humanities apply methods of analysis, narration, and critique, the digital humanities increasingly rely on computational methods allowing for automated analysis, including digital data and new techniques and forms of (re-)presentation. In brief, the concept of the digital humanities refers to the change in scholarship in the humanities driven by digital tools, digitally available (big) data, digital repositories, and virtual research environments. These not only bring to light new research questions but also new ways of analysing, combining, visualising, presenting, storing, and sharing pre-existing data as well as new ways of publication and collaboration among scholars.

Current developments in the digital humanities provide new tools, methods, and infrastructures and allow for various new forms of collaboration and communication with citizens and nonacademic actors in humanities research. However, voluntary contributions to the humanities have a long tradition. In addition to the generation of new knowledge (through research), they have been important for cultural institutions in various ways, such as establishing and maintaining contact with members of local and special interest communities.

History

Although the term *citizen humanities* was only coined recently (Adamson 2016a; Hedges and Dunn 2018), its practice has a long tradition. On the one hand, citizens may initiate and undertake studies without the help of scholars, such as genealogy, local history, and research on cultural heritage. On the other hand, professional researchers may rely on contributions from citizens. In both cases, they may draw inspiration from each other.

Citizen humanists are working both in digital environments and on-site and are applying methods from the humanities, such as collecting, transcribing, and annotating (historical) primary sources. Research undertaken by citizens is both old and new (Finke 2014). Professional research in the humanities, as we know it today, could only emerge because citizens who were not part of institutions engaged in research. Until the late eighteenth century, citizens collected (historical) information and objects and compiled them in catalogues and publications or developed typologies. One of these citizens was Johann Joachim Winckelmann, who lived in eighteenth-century Germany. Today, he is known as the founder of academic archaeology and art history, but his family was poor. While working as a librarian in Italy, he developed the first typologies for ancient art, which he published in epoch-making works. He also stressed the importance of archaeological excavation campaigns, which had hardly existed before that time (Disselkamp and Testa 2017). The passion and curiosity of people like Winckelmann made the institutionalisation of museums and the humanities disciplines, as well as the preparation of academic publications, possible in the first place (Mahr 2014). Although academic research in the humanities has been conducted in academic institutions since the nineteenth century, private engagement with the humanities has never completely ceased. Citizen researchers are still active, be it autonomously, in private associations, or as partners of public heritage authorities, archives, libraries, and museums. In universities, however, the citizen humanities are currently still struggling to gain a foothold.

Over the past few years, citizens have also increasingly engaged in digital research projects – most of the time initiated by museums and heritage authorities. Among the first digital projects in the citizen humanities mentioned in the literature are the British projects Old Weather and Transcribe Bentham. Both projects started in 2010 and focus on transcription (with and without additional markup) for the purpose of academic research.

Participants may also tag historical objects so that automatic tools can enrich data. In 2004, several North American museums joined forces under the pseudonym *Steve* (steve.museum) to make cultural heritage accessible through tagging and to explore new forms of relationships between visitors and cultural heritage (Trant 2009).

This shows that digital infrastructures, tools, and techniques can facilitate citizen humanities. Nevertheless, volunteers also contribute in various non-digital ways to humanities research, for example, by travelling to archives and collecting local and special knowledge and documents (e.g. on declining professions or changing cultural landscapes) and conducting archaeological field surveys and experimental archaeology.

In the English-language literature on citizen science, the Christmas Bird Count is described as the longest running citizen science project in the world (Silvertown 2009). In the humanities, the compilation of a *Dictionary of Mediaeval Latin* also required more than 100 years of public participation (Dobreva and Azzopardi 2014).

The visibility of citizen humanities projects is low compared to citizen science projects. This is especially apparent in the European citizen science landscape (see Haklay et al., this volume, Chap. 2; Vohland et al., this volume, Chap. 3) and citizen science project directories (Heinisch 2017). Nevertheless, the citizen humanities are gaining ground in different academic disciplines, such as linguistics, history, archaeology, art, and philosophy.

Types of Citizen Humanities

Similar to citizen science, typologies to classify activities in the citizen humanities have been proposed. Although termed *humanities crowdsourcing* and focusing on digital approaches, the typology by Dunn and Hedges (2012) covers the main aspects of humanities research, that is, tasks, assets, processes, and outputs. It links assets, primary resources such as text, audio, and video with outputs, for example, structured data. The processes and tasks between input and output refer to the methods used in the citizen humanities, such as collaborative tagging, transcribing, categorising, mapping, georeferencing, contextualising, and translating.

Simon (2010), on the other hand, elaborates on visitor contributions to institutions, such as museums. Her typology addresses the degree to which participants are involved in creating content, developing research questions, analysis, and have their say in the project framework. Based on the 'Public Participation in Scientific Research' study (Bonney et al. 2009), she derives four forms of citizen humanities in the museum context – contributory projects designed by researchers, to which participants contribute data; collaborative projects designed by researchers, to which participants contribute data and input; cocreated projects, which are not only designed by researchers and members of the public together, but public participants are also involved in most steps of the research process; and hosting, which means that institutions are mere hosts for citizen research projects.

Citizen Humanities in Different Disciplines

Exemplified by citizen humanities projects in the fields of archaeology, history, and linguistics as well as crowdsourcing in the cultural heritage domain (Oomen and Aroyo 2011) and interdisciplinary projects, this section gives an insight into projects characterised by public participation in the humanities.

Archaeology and History

In the fields of archaeology and history, the citizen humanities are well established since historical records and archaeological finds lend themselves to public participation. This may take the form of transcription of handwritten texts, tagging, interpretation of pictures or text, provenance research, or field studies often relying on local knowledge and local research material. The citizen humanities hold the potential to open up historical data for humanities research. This is illustrated by the Ancient Lives project, which was one of the first Zooniverse humanities projects. It enabled volunteers to help decode the papyri of the ancient Egyptian city of Oxyrhynchus. Documents recovered from ancient rubbish mounds, preserved through time by drifting sands, have, through the combined powers of digital technology and international volunteers, been read for the first time in two millennia, adding to our understanding of Graeco-Roman Egyptian culture. This shows that the discarded information of the past can become the knowledge of the future, fuelling new possibilities for humanities research.

Linguistics

In the field of linguistics, the two projects below address language and depict different forms of participation. The first project covers multilingualism and linguistic landscapes and the second one language variation in a monolingual country.

First, Lingscape has been combining citizen 'science' and linguistic landscaping in Luxembourg since 2016. Participants are asked to make pictures of signs and lettering in public spaces, upload them to an app, and provide additional information, such as geographic location or language (variety) used on a sign. Since signs in the public space form the linguistic landscape of a place or community, the project aims to analyse the diversity and dynamics of public writing as part of a linguistic landscape (Purschke 2017).

Second, 'On everyone's mind and lips – German in Austria' (abbreviated as *IamDiÖ*) addresses the use and perception of the varieties of the German language in Austria. *IamDiÖ* combines different citizen science approaches. First, *IamDiÖ* engages in cocreation with a format entitled Question of the Month. Here, citizens can raise and answer questions related to the topic of German language in Austria supported by researchers. Second, in a linguistic treasure hunt, the project focuses on data collection and data analysis. Citizens take, save, and tag pictures of written information in the public space with the Lingscape app, thus contributing to the study of the linguistic landscape in Austria. The main challenge though proved to be the cocreation approach (according to Bonney et al. 2009) to the Question of the Month. Interestingly, the online strategy to collect research questions from participants proved less successful than personal dialogue with participants. Moreover, only one participant was willing to answer her own question. However, *IamDiÖ* was able to increase academic literacy among the participants and to illustrate that there are still research gaps that need to be addressed (Heinisch 2020).

Interdisciplinary Projects

Interdisciplinary projects are those bridging (citizen) (social or natural) science and (citizen) humanities. Their value ranges from harnessing differences, such as complementary approaches. These approaches, including knowledge, theories, concepts, data, methods, tools, and ways of interpretation, can complement each other to gain a holistic understanding of phenomena.

The Archaeological Spessart Project (ASP) (Ermischer 2016), for example, was founded by the archaeologist Gerhard Ermischer and funded by the European Union in the 1990s. The ASP addresses the cultural landscape of the Spessart region in south-central Germany in all its dimensions: history, language, culture, landscape development, and natural environment. Universities and research institutions are working closely together with people living in the region, for example, with citizen history associations, heritage and nature conservation associations, and schools, to conduct research and impart Spessart's history and development. Here, a wide range of formats is used, from research projects and archive research, archaeological excavations, and surveys to the collection of geographical or biological data, which are combined in a geographic information system that draws a comprehensive picture of the Spessart for the first time. The ASP acts as an initiator and coordinator of research in the region since both researchers and citizens can suggest and address topics. Additionally, citizens can suggest or initiate communication measures to connect local people to the history of their region. These include the establishment of cultural routes, publications, exhibitions, lectures, seminars, the training of landscape guides, and projects with children. The ASP is currently active in various European projects and is involved in the implementation of the European Landscape Convention as an advisory non-governmental organisation to the Council of Europe. In addition to this far-reaching impact, the project also reflects an open understanding of who is a researcher and who is a layperson. This becomes apparent when citizens teach researchers and students about local history or archive research.

Another large research project was Constructing Scientific Communities: Citizen Science in the nineteenth and twenty-first centuries (2014–2019) funded by the Arts and Humanities Research Council in the UK. It had both citizen science and citizen humanities at its heart and broke down barriers between the two forms. In the nineteenth century, it looked at the role played by non-professionals in the construction of scientific practices, paying particular attention to the huge growth of periodicals, from local natural history magazines to the proceedings of learned societies, in order to track the ways in which science is actively created through the processes of exchange, processes which the humanities are best equipped to understand and address (Dawson et al. 2020). This understanding then informed the work with citizen humanities and science in the digital age.

The Constructing Scientific Communities project created two projects which draw on research into nineteenth century natural history and bridge citizen science and humanities: Science Gossip and Orchid Observers.

Science Gossip was developed in collaboration with the Biodiversity Heritage Library and the Missouri Botanical Garden to uncover the rich imagery hidden away in natural history periodicals. The project was based on the premise that *optical character recognition* (OCR) has become valuable in allowing researchers to word search and transcribe historical texts but has entirely overlooked the visual landscape of books and periodicals. No other automated technology, moreover, could accurately search out and identify when and where images were located on printed pages. Working with 17 fully digitised natural history periodicals from the nineteenth century, Science Gossip asked participants to help identify six key attributes: was there an image on a page; where was it located on the page; what kind of image was it; did it depict any species of plant or animal; who made the image or engraving; and were there any keywords we could associate with it. The project was launched in 2015 and has had over 10,000 participants classifying over 160,000 pages of nineteenth-century periodicals. The data from the project have helped uncover a broad range of image makers and producers working in the nineteenth century and has allowed the Biodiversity Heritage Library to incorporate thousands of keywords and historical animal and plant species identifiers into their online portal. Working with citizens on this data set also opened up new research questions which were not part of the original framing of the project. For example, a group of citizen scientists who worked regularly on the project decided to start up their own thread on the discussion forum for participants and to create a new hashtag for any image produced by a woman. The participants of Science Gossip were not merely involved in classifying images; by engaging with the materials themselves, they posed new questions and in the process contributed significantly to the understanding of previously invisible labour in the work of Victorian natural history.

The interdisciplinary project Orchid Observers combined natural science and historical studies and was able to provide evidence of climate change. It was run in collaboration with the Natural History Museum, London, and has helped transform the museum's modes of engagement with citizen science. This was the first large-scale citizen science project to combine field and online approaches and to bring aspects of citizen humanities together with active science research. The project drew together outdoor nature enthusiasts and amateur–expert naturalists with an online community of citizens focusing on historical transcription. Orchid Observers worked with the country's expert orchid community and the Botanical Society of Britain and Ireland (BSBI – an organisation which brings together all those interested in nature study, dating back to 1836) to devise the field study, thus involving members of the public in scientific design as well as analysis. Those taking part in the study, either photographing the orchids in the field or identifying them online, were from a more diverse background, many with little or no experience of orchids or nature study. In addition, the project included a historical dimension, analysing data from nineteenth-century herbarium sheets. Overall, 1956 participants were involved in the study which aimed to investigate how the flowering times of 29 orchid species have been influenced by climate change. The field observations have been shared with the BSBI and will be made freely available through the charity and umbrella organisation, the National Biodiversity Network, contributing to the records of biodiversity which have been maintained by the natural history community since the nineteenth century. By bringing together the historical data from the herbarium sheets, records of the BSBI, and the contemporary data, the project has produced evidence of climate change stretching over a 180-year period. The study has also led to the identification of over 200 new UK locations for the orchid species concerned, including rare and threatened taxa. Accuracy of online identification and transcription has been very high, demonstrating the potential for building on this model for drawing large numbers of the general public into nature study, historic research, and scientific practice. In essence, the project was a digital extension of the practices of nineteenth-century natural history, drawing in large numbers of the public to participate in a community of science.

Platforms

Similar to citizen science projects that focus on crowdsourcing (collecting or analysing huge amounts of data with the help of a large number of volunteers), citizen humanities concentrating on the collection or analysis of large amounts of data may use citizen science platforms, such as Zooniverse or SciStarter, to attract participants to their projects. These platforms lend themselves to increasing a project's visibility (Liu et al., this volume, Chap. 22). However, citizen humanities projects that have another focus, for example, gathering research questions or collecting local or implicit cultural knowledge, may need different ways of approaching potential volunteers.

The US platform SciStarter lists about 40 projects from the humanities among 5000 projects; while the *Bürger schaffen Wissen* platform in Germany, featuring citizen science projects in Germany, lists about 45 projects from the humanities among 130 projects (in November 2019). Although Zooniverse started initially with a scientific project, it has developed a strong portfolio in humanities projects and offers considerable potential for a range of future humanities work. The platform can, for example, be applied to historical data in the service of science: the Old Weather project, for instance, draws on volunteer historians to work on old ships' logs to chart historical weather patterns, which can then be fed into current climate change research. A similar interface powers another of the Zooniverse projects, Notes from Nature. This is a project for the transcription and identification of materials held in natural history museums, with the aim of increasing our understanding of historical biodiversity and thus enabling current research on species extinction, ecosystem changes, and environmental health. Zooniverse has helped launch over a hundred new projects and is particularly valuable for humanities researchers who have documents that require transcription or images that need analysis.

In addition to these platforms listing all forms of citizen science, there are also platforms dedicated to digital crowdsourcing in the citizen humanities alone. For example, MicroPasts presents only projects from the humanities, listing about

200 projects for thousands of users. This international platform, which is hosted by the British Museum, started in 2013 and is one of the most comprehensive platforms for citizen humanities projects in Europe. It comprises mainly tagging and transcription projects from all historical eras and different regions in Europe and the Mediterranean (Bonacchi et al. 2014). The platform hosts projects, fosters community interaction, offers learning opportunities for the participants, and provides research data. It is also an experimental platform for researchers to dive into more general questions about citizen humanities, such as how to attract citizens and get their contributions in the long run or how to assure quality in digital projects. While MicroPasts is using approaches and tools similar to other citizen humanities platforms, it differs in one respect: its website is a whole ecosystem and unites different institutions in one location. This has the advantage that website visitors become aware of all projects and thus also of institutions they may have not known before. This relieves individual institutions from the burden of having to appeal to participants.

Artigo is a German citizen humanities platform focusing on art museums and historical paintings. It is dedicated to the tagging of historic pictures from museum collections (Weinhold 2016). Founded in 2010 at the University of Munich, the project started with a mere tagging approach to enhance the information in museum databases with both academic information on art history as well as non-professional user-centric information. Due to time constraints and engagement barriers on the museums' site, the platform has only been used by two museums. However, it is still being developed by the university in order to test new approaches in the digital citizen humanities. Over the last ten years, the platform has featured tagging games and an open analysis tool based on the data created by Artigo. Anybody can use this tool to raise and answer research questions related to art history, perception of art, or user behaviour. However, its main users are researchers. This platform also tries to connect people to build face-to-face communities.

Implementing Citizen Humanities

Institutions that engage in citizen humanities are, among others, universities and cultural heritage institutions, such as libraries, museums, and archives (Ridge 2014). Depending on the project objective and/or research purpose, public participation in the citizen humanities can take different forms, such as transcribing and annotating (hand-written) text or museum objects, adding (contextual) information from different sources, interpreting digitised documents, or even developing citizens' own research questions related to the humanities. The tasks of citizen humanists may also include historical geocoding (Cura et al. 2018). The contributions from the participants may be collected online or in person.

Citizens can contribute to citizen humanities projects in different ways, for example, by participating in various research steps or even in project development. To implement a citizen humanities project, a number of aspects have to be considered: first, projects need participants. To recruit and retain participants constant communication is needed, including information about the relevance of the project's topic for both the academic discipline and society, the project's goals and progress, and the specific contributions and tasks of the participants. The project managers should therefore be trained or experienced in community management, participation, and humanities communication. This is illustrated by the Spessart project and the Bavarian State Archaeological Office introduced in this chapter. Also, the example of Artigo underlines how even the best approaches may fail due to lack of time and engagement by the related institutions. In the following, the up-to-date approaches of *gamification* and *artificial intelligence* are highlighted to illustrate possible formats and designs of citizen humanities projects.

Gamification

To make tasks more appealing to participants, gamification is the means of choice in some projects. Gamification refers to elements of game playing, such as competition or point scoring that can be applied in citizen science to encourage the participants' engagement with an activity. The different ways to design citizen humanities games are illustrated by Artigo, which offers different options for different objectives. In the basic game, two players are connected anonymously and are shown a series of pictures to which they should assign keywords. Users only get high scores if both players assign the same terms. Only these matching terms are transferred to the database. This four-eye principle helps to collect the probably most meaningful and/or fitting terms. The game variants Artigo Taboo, Karido, Tag-a-Tag, and Combino supplement this principle. When playing Taboo, the most frequently used terms for the respective pictures are taboo, so that the user is forced to use less trivial terms. In Karido, the players have to find the most exact, selective terms for pictures which previously have been tagged very similarly. The variants Tag-a-Tag and Combino do not use the pictures but the tags assigned to them. Tag-a-Tag is used to describe individual tags in more detail. In Combino, many of the tags assigned to a work are displayed, and users have to combine them with each other to allow a more precise description of the work (Weinhold 2016).

Artificial Intelligence and Big Data

However, tagging tasks in citizen humanities may become obsolete due to two recent developments (Oswald 2019; Oswald and Mucha 2021), such as *machine learning* (Franzen et al., this volume, Chap. 10). First, artificial intelligence has made advances in tagging and transcribing text. This means that a lot of digital citizen humanities fields may not need a large number of participants for these tasks in the future and only require minimal human intervention. This applies mainly to contributory projects in which participants are principally data collectors and do not bring in their own perspectives or ideas. Second, tasks such as tagging do not address participants' desires to be working in communities and forging connections to people with similar interests. This applies especially to participants in digital citizen humanities projects, who – as the challenges section below shows – represent a certain group of society that is especially interested in spending time on cultural contents or activities together with other interested people. This potential still needs to be exploited in the citizen humanities.

Although *big data* is often perceived as a distinctly modern phenomenon, that is, the product of computer-generated information, it is important to place it within an historical framework: Linnaeus's undertaking to classify the entire flora of the world, or the dedicated observations of nineteenth-century amateur naturalists who mapped their local regions, for example, also generated huge quantities of data. The rise of statistics in the nineteenth century also gave birth to the new sciences of epidemiology and preventive medicine, founded on the aggregation of large quantities of locally gathered statistical data. Additionally, the development of documentation methodologies for population censuses and electoral behaviour in the nineteenth century have resulted in large data sets that are still used today by historians and political and social scientists for their research (Heidborn 2017). Research on topics such as biodiversity and climate or the development of societies, including the formation and shift of majorities in favour of political parties, the change of cultures through migration, and the change of languages, have highlighted the importance of understanding historical patterns if we want to predict, and meet, the challenges of the future. Citizen (social) science and citizen humanities play an important role in this respect.

Unique Methods

While tasks such as tagging and online participation are also used by the sciences, the humanities do employ some exclusive methods. These include experimental archaeology and (historical) re-enactment. Although they apply similar methods, they differ in their actors and motivation. Re-enactment (Agnew et al. 2020) is mainly carried out by non-researchers based on their personal interest in history. They reconstruct events or lifestyles of a certain historical epoch – ranging from the Germans to the Vikings or from the Middle Ages to the world wars – and re-enact them. In experimental archaeology, they not only read original sources but also recreate the artefacts necessary for the re-enactment themselves using only historically accurate technologies. Re-enactors, for example, weave clothes on replica looms, forge weapons, and make fishing nets. In the process, they acquire profound knowledge, which is usually not considered in academia because; on the one hand, a replica of the past can only be achieved to a certain degree, even when paying attention to details. On the other hand, re-enactment is often accompanied by falsification, idealisation, or political abuse, for example, when certain groups present the ‘real’ ways of life of their ‘ancestors’ to justify their ideology. Nevertheless, cooperation with re-enactors can help to document their experimental approaches and make them accessible for research, for example, for experimental archaeology. Experimental archaeology follows an approach similar to re-enactment: to find out how people of the past have produced certain objects or carried out certain activities with experiments (Flores 2014; Narmo and Petersson 2011). In the case of experimental archaeology, however, the performers are archaeologists supported by interested citizens at the various stages. In contrast to re-enactment, the experiment takes place in a controlled environment, and it is verifiable.

Challenges

The challenges in the field of citizen humanities are twofold. On the one hand, the citizen humanities face challenges related to the research design and, on the other, challenges concerning the management of participants. The approaches may also be twofold: first, scholars may need the help of the crowd to work on (large amounts of) data. In this case, the research design may need to be changed so that the tasks accomplished by the citizens meet academic rigour as well as the expectations of the participants. Participants may become quickly bored of simple tasks such as tagging. Therefore, they may cease contributing to the project. Meaningfulness, and if applicable, also fun and entertainment, should be considered from the start, for example, by adopting gamification approaches. This may not only require the training of the participants but also require the academic professionals to be open-minded and patient regarding the input of participants.

The second approach may go beyond using the work capacities of the crowd and may include tapping into local knowledge, challenging existing paradigms, and gaining new insights. Here, the expertise and knowledge of the participants are seen as resources. In both cases, the challenges regarding participant management comprise the recruitment of, communication with, and training of the participants (Land-Zandstra et al., this volume, Chap. 13).

Objectivity and Biases

The humanities are often seen as rather interpretative in nature without applying strict methods. However, the humanities are also characterised by academic rigour. Therefore, the challenges related to research include biases, the selection and application of methods, as well as data coverage and quality. In research, *observation* cannot be neutral since values, ideologies, theories, and instruments frame our perception and interpretation (Adamson 2016b). For example, the transcription of primary sources necessitates a certain degree of interpretation and, sometimes, also research for additional information to understand the material to be transcribed (Dunn and Hedges 2018). Although some biases can be reduced by means of clearly defined research methods and training, other biases, such as the self-selection of project participants, are harder to eliminate.

Regarding the self-selection of participants, studies in Western Europe show that only a small number of the population visits cultural and research institutions regularly. The main barrier mentioned by visitors is the unapproachable image of these institutions. Therefore, the citizen humanities are sometimes regarded as an instrument to address hitherto uninterested people, due to the idea of open participation. Unfortunately, this aim can rarely be reached. This is demonstrated by a study on MicroPasts, which is a popular platform, especially in the UK. The platform primarily addressed academics and people who are already interested in humanities topics and institutions (Bonacchi et al. 2019). To attract new participant groups and keep them active in the long term, citizen humanities projects have to target the interests of broader social groups, and address certain groups and minorities directly.

Participant Training and Retention

As in any citizen science project, the comprehensible explanation of research methods and the usability of the tools are additional challenges. Even though citizen humanities projects are intended to save time for the institutions in the long run, their implementation needs a lot of time and resources, especially in projects where participants are not only supposed to perform simple tasks like tagging but have to be trained and supervised extensively in order to acquire the necessary competences and to understand how the researchers of the respective discipline are working. Heritage institutions where participants are involved regularly in specific tasks over a long period, such as archaeological surveys, transcription, or research, have therefore developed special gradual training schemes with permanent supervisors. The Bavarian State Archaeological Office, for example, has a department for working with volunteers. These volunteers are not only trained but can also develop own ideas for the preservation and communication of cultural heritage together with the department (Obst and Mayer 2016).

To attract participants and engage them actively in the long run, a project must not only be interesting to the researcher but also to broader groups of people. Therefore, projects should offer links to the participants' everyday lives, both in terms of topic and the lessons learned and the competence acquired by the participants. In addition, science communication and guidance play a central role in any citizen science project. However, in some projects, for example, due to orientation towards research, these can be addressed only to a limited extent, which may not be sufficient for successful participant retention. The reasons may be a researcher's lack of time and resources or a lack of competence when communicating with the public. Opening up the humanities and cultural heritage institutions by allowing public participation is not enough to attract participants. If projects want to address certain groups, for example, minorities, these must be invited directly. The project's added value as well as the relevance for them has to be clarified.

Digitalisation

Another challenge in the citizen humanities is the use of digital tools and techniques by the participants. Digital (humanities) tools primarily target researchers and specialists. Moreover, annotation schemes used for analysis may be hard to grasp for non-specialists. As with any citizen science tool or method, the usability for the participants is key. Therefore, adaptations and simplifications may be necessary without sacrificing academic rigour.

Moreover, the data compiled and analysed in citizen humanities projects should be as re-usable as possible and may feed into digital (humanities or cultural heritage) infrastructures. Research in the humanities may rely on collections (of text), that is, corpora and databases. These corpora may be compiled individually or re-used. CLARIN, which stands for Common Language Resources and Technology Infrastructure, or DARIAH, which is the acronym for Digital Research Infrastructure for the Arts and Humanities, are existing infrastructures providing resources. Moreover, specialised tools are used for the collection, analysis, and visualisation of (textual) data. These allow the creation and visualisation of (historical) data in networks and maps. In addition, the Text Encoding Initiative (TEI) XML standard, which is a common standard for encoding electronic text, is widely used in the digital humanities to enrich digital objects.

This shows that the citizen humanities are embedded in larger research and cultural heritage frameworks and that standards should be followed to allow for interoperability. Digitalisation also allows for 3D reconstructions of cultural heritage, such as the 3D models used in archaeology, the combination of data from different sources in visualisations, the use of linked data and ontologies, as well as the analysis of large amounts of data and the creation of digital collections.

Added Value of the Citizen Humanities

The epistemic and societal outcomes of the citizen humanities include the enhancement, preservation of, and access to cultural heritage, the creation and access to databases of lasting value, or the generation of new findings and new knowledge in the humanities (see Fig. 6.1).

Public participation may help enhance (cultural) material and may change the relationship between citizens and cultural organisations. The citizen humanities,

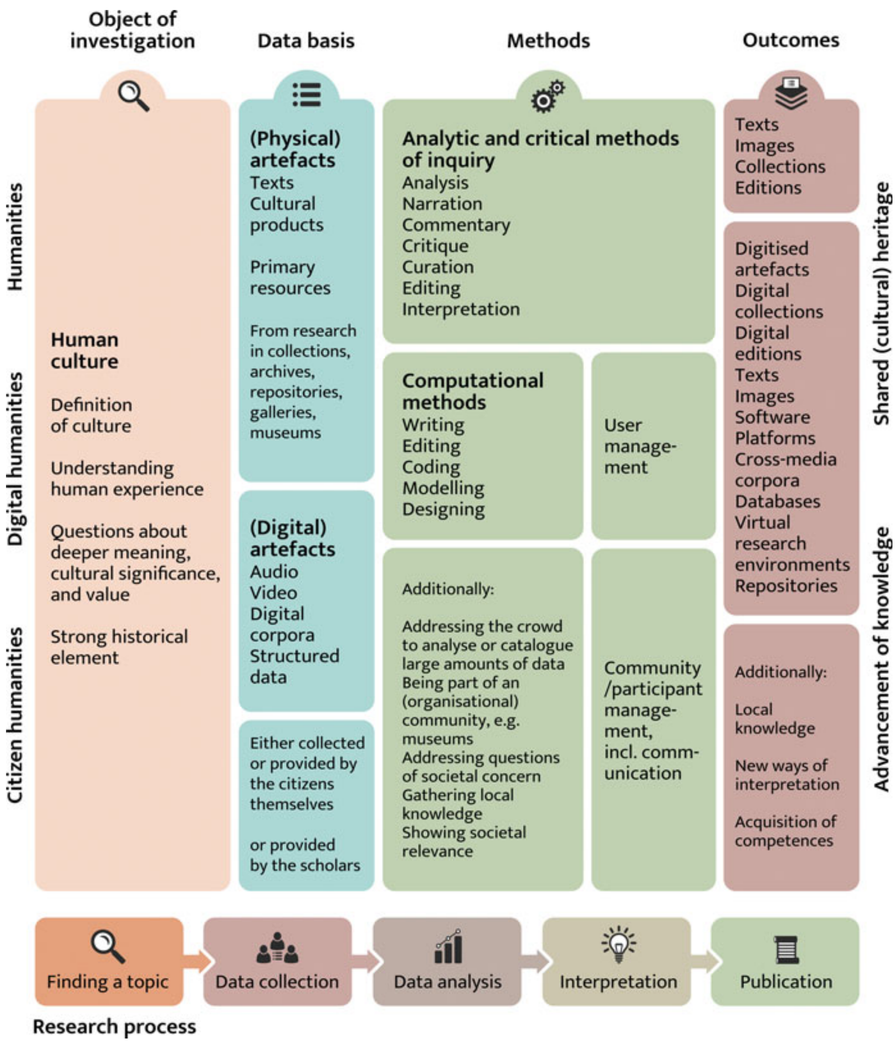

Fig. 6.1 Comparison of humanities, digital humanities, and citizen humanities throughout the research process

similar to citizen science, provide an insight into the academic research process and thus increase academic literacy among nonacademics. Participants may increase their knowledge of the topic, may apply more critical and connected thinking, enhance their presentation and writing skills, use generic platforms as tools for learning, and become well versed in using primary sources (Dunn and Hedges 2018).

Tapping Local Knowledge and Critical Reflection

The inclusion of non-professional researchers brings new and different knowledge into the research process. This is particularly evident from indigenous or experimental knowledge, which is embedded both locally and in everyday practices, for example, knowledge about the occurrence of animal and plant species and their use, about local (mythically embedded) heritage sites and objects, or about cultural traditions. Studies have shown that indigenous knowledge of local biodiversity is often similar to the results of scientific field studies (Danielsen et al. 2018). This form of knowledge is called *situated knowledge* (Haraway 1988), and objectivity may only be generated from it if specific perspectives are added.

The participation of citizens in scholarly research thus has the potential to question the common view that academic knowledge is objective and to expand our concept of knowledge. This discussion goes beyond the dimension of authentic knowledge and relates to questions of locality, experience, and perspective. Nevertheless, citizen science does not always generate site-authentic or situated knowledge. This is rather one aspect of a diverse practice that revolves around participation in and access to the academic exploration of the world. The dimension of local knowledge may not be specific to the humanities as such, as the example of indigenous biodiversity knowledge shows, but the humanities alone provide the methodological apparatus for the appropriate recognition of this kind of knowledge. With the approach of understanding, the humanities preserve and interpret the diversity of perspectives and their cultural embedding in local contexts. If local knowledge is regarded merely as a resource to supplement the 'objective' knowledge of science, its special quality may be lost.

The humanities also provide a rich pool of approaches and theories that re-evaluate the knowledge of non-experts and highlight it as a complement to academic knowledge (Boltanski and Thévenot 2006; Rancière 1991). Additionally, reflections on the change of societies, knowledge systems, and canons are among the core tasks of the humanities – they can help other fields of research reflect on the changes they undergo through the influence of citizen science.

In the heritage sector, for example, there is currently an intense and emotional debate about postcolonialism and the handling of objects with a colonial background. The use of citizen humanities here is closely connected to the topics of learning in citizen science as well as citizen science leading to social innovation (Butkeviciene et al., this volume, Chap. 16). The term postcolonialism describes the fact that although there are almost no (European) colonies remaining today, former colonial powers have often not come to terms with their colonial history and its consequences until today. This is illustrated by power–political divides and the patriarchal behaviour of the colonial countries (i.e. the 'Western world', or the 'Global North') towards their former colonies (i.e. the 'Global South'). This affects the cultural sector and the humanities, for example, in the form of the low recognition of indigenous cultural traditions in the humanities canon and their designation as 'exotic' or "indigenous' compared to the allegedly global universality and meaning of European cultural traditions and objects (Albrecht 2019; Durer et al. 2018). The current debate mainly focuses on objects from former colonised countries that still remain in the hands of the colonial powers' museums and heritage institutions. In addition to limited resources and legal issues, provenance research for these objects can be difficult (Stack 2019; Storm 2019). Here, citizen humanities research undertaken with people from the countries of origin can help collect information that would otherwise be difficult to reconstruct and to establish relationships with their original owners. Additionally, these forms of citizen humanities do not only contribute to a better political relationship with former colonies but also broaden the understanding of objects and object groups through the perception and knowledge of the local population, by associated traditions and rites as well as by the relevance of these historical objects in today's living cultures. Thus, these citizen humanities approaches can contribute to the academic knowledge which is strongly influenced by the European or North American perspectives. In addition, the participating citizens do not only provide researchers with information but also with new research questions and topics – and at the same time they gain access to the academic institutions and knowledge of the Western world. A similar application of citizen humanities is in the field of future-oriented studies of the past, for example, on the topics of house building, climate, and environment. Here, researchers together with local communities can research and revive the specific historical building activity, the tools and materials used to adapt to special climate conditions, the construction methods, and use of resources in the respective region in order to convey the importance of resource conservation, improve people's lives, and learn from and with them. These approaches can be regarded as so-called extreme citizen science initiatives and technologies for social innovation, which have mainly been applied by the social sciences so far.

Relevance

The humanities are relevant to the citizen science landscape in various ways. Digital humanities that combine humanities and digital technologies in manifold ways open up new opportunities to collaborative research and, thus, to citizen humanities. Nevertheless, recent advances in the field of artificial intelligence are likely to render some tasks done by volunteers obsolete, since tasks such as tagging and transcribing lend themselves to automation. Thus, the citizen humanities need to adapt to recent developments and find new approaches to engage and involve volunteers. This may require different ways to participate in a project or a stronger focus on the value of the project for the participants.

The humanities play a crucial role in teaching critical thinking competences. In a world that is driven by technological progress, citizens need a critical mind when confronted with novel information and developments. In times of fake news, misinformation, and scepticism towards research and academia, it is necessary to see citizen humanities not only as a way to generate new research data and knowledge but also as a means to establish closer links between scholars and citizens. Citizen humanities means to learn from each other. Scholars can learn from the participants' ideas and perspectives on their research, and the participants can learn the critical handling of sources and the application of research methods to classify and assess information. In addition to the acquisition of specialist knowledge, participants in citizen humanities projects can gain transferable skills, such as presentation or analytical skills. This means that the citizen humanities are not only a way to learn *about* the humanities but also a way to acquire critical competences and increase life quality via the humanities (Matarasso 1997). The acquisition of these competences and the related effects can be placed at the centre of project communication. This may help to address those people that do not have an intrinsic motivation to participate in citizen humanities projects. Certificates that document the participants' competences may help address new target groups through extrinsic motivation. Additionally, well-educated citizen humanities participants can play a central role as multipliers and advocates for humanities topics and research in society, starting with their families, friends, and neighbours.

One of the exciting possibilities of citizen humanities is that they can place the large quantities of information languishing in notebooks in museum collections in a new light: no longer 'dead' information but potentially the key to new forms both of historical understanding and scientific advancement.

Compared to (digital) citizen science, (digital) citizen humanities are a rather new development, but the contributions of volunteers have always played an important role in preserving, understanding, and making accessible cultural heritage.

A future trend for the citizen humanities is their contribution to the achievement of the Sustainable Development Goals and the biocultural diversity discourse (Adamson 2016b; Poole 2018) since they raise questions about values, cultural significance, and deeper meaning. Citizen scientists are also regarded as a universal data source, for example, for the reporting mechanism of the Sustainable Development Goals. The topic of postcolonialism shows how citizen humanities projects can combine current topics with academic knowledge, demonstrate the relevance of the humanities for society and politics, and establish a direct link to society.

Conclusions

Although there are many commonalities between the citizen humanities and citizen (social) science, related to the research process and participant management, their objects of investigation and their methods differ in several respects. The citizen humanities aim to reach people who join forces in applying humanities' methods that range from transcribing and tagging to tapping local knowledge. The citizen humanities can help uncover rich treasures hidden in archives, digital environments, and the minds of people. They may open up new research questions through mutual learning between scholars and participants or through the analysis of previously discarded information. Additionally, the profound (local) knowledge of citizens may challenge the understanding of experts.

While the digital humanities revolve around the application of digital tools and digital resources to the humanities, developments, such as artificial intelligence, may replace citizens in those projects that are oriented towards crowdsourcing. Therefore, citizen humanities may need to concentrate on the added value for the participants, competence development, and societal relevance.

The different approaches to the citizen humanities range from on-site projects to digital-only projects, from researcher-driven projects to community-driven initiatives, from data collection and data preparation that makes (scholarly) research possible in the first place to knowledge production and critical reflection on practices. They also range from cultural heritage considerations, revolving around issues of preservation and access to cultural heritage, to research considerations which are primarily aimed at the advancement of knowledge. This demonstrates that citizen humanities can take different forms, for example, from crowdsourcing to solving issues of public concern (in a wide range of disciplines). As part of interdisciplinary projects, they place issues in a historical context or allow for their critical analysis, which is required to predict and meet the challenges of the future.

In addition to the advancement of knowledge, citizen humanities can unlock the potential of embedded, diverse, and culturally sensitive knowledge and play a crucial role in preserving and enriching cultural heritage.

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Chapter 7
Citizen Social Science: New and Established Approaches to Participation in Social Research

Alexandra Albert, Bálint Balázs, Eglė Butkevičienė, Katja Mayer, and Josep Perelló

Abstract This chapter explores the ways in which the roles of citizens and researchers play out in the social sciences. This is expressed by numerous overlapping and related terms, such as co-production and participatory action research, to name but two, and by the different social topics that citizen social science draws attention to. The key question this chapter seeks to explore is what does naming citizen social science as such bring to the fields of citizen science and the social sciences? The chapter explores the different epistemic foundations of citizen social science and outlines the development and provenance of citizen social science in its broadest sense, reflecting on how it is currently practised. It draws on different examples from the experiences and work of the authors and notes the boundaries and overlaps with citizen science. The chapter also highlights some of the key issues that citizen social science gives rise to, emphasising that while citizen social science is a relatively new term, its underlying approaches and epistemic foundations are at least partially established in the social sciences.

Keywords Social impact · Co-production · Participatory action research · Co-creation

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'Citizen Social Science': A New Term or Old Hat?

Citizen social science is the term most commonly associated with a form of citizen science in the social sciences or alternatively one that has a specific focus on the social aspects of citizen science. It can involve citizens in the design and/or conduct of social research, including engagement in some or all research processes, such as ideation, research design, data collection, analysis, dissemination, and impact. This is seemingly not starkly different from what can be understood to constitute citizen science in the natural sciences (see Frigerio et al., this volume, Chap. 5). However, discussions about citizen social science bring to the fore its particular legacy, and the dichotomy citizen social science gives rise to in terms of whether it is perceived as a new term or a concept that has been in existence for some time, even if under a different name.

How can participation be organised in the social sciences, how does the involvement of citizens in social research impact society, and how can this impact be accounted for? A crucial starting point when considering these questions is to focus on the role of *citizens* in science and the social sciences – since the role is different to volunteering to participate in a research study, giving an interview, joining a focus group, or responding to a survey. By 'citizen' we mean 'citizens, publics, social groups and communities' (Kennedy 2016), in other words, social actors that are not necessarily professional scientists. Some view citizen social science as being about citizens gathering data about the world they observe around them (Purdam 2014), in other words, primarily observational data. Others make the case for citizen social science providing a basis for forging a new relationship between the social science academy and society (Housley et al. 2014) – a logical step towards more public social sciences (Burawoy 2005), building on the development of *participatory methods* that have a long legacy in the social sciences. These different types of citizen social science also bring with them different societal expectations, from researchers, participants, and everyone in-between, as well as a broad range of outcomes and impacts.

With the aim of being inclusive and simultaneously open-minded, in this chapter we propose combining under the 'social' label of 'citizen social science' not only a consolidated set of social science methodologies placed in an out-of-the-lab context but also social issues or concerns raised by groups of citizens and the ways in which these produce new scientific knowledge. Situating these social concerns at the centre of research, and its publics, has important implications in terms of the legitimacy of the research and of giving voice to under-represented or vulnerable groups. Citizen social science can be a powerful practice for both the inclusion of marginalised communities and the design of new evidence-based policies supported by the participation of citizens. Citizen social science also offers new routes to innovation and scientific research that deserve to be published in recognised scientific outlets and disseminated via public media.

In this chapter, we want to address the challenges and opportunities of citizen social science for bridging participatory traditions from the natural/technical sciences, the social sciences, and the humanities. In addition, we focus our attention on the question of what added value citizen science approaches can bring to the social sciences, especially to those that have a long-standing engagement with research partnerships, co-creation, and inclusive research practices – from the design of research questions to the translation of the results for social change. We discuss our own experiences with these bridging efforts and systematise our findings as a group of co-authors from diverse backgrounds, including science and technology studies (STS), geography, innovation studies, sociology, complex systems science, environmental science, and behavioural science. The second section of the chapter notes the different epistemic foundations of citizen social science – the development and provenance of citizen social science in its broadest sense – drawing on different examples from the experiences and work of the authors. The third section explores the boundaries and overlaps between citizen social science and citizen science. Academic interpretations of citizen social science are set out in the fourth section, reflecting on the current landscape. We present some of the key issues of citizen social science in the fifth section, before concluding with our reflections on what citizen social science adds to the fields of social science and citizen science.

The Epistemic Foundations of Citizen Social Science

Regarded as a form of citizen science that takes place in the social sciences, citizen social science is confronted with varying epistemic cultures (Knorr-Cetina 2003) and ways of doing or practising it (see Box 7.1). The epistemic foundations of citizen social science are set out in more detail in this section. When the social sciences are utilised in the context of citizen science, they are commonly mobilised for organising the participatory dimensions of a project and also for the evaluation of the processes, results, and learning (Phillips et al. 2018). However, although the social sciences represent a long-standing tradition and a whole canon of participatory methods in their own right, they are still regarded as an ancillary science (Darch 2017).

Box 7.1: The Mass Observation Project
The Mass Observation Project, which can be considered a prototype of citizen social science, consists of two parts: (1) the Mass Observation movement, 1937–1950s, and (2) the Mass Observation Project, 1981–present. Since it began, almost 4500 people have volunteered for the project. Many of these volunteers have been participating for several years, making the project rich in qualitative longitudinal material. In its current format, around 450 volunteer participants are recruited from all over Britain, to participate on the Mass Observation Project writing Panel. These writers (often known as 'Observers') respond to 'Directives', or open-ended questionnaires, sent to them by post or

(continued)

Box 7.1 (continued)
email three times a year. The Directives contain two or three broad, open-ended themes, which cover both personal issues and wider political and social issues and events. The project solicits in-depth accounts (both opinion and experience) of everyday life: stories, memoirs, lists, letters, diagrams, drawings, maps, diaries, photographs, press cuttings, confessions, and reports on people, places, and events, across a wide variety of topics. The project is open in terms of the data generated being available for use by all, but also in terms of the ways in which the project organisers regularly consult and engage with the volunteer panel of Observers, to reflect on the developments of the project and how the process of participating in writing for Mass Observation impacts the Observers themselves. This adds to the overall research integrity of the project.

Citizen social science is linked to the participatory approaches of co-production and PAR, each of which has a distinct legacy in the social sciences. Co-production is becoming an increasingly popular term in policymaking, governance, and research (Filip et al. 2017), particularly in terms of a shift towards a deeper or more complex form of impact (Flinders et al. 2016). In co-production, practitioners and potential research users are drawn into all stages of the research process. Co-production promises to be transformative, not solely in research terms, but in social terms, by engaging citizens and thereby facilitating a renewal of democracy (Flinders et al. 2016). Co-production emerged as a solution to what was argued to be a relevance gap in research and to meet the demands of *impact* agendas (Durose et al. 2011), since co-production in research aims to put the principles of empowerment into practice. This entails working *with* communities and providing opportunities to learn and reflect from their experiences. It is also important to note that the term co-design is often used synonymously with co-production. *Co-design* (also referred to as co-creation) is more of an umbrella term to describe different processes of involving multiple partners in the development and/or provision of interventions (see Senabre Hidalgo et al., this volume, Chap. 11).

Citizen social science can also be viewed as building on the field of PAR, which in turn draws on a model of community organising that supports the capacity and expertise of people experiencing issues first-hand (Friere 1996). Arguably PAR is a research style, an orientation to inquiry (Reason and Bradbury 2013), and not a 'method' or a 'procedure' for research as such. It involves 'a series of commitments to observe and problematise through practice a series of principles for conducting social enquiry' (McTaggart 1996, p. 248). PAR is an approach that seeks to actively engage participants as co-researchers in the research process, from research design to dissemination. It not only challenges the status of researchers as experts but also raises questions and creates spaces of reflexivity about how knowledge is generated (Tolman and Brydon-Miller 2001); it questions the power dynamics in the research process. PAR is a complex effort, with research questions generated by the participants and with the overall aim of making a practical difference to participants.

However, few PAR projects fully involve participants in the entire research process or the governance of the project, often for practical or ethical reasons (Cahill 2007). It is difficult, in practical terms, to strictly adhere to the basic tenet of fully collaborative research, in which the community under study is engaged in every step of the research process. Furthermore, PAR projects predominantly focus on collecting and presenting information to inform and mobilise collective action, rather than on theory development, which can create tensions for academic researchers (see Box 7.2 for an example of a PAR project). Ethical questions about the approach can also be raised. For many, PAR is not actually research, but a form of activism to affect change (Cahill 2007). Arguably the body of literature that accounts for the practices of PAR positions it at the intersection of research and activism. The concept of citizen social science can thus contribute to better solidifying these sets of practices in scientific research, as well as in publication and dissemination activities, rendering them more readily usable, recognisable, and comparable.

Box 7.2: Voices for Change

The PAR project Voices for Change was run by a charity in Australia between 2007 and 2011 (Stevenson 2010, 2014). The aim of the project was to develop an Emancipatory Disability Research (EDR) framework, by involving young people with intellectual disabilities in academic research. In this case, researchers included lay people in the data analysis stages of the research process. Participants undertook a journey from research informant to co-researcher and engaged in elements of data collection, immersion in the data, interpretation, negotiating meanings, and critically appraising research outputs. The project was developed in consultation with young adults (18–25 years) with Down's syndrome and sought to assist young people in achieving their life goals and greater social connections using a *circles of support* model (Stevenson 2014). The core strategy of the research 'was to make all aspects of the research process as participatory as possible in respect of the co-researchers; to draw on their "local expertise", and ensure that their "voices" were heard throughout' (Stevenson 2014: 24). This example of a PAR project highlights how framing a project in certain ways allows for participation from targeted groups.

Another strand of citizen social science makes use of experimentation to engage with *civic epistemologies* – culturally specific ways in which publics expect expertise to be produced, tested, and used in decision-making (Jasanoff 2002). An interesting example is the computational social science work of OpenSystems in Barcelona – outlined in Box 7.3. Game-based civic learning is used, for example, to improve and foster the skills of citizens to collectively reflect on social issues (Devisch et al. 2016). Arguably, such approaches can also be manipulative and used for social control; gamification can fail to take into account citizens already participating in discussions on social issues, as well as in the design of the game itself.

Box 7.3: Games for Mental Health

The OpenSystems research group in Barcelona developed a set of public experiments in urban contexts: more than 5400 neighbours participated in over a dozen initiatives from 2012 to 2019. One example was a research collaboration to improve the lives of people with a mental health condition and their families and friends, initiated by a major organisation for the families of people with a mental health condition in Catalonia (Bonhoure et al. in press). The outputs of this collaboration included a scientific publication in an *open access* multidisciplinary journal (Cigarini et al. 2018), whose scientific data is openly accessible jointly with a report for the community, policymakers, and the general public.

The dominant paradigm in mental health research and practice still affords biomedical knowledge a privileged status, but other models entail more holistic approaches. The Community Mental Health Care model (Thornicroft et al. 2016) supports care in community and domiciliary settings. Individuals with a mental health condition, jointly with their informal and formal care-givers, social workers, and relatives, form an ecosystem in which social interactions play a central role in promoting efficient and sustainable care in the community. The research in practice is an informal mission-oriented *joint venture* undertaken by researchers and representatives of the mental health-care community. Participants are engaged actively and consciously to learn about the research outputs through an additional set of activities that can empower specific vulnerable groups. Furthermore, self-selection issues, which apply to standard experimental settings (Henrich et al. 2010), are considered through different lenses when participation is enhanced. This example provides a broad outline of the potential for a synergistic relationship between citizen science, mental health care, and the social sciences (social dilemmas) under the umbrella term of *computational social science*. It represents a novel addition to the approaches that have already been thoroughly analysed in the context of health (Wiggins and Wilbanks 2019).

On the other hand, notions of both public and collective experiments are already well developed (Latour 1983) and have been extensively discussed in the context of STS (see Karvonen and Van Heur 2014). Through the lens of such experiments, we can acquire a better understanding of citizen social science practices (Sagarra et al. 2016). In particular, attention has focused on the specificities of expanding participation in the field of human behavioural sciences (Cigarini et al. 2020). Public and collective experiments, first, have to capture the interests of non-professional scientists (Latour 1983); second, they have to collect information on 'real-world' problems in the form of in-the-field or in-the-wild research (Gneezy and Imas 2017); and, third, they have to extend the laboratory to wider society by carefully relaying results back into the field in a fast and efficient manner. In this sense, impact is considered to be part of the experiment. Including citizens' social concerns in the research process can affect the whole research design: the main theme, the research question, data gathering through public intervention, data interpretation, and collective action (Bonhoure et al. in press; Sagarra et al. 2016). From a citizen social science perspective, this requires some effort: crowdsourced data gathering is comparable in volume to traditional in-the-lab work. In addition, collective action directed at social change to respond to citizens' concerns must be based on social science evidence. Therefore, in many ways, public participation – ranging from micro-sociological co-research to large-scale public experimentation – is faced with the challenge of not only being a significant pathway in the public sphere for raising social concerns but also of properly including and representing vulnerable, or marginalised, groups in the public sphere. Undertaking truly collective research must combine new scientific insights with very specific objectives that are valid and beneficial for all participants. In this sense, public experiments not only amplify the social dimension of citizen social science practices but also, more specifically, enhance the importance of making experiments public, and even placing experiments in public spaces, so that they might have proper impact.

These are just some of the varying epistemic foundations from which citizen social science can be seen to have developed. As previously stated, since citizen social science is still not an established term in the social sciences and is gaining traction in new ways as the field develops, this list is not exhaustive; it merely offers an initial overview of the landscape.

Boundaries and Overlaps with Citizen Science

The social sciences have more to offer to citizen science than bridging and mediating, and citizen social science has many more facets than merely mimicking natural science approaches. Based on the long tradition of participatory approaches in the fields of *participatory action research* (PAR) and the *co-production of knowledge*, tools and concepts in the social sciences are available to impart both scientific rigour and inclusivity to knowledge production. On the other hand, the social sciences can learn from citizen science about new forms of mobilisation, technological platforms, as well as socio-technical skills. STS promotes cross-disciplinary integration, civic engagement, and critical thinking in the study of science and explores how scientific knowledge and technological artefacts are constructed. Arguably STS seeks to overcome the divisions between the two disciplinary cultures of the humanities (interpretive inquiry) and the natural sciences (rational analysis). In STS, public participation in science is observed and analysed in terms of governance, regulation, and 'translation' into practical applications. It is now easier than ever for non-professionally trained people to participate in the governance, regulation, and

Table 7.1 Criteria for the classification of citizen science projects (Prainsack 2014)

Coordination: Who has influence in
1. Agenda setting
2. Determining the terms of the execution of the idea/procedural aspects
3. Deciding what results are (and what 'good' results are)
4. Deciding what will be done with the results
5. Deciding on intellectual property questions
Participation
6. Who participates (demographic and social parameters of those who participate)? Why, and how much, do they participate?
7. How much, and what kind of, training, skill, or expertise is required to participate in the project?
8. Are there cultural, institutional, and/or other differences in perception and framing of core issues and stakes?
Community
9. What forms of community pre-exist this project, if any? Which new communities does the project facilitate or give rise to? What is the constitutive factor for the feeling of belonging for participants?
Evaluation
10. How, and by whom, is it decided what good outcomes are?
11. What happens to the results of these evaluations?
Openness
12. Do participants in the project have access to the core data sets?
13. Can participants in the project edit the core data sets?
14. Is the contribution of participants adequately acknowledged in published materials?
15. Are data sets made publicly accessible (open-source/open access)?
16. Are the main findings made publicly accessible (open-source/open access)?
Entrepreneurship
17. How is the project funded?
18. What is the role of for-profit entities in this project? Are these small, medium-sized, or large entities, and where are they located?
19. How are for-profit and other interests aligned in this project (and/or do they conflict, and where)?
Locality
20. Where does the project take place (online/offline, in public/in the lab, geographical location, local/national/international)?

translation of science, as well as some of the core activities of science itself (Prainsack 2014).

In order to consider whether – and, if so, how – citizen science makes science more socially robust and can produce results that may be better in some ways than knowledge created by professional scientists, it is necessary to understand the nature of citizen social science in more detail. The list of criteria in Table 7.1 is a helpful schema for both understanding and classifying projects in citizen science and is a fitting typology that addresses dimensions which are also important in citizen social science. In this sense, it is a useful reminder of the overlaps between citizen social science and citizen science, and it allows us to explore the kinds of participation that different citizen science and citizen social science projects involve.

There are many perceptions of citizen science, and there is no clear, concise definition of what constitutes citizen science (see Haklay et al., this volume, Chap. 2). The same is arguably true of citizen social science, with the added complication that few projects define themselves under the term citizen social science. The aim of the classification below is to give examples for the perspectives provided by Prainsack 2014 (see Table 7.1) and to provide an overview of the current landscape of citizen social science. Furthermore, considering the criteria listed adds a reflexive dimension to projects and should be regarded as a fundamental part of the research integrity of all citizen science and citizen social science. It is important to understand the ways in which projects and participation are organised, and their locality, sociopolitical contexts, and distributed interests, since these all co-shape the methods developed and used in projects.

Coordination As in citizen science, the coordination of a citizen social science project is important to better understand and think through who has influence in setting the agenda of the project, to determine how the project will be carried out, what 'good' results look like, how the results will be used, and any issues surrounding intellectual property. It also helps to systematically explore how coordination is organised and agency distributed in such projects (Prainsack 2014).

Participation It is also useful to consider who participates, or might participate, in a citizen social science project; requirements for participation in terms of skills, training, and expertise; and whether there are other ways to frame questions or approaches to allow for participation from targeted groups or indeed more diverse groups. Vaughn et al.'s study of the concept of *peer models in scientific research* found that non-academic partners involved in peer models of research, education, and social care, when identified, were mostly community members (16%), youth (11%), community health workers (8%), people with known health issues (8%), employees (6%), and immigrants (4%) (Vaughn et al. 2018, p. 777). Some citizen social science projects, although usually not named as citizen science or, indeed, citizen social science projects, also included disadvantaged communities and people with disabilities in the research process, facilitating social inclusion.

Community Community refers to whether the formation of new communities is facilitated by a citizen social science project or if the project taps into pre-existing communities. This is important in terms of the visibility and empowerment of marginalised groups. It is also important for community governance and other issues that can occur when bringing together new communities or groups or accessing existing communities that may already have their own governance structures to be considered.

Evaluation As with any research project, it is crucial to consider how to evaluate a project, and, more specifically, how and who can determine what good outcomes are and what happens to the evaluation results. Thus, in addition to scientific processes and results, evaluation has to incorporate social, socioecological, and economic dimensions if it is to serve the needs of researchers, citizens, and funders. An exemplary model of such an evaluation focuses on the ethical and legal implications of a project. It is also important to consider how such an impact would be assessed and evaluated by the different actors in a project.

Openness The openness of a citizen social science project considers the extent to which the data collected in a project is made accessible for participants to use for their benefit, as well as whether the findings from a project are made publicly available. Also, the openness of a project is reflected in whether participants are adequately acknowledged in any published materials produced.

Entrepreneurship In this context, entrepreneurship refers to the ways in which the project is funded, taking into account any for-profit entity interests and what kind of entrepreneurial and innovative potential they utilise and foster. For example, projects may gain support and funding from various organisations, grants, and corporate social responsibility schemes. Local charities and informal citizen groups might promote projects locally, in newspapers and forums. Furthermore, municipal non-profit companies can act as donors.

Locality Another crucial factor in terms of undertaking citizen social science, which cuts across most of those listed above, is the importance of considering the locality of the project – whether that be online or offline and how formal the setting is. This is particularly true of citizen social science, as opposed to other areas of citizen science, since projects tend to take place outside of the traditional laboratory setting in social spaces where the roles of actors are not necessarily as clearly defined as in other types of research.

Academic Interpretations of Citizen Social Science

In the academic literature, citizen social science is a relatively new term, first appearing in the context of reassessing the roles of experts and publics in addressing social problems (Ochu 2014), whereas citizen science has a lengthy tradition (Irwin 1995; Bonney 1996). When citizen social science was first conceived as a distinct set of methods, the focus was on citizens collecting data on the world around them for social science research (Purdam 2014). Conceptualisations of citizen social science tend to converge around notions of mass participation and data collection at scale, where members of the public assist with research, and record their beliefs and opinions, generating large volumes of data (Procter et al. 2013). Citizen social science is perceived as having the pragmatic goal of securing scalable human effort for the analysis of large data sets (Housley et al. 2014) while preserving more equitable relationships than those generally established in, for example, computational social science. This relates to the growing body of work that explores *crowdsourcing* and *participatory sensing* in more detail, arguably approaches more often associated with citizen science. Crowdsourcing is a portmanteau of 'crowd' and 'outsourcing' (Solymosi et al. 2017) that refers to open-source data, produced by online collaborative effort, to contribute content to a central repository. Participatory sensing is an open-ended concept referring to the narratives, practices, and devices used to engage the public in using sensing devices (Nold 2017). A crowdsourced data methodology can be a powerful tool for large sample quantitative social science research (Purdam 2014). Crowdsourcing becomes citizen social science when managed within a framework of social science research (Dadich 2014).

The references to citizen social science in the academic literature are becoming more prevalent, though are still not widespread in social science literature, and can commonly be found in the literature on citizen science (Heiss and Matthes 2017) and environmental sciences (Kythreotis et al. 2019). As outlined in Irwin (1995), one of the most cited foundational works in citizen science, the term 'citizen science' should be associated with science that focuses on the concerns of citizens, as well as citizens' contextual knowledge generated outside formal scientific institutions. In more recent literature, the focus is on new socio-technical opportunities of digitalisation; thus, citizen social science is referred to as having a significant innovative potential for knowledge production by working collaboratively with citizens to enable access to both large-scale data and 'hidden' data which are collected in situ (Heiss and Matthes 2017). In spite of this, social science research projects 'which experiment with the idea of citizen science, are still hard to find' (Heiss and Matthes 2017, p. 24). There appears to be a disconnect between citizen science practitioners and scholars from the social sciences and the humanities (Mahr et al. 2018). The setting up of 'self-reflective and multi-perspective citizen science projects might hold the key to finally overcoming old distinctions, not only between "experts" and "laypeople" but also between the "sciences" and "humanities"' (Mahr et al. 2018, p. 101). In this way, there is potential for citizen social science being practised as both an approach and a bridging concept between the natural and environmental sciences and the social sciences and the humanities.

From a theoretical perspective, the practices and processes of citizen social science contribute to debates around the *social life* of methods – that is, the 'exploration of the changing historical boundaries between the implicit and the explicit, and the mechanisms and devices which can produce formal knowledge' (Savage 2013, p. 18) – and the literature on social studies of social science, which seeks to examine the ways in which participatory methods, in and of themselves, operate. Cohen (2017, p. 4) suggests that citizen social science has 'begun by repeating the project of classical social science, namely to found itself on the principles of natural science'. However, while it is possible for amateur naturalists to develop a distinct community of practice around spotting and identifying flora and fauna, Cohen (2017) draws attention to how unnatural it is to pretend to observe the social world as a natural science experiment. Cohen's critique strikes at a key tension that citizen social science gives rise to: between sourcing more data on a mass scale and the more democratic aim of opening up social science research.

What Are the Key Issues for Citizen Social Science?

This section focuses on five main intertwined challenges in undertaking citizen social science: (1) attempting to resolve diverse interests and motivations; (2) ethical issues; (3) the relations between researchers and participants; (4) evaluating the outcomes and using citizen social science as a form of evaluation in and of itself; and (5) the hollowing out of terminology as terms are adopted and used in multiple divergent ways. Arguably for many of these challenges facing citizen social science, parallels can be drawn with projects using other forms of citizen science, such as in the natural sciences. As set out in the previous sections of the chapter, there are fundamental similarities between different types of participatory research. However, the issues listed below play out in specific ways in citizen social science and in the social sciences. This is because participatory methods in and of themselves require a commitment to values and a high degree of flexibility, while the roles of different actors in the research process are not always clearly demarcated.

Diverse Interests and Motivations Some of the biggest challenges in undertaking citizen social science are around attempts to deal with, and potentially resolve, competing motivations and diverse interests amongst those driving and participating in citizen social science projects. Also, many citizen social science topics emerge around challenging issues, such as making citizens' voices heard in urban infrastructure developments and community mental health improvement experiments – examples include the projects undertaken by OpenSystems in Barcelona (see Box 7.3). It is also true that to build projects involving participants and organisations that have diverse interests but are allied to reach a common goal can be a powerful approach; diversity can thus reinforce and strengthen the robustness of projects if carefully handled. There are many parallels with the issues faced in citizen science in the natural sciences, especially around volunteer recruitment and management, considered by Land-Zandstra et al. (this volume, Chap. 13).

Ethical Issues Within the challenges of dealing with diverse interests and motivations, there are also ethical issues to consider, particularly around consent. Some of the aspects of ethics in citizen science are discussed by Tauginienė et al. (this volume, Chap. 20), though arguably there are ethical issues that are specific to the undertaking of citizen social science. While ethical review procedures in research and higher education institutions are a good starting point for discussions with community members and project partners about potential issues and power dynamics in the processes of the projects, what happens when projects are initiated by those working outside of those institutions? Who oversees the ethics of a project then? Also, related to this issue is the challenge of making use of the data generated in citizen social science projects. How do we ensure that, where relevant, the data generated is compatible with official data sources or in a format that can be reanalysed or reused where possible?

Hierarchical Power Relations Between Researchers and Non-academic Partners There are often unevenly distributed power dynamics at play when academic researchers work with non-academics; thus, one of the challenges in citizen social science is to keep the right balance in collaborations between academic and non-academic participants and different types of expertise. In many cases, citizen social science projects employ methods where, ideally, a process of mutual learning and co-creation takes place (Balazs and Morello-Frosch 2013). In this process 'the change is more likely to occur when non-academic researchers have participation, influence and control in the research process' (Vaughn et al. 2018, p. 771). Furthermore, the process is made easier when collaboration happens on an equal footing, and non-academic participants feel some degree of ownership of the research process as well as research results. The personal characteristics of researchers can also challenge the successful implementation of citizen social science projects. This is particularly the case considering 'the importance of the researcher [in] listening to participants, taking time to reflect with participants, [and] recognising the significance of apparent trivia, data interpretation and the value of silence' (Richardson 2002, p. 47).

Evaluation Until now, questions surrounding the evaluation of citizen social science and, indeed, citizen science, have rarely been discussed in the literature in the context of citizen social science (Mayer et al. in press). We need to bridge some of the positions on quality and evaluation in citizen science (Kieslinger et al. 2017; Schaefer et al., this volume, Chap. 25) with the scarce attempts to evaluate across methods and interventions in participatory research (Home and Rump 2015) and add insights from the broad literature of community-based participatory research, for example, on participatory monitoring (Estrella and Gaventa 1998) and participatory evaluation (Cousins and Whitmore 1998). Given the plethora of approaches – from platform-based crowdsourcing activities (including human-computer interactions and citizen-generated data) to micro-level interventions in daily social routines – the perceived value and success of a project are always affected by the setting and stakeholder dynamics, the goals and expectations spanning diverse fields of knowledge, as well as the feasibility of change-making and structural sustainability. Moreover, some of the intended results might only come into effect long after projects end, when no impact assessment scheme is in place to monitor activities. Citizen social science, despite only recently being considered a distinct set of research approaches, makes significant claims (Purdam 2014; Heiss and Matthes 2017). One of the claims is to foster productive exchanges of science in society, namely, driving sociopolitical change based on robust social scientific evidence for social good. Hence, an important question is how to assess the design, process, and outcomes of such activities? How can we evaluate the results, as well as the impact in terms of the proposed transformative or representative participatory, even emancipatory, dimensions? In citizen science most evaluation approaches focus on scientific outcomes and learning effects for individual participants, requiring the adoption of comprehensive and inclusive evaluative methods that consider different types of stakeholders (Shirk et al. 2012; Jordan et al. 2012). However, it would be counterproductive to define overly strict quality criteria for participatory research, as they always depend on the objectives of the projects and initiatives – just as in any other citizen science project. The difference in citizen social science is that the quality criteria should be co-created with the participants. Similar to other community-based participatory research, citizen social science evaluation schemes should be assembled according to the project goals and the participants' expectations but also have to be flexible enough to meet changes in the dynamics of participatory research routines. The challenge, therefore, is to plan accordingly and develop the necessary skills and incentive structures for such inclusive evaluation settings, so that assessment is not left to the project's end, but actively implemented continuously from the research design stage. Evaluation should also include often neglected aspects, such as trust building and power relationships (Bryson et al. 2011). Another big challenge is how to bring those aspects together with more conventional evaluation measures for scientific quality and integrity, alongside quantitative indicators. How do we ensure projects are comparable beyond their unique features of effecting change in science and society?

Hollowing Out of Terminology Arguably many of the terms associated with citizen social science are used interchangeably, but often with different meanings and disciplinary understandings, leading to a hollowing out of terminology. The overuse and abuse of terminology in this context – particularly of terms such as citizen, social, laboratory, experimentation, and participation – have evacuated some of the meaning of these terms, rendering them increasingly imprecise. This constitutes one of the main reasons for our cautious approach to citizen social science. Furthermore, the term citizen science is mostly used in the Global North, whereas many other invisible participatory social science practices exist there and elsewhere that do not use such a term (Tauginienė et al. 2020). For example, the Global Informality Project is an online resource for 'ways of getting things done'. It is a global and growing database of invisible, yet powerful informal practices and the first multimedia online resource that explores informal practices and structures from a global perspective. Through its comparative and ethnographic investigations, the database includes entries from 5 continents, over 60 countries, and over 200 researchers. In Eastern and Central Europe, where democracy is only a relatively recent (and often questioned) experience, citizen participation in scientific research and policymaking is not well-institutionalised, and the social sciences and the humanities' efforts in knowledge co-creation are not yet realised. Such hidden forms of citizen science, practised by volunteers, can be considered a form of *marginalised science* (Frickel et al. 2010) – due to the lack of academic or government activity in a specialised area of knowledge and research interests that are unfunded and ignored, even though citizens, community-based organisations, and social movements identify them as worthy of investigation. Furthermore, there is also a danger of participation being seen as an increased burden of responsibility placed on the 'good citizen' and attached notions of citizenship.

What Does Citizen Social Science Add to the Fields of Social Science and Citizen Science?

Citizen social science is still an emerging area, but it raises important questions about the methods of participation and data collection in the social sciences, as well as conceptualisations of the 'social' in citizen science in general. We hope that this chapter illustrates that these concepts are constantly being negotiated in citizen social science. The opportunities for participation and co-production appear to be more prevalent than ever, and the social sciences have certain responsibilities in that regard. Including vulnerable groups in research, making citizens' concerns visible, and co-designing and co-evaluating projects with affected individuals (Mayer et al. in press) are all aspects that should be taken into account.

Citizen social science not only generates new scientific knowledge and understanding but also highlights the impact and applicability of citizen-generated data for the social sciences, as well as for participants (Fig. 7.1). Citizen social science contributes to an opening up of social science methods and feeds into debates about the politics of methods, giving rise to questions around what counts as data, who can collect it, and how it can be used (Albert in press). Furthermore, citizen social science provides many opportunities to systematically handle and reflect the blurring of boundaries between research objects, subjects, and researchers directly engaged in the everyday realities of science and society. The notion of citizen social science also feeds into the consolidation of the public engagement agenda and the belief that active participation in research can improve research quality, make it more relevant to society, and have significant benefits for those who participate.

Citizen social science offers the potential for including more reflexive dimensions in the practice of citizen science, particularly in terms of building on the legacy of

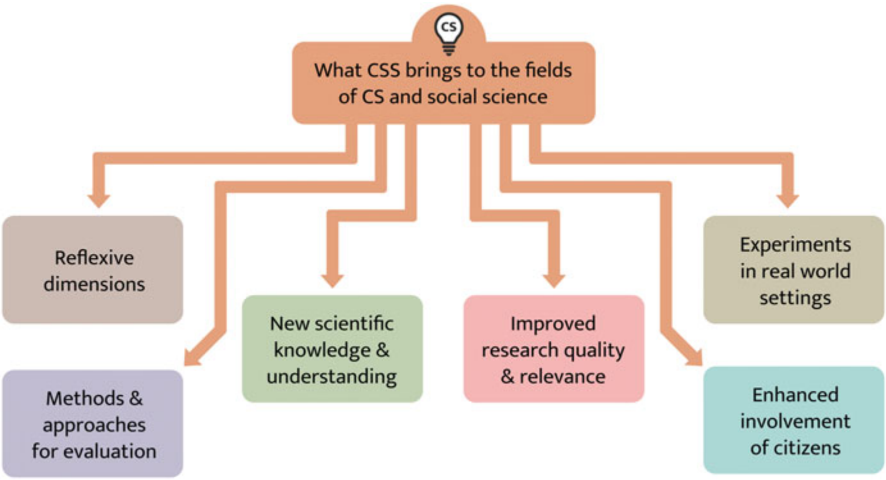

Fig. 7.1 How citizen social science contributes to citizen science and social sciences

participatory methods in the social sciences. In the context of evaluation, measuring learning and impact requires dedicated time, resources, and expertise in conducting social science research, which many citizen science projects lack. Furthermore, citizen social science addresses the societal distribution of expertise, from authoritative, institutionally accredited knowledge to individually expressed concerns (Nowotny 2000). It thus encompasses collaboration and partnership between different kinds of expertise, with a focus on emancipatory *citizen expertise* and *civic epistemologies* (Jasanoff 2002). Citizen social science also considers the expectations citizens have of the social sciences and their applicability in decision-making (Mayer et al. in press; Bonhoure et al. in press). Addressing ethical issues, the expected and actual benefits of research for participating social actors, diversity, as well as multiplying perspectives with new methods is far from straightforward. However, we are confident that new modes of inclusion, participation, and mobilisation will bring about improved and relevant insights and connections for action. The complexity of such research, however, requires learning, recognition from research policy, and funding. In the realms of performance-based funding and the 'publish or perish' knowledge markets, with their fetish for high-impact indicators, it will indeed be challenging to conduct citizen social science and realise its full potential.

What, therefore, are the benefits of naming citizen social science as such? Due to developments in the understanding of the importance and role of citizen participation in social research, and the way in which the term bridges different approaches, disciplines, and values, the adoption and understanding of citizen social science are increasing. Arguably, as this chapter has sought to demonstrate, the acknowledgment of different practices and approaches as citizen social science serves to consolidate and improve the ways in which citizens are involved in the undertaking of social research. This also serves the purpose of allowing the field to question and justify its own methods, and to contribute to, and hopefully improve the ways in which social research is undertaken.

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Chapter 8
Data Quality in Citizen Science

Bálint Balázs, Peter Mooney, Eva Nováková, Lucy Bastin, and Jamal Jokar Arsanjani

Abstract This chapter discusses the broad and complex topic of data quality in citizen science – a contested arena because different projects and stakeholders aspire to different levels of data accuracy. In this chapter, we consider how we ensure the validity and reliability of data generated by citizen scientists and citizen science projects. We show that this is an essential methodological question that has emerged within a highly contested field in recent years. Data quality means different things to different stakeholders. This is no surprise as quality is always a broad spectrum, and nearly 200 terms are in use to describe it, regardless of the approach. We seek to deliver a high-level overview of the main themes and issues in data quality in citizen science, mechanisms to ensure and improve quality, and some conclusions on best practice and ways forwards. We encourage citizen science projects to share insights on their data practice failures. Finally, we show how data quality assurance gives credibility, reputation, and sustainability to citizen science projects.

Keywords Peer verification · Expert verification · Quality assessment

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Introduction

Imagine that a group of city-level stakeholders (a researcher, a citizen, a policymaker, and a business consultant) would like to create a new citizen science project. How can they conceptualise *data accuracy* and design *data quality* protocols? During their planning, they would need to think through a range of issues about the arrangements of their city-level project with unforeseeable knowledge difficulties and reach a collective understanding. However, from the outset of any citizen science project, there are contrasting data needs and motivations. A researcher might look for a level of scientific accuracy to achieve their analytical objective and therefore set thresholds for unreliable data and implement training protocols for volunteers. In contrast, a policymaker may rank avoiding bias in the data of the highest importance, whereas a citizen may require easy to understand data which is relevant to their perceived problem.

How then, even in this hypothetical example, can these different stakeholders create a minimum standard for data quality practices in a citizen science project? It is not an easy task – thousands of citizen science projects have produced extensive data sets that would otherwise be prohibitively expensive to collect. Many citizen science projects produce high-quality data (i.e. accurate, complete, relevant), but some projects are plagued with deficits in data practices: lack of accuracy, no standardised sampling protocol, poor spatial or temporal representation, and insufficient sample size (Anhalt-Depies et al. 2019). This is not unique to citizen science: a 2016 poll by *Nature* of 1500 scientists showed that more than two-thirds had failed to reproduce at least one other scientist's experiment and half of them had even failed to reproduce one of their own results (Baker 2016).

In this chapter, we show that data quality in citizen science is multifaceted and often disputed, with no 'one-size-fits-all' approach. In fact, data quality is the most valued normative claim by citizen science project stakeholders, anchored in multiple levels of expectation. Our focus is on the most typical data quality problems and the generally accepted mechanisms for assessing and verifying the quality of data generated by citizen science. We propose that citizen science project owners can always seek to improve data quality if necessary.

Furthermore, citizen science can learn a lot from purely academic research (basic, applied, or frontier research), for example, from the replication crisis that hits the classic results of social psychology and medicine. Data quality improvements create trade-offs between project resources (time, skills, technology, participants), but there are also protocols, training, and automated solutions to maintain minimum standards of data quality. Moreover, citizen science projects can do more to facilitate the learning among projects by sharing their insights and data quality reports on failures and pitfalls in their data practices.

Coming from various countries in Europe to join the community of practice created by COST Action CA15212 *Citizen Science to Promote Creativity, Scientific Literacy, and Innovation throughout Europe*, the chapter authors have gained their professional experience at the intersections of ecological and social sciences and are now engaged academics in fields including systems analysis, environmental sociology, land change modelling, geoinformatics, and environmental justice. Citizen science projects have been formative experiences in our lives as researchers. We recognise that academic researchers are now more privileged than ever due to the abundant funding available for professional scientists. In contrast, *volunteer-based citizen science* does not enjoy the same investment. Participants most often find that their greatest challenge is not enough training resources (Turrini et al. 2018; Larson et al. 2020). We identify that, despite the lack of resources, data quality issues are the Achilles heel of citizen science projects. Here we deliver a critical understanding of the positionality of data quality in citizen science and promote an approach to improve citizen science projects.

Science wars and the replication crisis have led to considerable distrust in science, and analysts remind us that we need to face the challenges of the post-truth science era (Saltelli 2018). It has been clear since the inception of citizen science that building up trust with volunteers is difficult due to the structural contradictions of modern science. Data quality and funding (sustainability) of citizen science projects are still the most critical concerns of citizen science practitioners (Hecker et al. 2018). The literature in this field tends to be mostly project specific and provides no framework on how to transform multiple approaches on data quality to more general guidance. Even within a specific domain (e.g. invasive species monitoring), a wide range of approaches and protocols exist. The quality of the collected data may be adequate according to the standards of each project. However, if, using aggregation or meta-analysis, citizen science data from different initiatives are reduced to their minimum common facets or generalised to the lowest common granularity, the resulting data set may no longer meet the original quality thresholds.

Several factors combine to make structuring and forming the focus of data quality discussions in citizen science challenging. Firstly, the growth and popularity of citizen science present citizens, civic society, and governments with multiple challenges and opportunities. New citizen science projects appear daily (Larson et al. 2020). The proliferation of literature in this area is hard to digest: a Google Scholar search using the search terms ‘citizen science’ and ‘data quality’ identifies more than 200 articles published in January–February 2020. However, if existing citizen science projects all have different and potentially incompatible ways of dealing with data quality and sharing data, then the future reuse of project data is significantly impacted. In turn, this has the knock-on effect of making developing ‘follow-on’ citizen science projects from previous projects problematic.

Secondly, the majority of citizen science projects are *contributory* in approach, with three major stages: *data gathering*, *data manipulation*, and *data classification* (Haklay 2013). Some projects are solely quantitative data projects, while others are solely qualitative. Mixed-method citizen science projects also exist which include both quantitative and qualitative data collection, generation, and manipulation. To ensure a minimum standard of data quality, a plan or protocol of data collection (methods) must be set out at the start of a project (Freitag et al. 2016). We consider a dimensionality of data quality needs in both practical and philosophical terms. For example, in some projects, geographical positional accuracy may not be relevant; in other projects, quality may not relate to data at all (Wiggins et al. 2011).

Thirdly, most citizen science projects have multiple goals, and all must deal with the various legitimacy problems around citizen science. Scientists, funders, authorities, policymakers, and citizens often have different and not always complementary requirements from citizen science data. Veiga et al. (2017) convincingly argued for prioritising data quality needs from the data user's perspective. All citizen science project stakeholders should be invited to co-develop standards for data quality and explicitly state the data quality levels they expect in order to form an agreed approach to data quality.

In summary, the data quality challenge exists at multiple levels. Data quality approaches developed for projects are usually reported when successful, but problems with these approaches are rarely shared or published. Variation in methods of data generation and capture has developed; and, similarly, the potential spectrum of end users, end user applications, and purposes for citizen science data can vary significantly. This leads to a broad range of expectations of data quality (accuracy, temporality, etc.) from varied stakeholders.

In this chapter, we deliver commentaries on five interconnected components of data quality. We begin by asking why is data a critical factor in citizen science projects? Given the wide variation in projects in citizen science and the types of problem domains, we then attempt to set out a definition of data quality in citizen science. Successful examples of high-quality, high-impact data generated by citizen science are plentiful, but what about the hidden cases that are not publicised? Our third commentary discusses the factors which can cause data quality problems in citizen science projects. Validation and verification of all scientific data are important, but how is this performed in citizen science projects? Finally, we discuss how to assure and control data quality in citizen science projects in a flexible, robust, and sustainable manner.

Data as a Risk Factor in Citizen Science Projects

Data from citizen science is unparalleled as it represents evidence that is otherwise difficult for professional science to generate or obtain. Awareness of data quality is growing in citizen science, but it is only one relevant aspect of data accuracy (see Fig. 8.1). Another significant aspect is *data contextualisation*, that is, how citizen science communicates the context in which a particular – often high-volume – data set has been created. Metadata, attribution, and curation are the most prominent examples of data contextualisation. More extensive metadata is helpful to communicate the 'known quality' of the data (Bowser et al. 2015), while *data reuse* is enabled by extensive metadata descriptions of data set purposes and methods of creation. Moreover, data reuse needs to clarify data ownership and future accessibility through open data, open standards, et cetera. This contextualisation is fundamental to understand why data quality is imperative in terms of the goals and

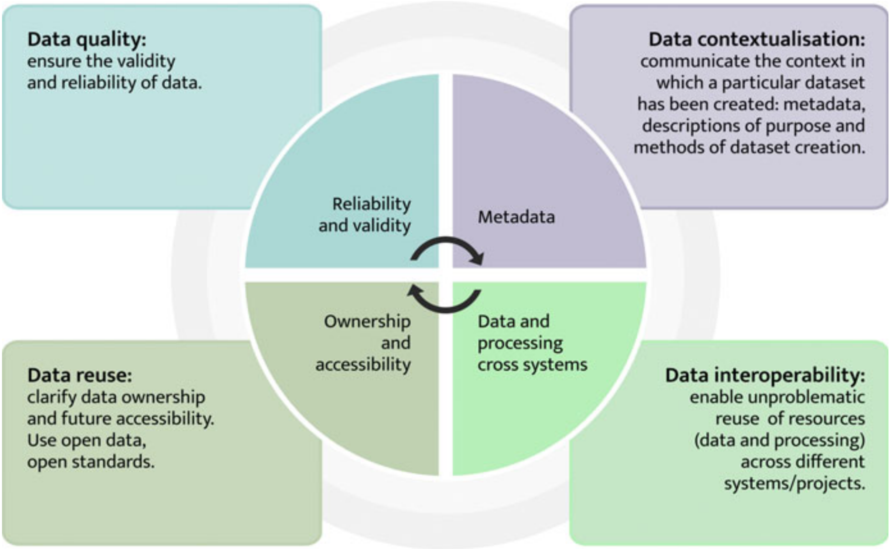

Fig. 8.1 Four aspects of data accuracy in citizen science

objectives of a project. A further aspect is *data interoperability* that enables consistent and straightforward handling of resources (data and processing) across different data sets, systems, and projects.

Citizen science often faces scepticism and distrust from professional scientists and significant resistance from policymakers (Kosmala et al. 2016; Bonney et al. 2014; Nascimento et al. 2018). The main prejudice against citizen science is that it is backward, marginal, and unprofessional; primarily this boils down to weakness in methodology, which can often be the case in professional science as well. On the positive side, citizen science has provided insights into fields such as biology and biodiversity and flora and fauna species and is complementary to traditional data collection methods. Therefore, citizen science as a proper research method should not be neglected by the professional scientific community. Instead, our classical scientific methods need to expand to allow citizen science data to be incorporated and used. This calls for holistic methodological approaches to accommodate citizen science approaches and data practices in the traditional way of studying scientific problems (see more in Pelacho et al., this volume, Chap. 4). In fact, citizen science, alongside technological advancement and increased availability and civic communities invested in solving real-life challenges, has revolutionised our access to more dimensional data. The transformative role of citizen science as an engine for addressing and monitoring Sustainable Development Goals (SDGs) should also be emphasised (Fritz et al. 2019).

For every stakeholder in citizen science, there appears to be a different definition of what constitutes data quality. Numerous terms are used in definitions of data quality, including completeness, availability, standards-based, validity, consistency, timeliness, accuracy, and bias. This is an illustration of a socio-technical artefact with (hard) physical and (soft) social properties that gains acceptance from humans (volunteers) and machines (artificial intelligence). Several examples will be presented showing machine and human failure as well as soft and hard validation tools.

While it may be hard to agree on an acceptable level of data quality in any given citizen science project, in practical-methodological terms, we can start with known quality, fitness for purpose, and intended use (e.g. in operations, decision-making, or planning). However, from an epistemological point of view, the question is how accurately does the data represent the real-world constructs to which they refer. Real-world constructs are often not clearly defined at the project design stage, so *toolkits* that compare off-the-shelf protocols are helpful.

Data quality is valued from various perspectives, and its levels vary (Lewandowski and Specht 2015; Williams et al. 2018). In terms of data collection, precision and accuracy are the most important aspects. In data processing, it is vital to have consistency in data sets over time. For data analysis, data sets must have adequate representation and distribution of the target population or area. From a more general research design perspective, the validity and the reliability of data are most important (e.g. Lewandowski and Specht 2015).

Reliability implies long-term stability and consistency of data. Data results should be able to be replicated repeatedly; this is necessary in most citizen science projects operating large data sets. Reliability of data ensures citizen science is trusted and aligns with policy requirements and stakeholders' interests. However, citizen science data is valid only if it signifies what it is supposed to. Data validity in science has many aspects including accuracy, confidence, completeness, and error-freeness. There are an increasing number of articles on citizen science data quality in academic literature (Purdam 2014; Riesch and Potter 2014). Suggested data quality definitions converge around sets of characteristics; this leads to heuristic approaches that illustrate the need for a *data quality review toolkit* – a harmonised approach to data quality assurance across different citizen science projects.

Data Quality Issues in Citizen Science Projects

In this section, to illustrate the characteristics of data quality in citizen science, we present some examples of how and where data quality problems can arise in citizen science projects. In order to structure these examples in a meaningful way, we illustrate these data quality problems using the following categories:

1. Data collection protocols are not followed by participants.
2. Data collection protocols do not match the goals of the project or the probable participants.
3. Data collection protocols are incorrectly implemented.

4. Data collection protocols are not comprehensive and are used by stakeholders with different data quality expectation levels.
5. Data used are not fit for purpose.

While these five categories are by no means exhaustive, we believe that they represent a good cross-section of the most commonly encountered issues around data quality in citizen science (Lukyanenko et al. 2016).

Data Collection Protocols Are Not Followed by Participants

Citizen science projects must follow complex data collection protocols. In many cases, volunteers stop participating in projects as they do not know how to collect data using these protocols. Other authors have reported that participants often indicate that they are less concerned about the aims of the project or are unaware of the potential end uses of project data and are only interested in participation. This is obviously a training and communication issue. It is important to explain why a specific protocol has been chosen; what the project data can be used for; and what impact quality has on these end uses. In many cases, the best available strategy is to simplify *user interface design* in data collection tools and make these tools engaging and compatible with the variety of skills and motives of potential citizen scientists (Danielsen et al. 2014). Citizen science toolkits have been developed in many different contexts to facilitate better user engagement as well as the design and delivery of citizen science projects (Kelly et al. 2019). Finally, citizen science projects should incorporate more intuitive data practice considerations to allow users to directly or indirectly follow protocols.

Data Collection Protocols Do Not Match the Goals of the Project or the Probable Participants

Often, protocols for data collection are either too complicated or too simple. In the case of Galaxy Zoo, originally only three categories were listed, but later an additional two categories were added. The protocol did not allow for adding new values, such as discovering new shapes of galaxies; this oversight could have significantly diminished data quality (Lukyanenko et al. 2016). Citizen scientists can miss important data which should be recorded or observed if the protocols are inflexible. Overcomplicated protocols can result in reducing the sense of fun and participation for many citizen scientists by introducing seemingly onerous and systematic rules and tasks. A possible solution is to introduce a permanent channel or forum that participants can use to contact creators and provide input. Finally, making data collectors' tasks more straightforward by pre-filling files with often-used values or providing examples for observations is an effective way to create better engagement and fulfilment for citizen scientists.

Data Collection Protocols Are Incorrectly Implemented

In citizen science, as in any research context, data quality can quickly deteriorate when the protocols are inaccurate and poorly implemented or do not reflect the relevant context. Often, the lack of 'do not know' or 'unsure' reporting options or fields can lead to false precision levels or recording of invalid values, for example, a value of 0 mm for a rainfall recording gauge which is broken and has not recorded any rainfall. This is a typical example when uncertainty is created without visibility. When devices or sensors are not well calibrated and present inaccurate observations, then data can be misplaced or misreported (Bell et al. 2013). This has severe downstream effects for the analysis of these data sets.

Many citizen science projects use *smart devices* for the collection of data. These devices can introduce technological problems such as the lack of a GPS signal or Internet connection and poor device quality (Bell et al. 2013) which can subsequently result in missing data. Different instruments and collection systems also often apply contrasting transformations to data before submission (e.g. automated altitude correction in some weather stations) which can hinder the accuracy of data (Bell et al. 2013). There are various solutions to these false protocol deployments, for example, by the thorough profiling of data scope, experimental pilots, and iterative development (see examples later in the chapter). Overall, it is essential to apply a common-sense approach to citizen science communities facilitating the reuse of successful data quality protocols. There is little value in constantly reinventing protocols for similar problems being tackled by other citizen science groups or projects.

Data Collection Protocols Are Not Comprehensive and Are Used by Stakeholders with Different Data Quality Expectation Levels

It is natural that authoritative bodies and other stakeholders seek the highest level of data quality for their applications and purposes. Different levels of data quality expectations can lead to tensions between the producers and consumers of citizen science data. Managing expectations of quality is a difficult proposition. Some authoritative bodies dealing with citizen science may only require a simple data protocol be used by citizen scientists. The reasoning for this is to maximise the data quality citizen scientists are capable of collecting. On the other hand, other authoritative bodies may implement complex scientific data collection protocols as they require citizen scientists to collect detailed data. This has the effect of causing data quality to become a contested matter. Different stakeholders can claim that protocols are obsolete or irrelevant or that the data collected does not match the high expectations of more complex protocols.

The design of data collection protocols can also lead to spatial inequality where different geographical areas or regions receive proportionally more or less attention from citizen scientists, for example, urban areas being favoured over rural areas. Poorly designed or overly complex protocols can also create skill inequality if some protocols assume a specific level of scientific training before they can be used. This carries the risk of overly complex protocols excluding whole (social) groups and, in the case of international citizen science research, excluding countries or even continents.

Data Used Are Not Fit for Purpose

One of the most common and easily understood data quality issues is when data are used for purposes they are not suitable or fit for. This often happens with quantitative data. A phenomenon which is easy to measure may be inappropriately used as a proxy for the phenomenon that needs to be monitored (e.g. wetland acreage vs. wetland quality, Dale and Gerlak 2007). This misuse of data is not confined to the citizen science context, but it is more likely to occur where data documentation is imperfect or incomplete. Negative outcomes (Hunter et al. 2013) from citizen science projects can lead to overcorrection, which can in turn lead to errors and suspicion of all citizen science data. Misuse of citizen science data has caused many in the scientific community to perceive citizen science data as not worthy of being considered serious scientific research (Delaney et al. 2008). Appropriate documentation and metadata are the most effective and appropriate deterrents against using data for unsuitable purposes.

Validation and Verification of Data in Citizen Science Projects

Many citizen science projects collect valuable, high-quality scientific data. The data is subject to *validation* and *verification* before being used. Multiple socio-technical mechanisms can be deployed in citizen science projects to ensure the collection of high-quality data (Freitag et al. 2016). Validating the data in citizen science projects happens both during and after the project has generated data. Freitag and Pfeffer (2013) observe that often the process of a citizen science project is more successful than the product (data) – ‘some citizen scientists point out that the data is “good enough” or “were not the main focus of the program”’. They further remark that this is in stark contrast with many published studies, many of which discuss citizen science as a method, evaluated against traditional methods by the same metric of success – data quality (Riesch and Potter 2014). Therefore, validation or verification methods are required for the data generated, collected, and managed by citizen science projects. As for validation and verification methodologies, several prominent approaches have emerged. These approaches do not belong exclusively in citizen science projects but apply to a range of other application domains such as crowdsourcing, citizen sensing, et cetera. Consequently, we consider four approaches: peer verification, expert verification, automatic quality assessment, and model-based quality assessment.

Peer verification involves experienced project participants (*peers*) helping to identify and validate observations and data provided by new or inexperienced participants. Ideally, quality standards are maintained by the peers to improve performance and provide credibility. This approach is dependent on the community within the citizen science project. It can also have the effect of slowing down the process of data collection as extra time is required for peer verification. Similar to the process of peer review on Wikipedia, the main goal is self-regulation by qualified members within the relevant domain and a convergence towards shared narratives on data quality. For more examples see Liu and Ram (2018), Johnson et al. (2016), and Segal et al. (2015).

Expert verification differs from peer verification. Here, specific contributors or stakeholders are identified as experts within a citizen science project. These experts then verify the data which is generated or collected by other participants. This approach is frequently used by biological surveys. Once the needs of data usability are defined, solutions for data quality can be formulated for expert verification. Continuous expert assistance is required. Examples include iNaturalist, Young et al. (2019), Falk et al. (2019), and Bayraktarov et al. (2019).

Automatic quality assessment involves the use of software-based systems to automatically carry out a quality assessment of the data generated or collected by a citizen science project. There is a wide range of approaches, such as data mining algorithms, which filter and search for problematic data, statistical analysis (plausibility of data), and qualifying systems. As *artificial intelligence* (AI) approaches become more sophisticated and are more readily available in software, these can be used to carry out more resource-intensive automated quality assessments. Examples include Njue et al. (2019), Wiggins et al. (2011), and Wessels et al. (2019).

Model-based quality assessment goes beyond automatic filtering techniques which can address random variation (e.g. unsupervised data mining or naive outlier detection) and tackles residual errors using an explicit model of how the phenomenon of interest is expected to vary in space or time. This requires a concrete understanding of how the relevant phenomena behave and appropriate experts are required. This approach can be more effective in establishing the statistical relevance of false positives and false negatives and extreme or unexpected values in a data set. Examples include de-biasing procedures and generation of contributor ratings, based on identified sources of systematic errors in the archive of observations. Examples include Bamford et al. (2009) and Kelling et al. (2015).

When Does Validation Occur?

The methodologies described above must be applied at specific stages in the data collection or generation process within citizen science projects. There are a number of key stages where validation can occur. We summarise these below and indicate the type of validation methodology which can be used at each stage.

At the Project Planning and Design Stage At this stage, there is an opportunity to reduce the number of erroneous contributions. For example, is the accuracy of the location of an object to within 100 m acceptable, is a plant identification to genus level useful, etc. Approach used: expert verification.

During the Project While citizens are actively collecting and generating data, it can be difficult to validate data. However, a number of tactics can be used. These include flagging outliers or potentially erroneous contributions; providing useful and understandable help sections and guides within software apps and websites used by the contributors; access to online suggestion systems which can automatically suggest a class or label and provide automated feedback on submissions (van der Wal et al. 2016); and correcting or updating of contributions by peer contributors, for example, by requesting additional content (photos, free text, etc.) which might help with ambiguous contributions. Approaches used: peer validation, automatic quality assessment, and model-based quality assessment.

After the Project (Before Data Publication) At this stage, there are still opportunities and resolve to identify data quality issues. Remaining outliers can be automatically detected and flagged (e.g. by GeoWIKI, GBIF, eBird); experts can respond to requests for checking (iNaturalist, eBird); and estimates of observer skill or reliability can be calculated (this can be updated based on their history of contribution and used to weigh the value of their submitted data; see Kelling et al. 2015). Approaches used: expert verification, peer validation, automatic quality assessment, and model-based quality assessment.

After the Project (After Data Publication) While end users and stakeholders may already be using available versions of the data generated or collected by a project, post-activity quality assessment is still possible. Experts and peers can change or correct contributions on an ongoing basis (e.g. OpenStreetMap). Iterative corrections or changes can be applied to project design, for example, if data mining identifies a systematic bias in contributions. Indeed, iterative corrections can be also applied in the earlier project stages (via training materials, adapted keys, and applying improvement suggestions in real time). Approaches used: expert verification and peer validation.

Data Quality Assurance and Control in Citizen Science

Data are considered reliable if the methods by which they are collected and analysed remain stable over time. Data quality assurance plans and control are strategies implemented to reduce estimation error and bias; measurement error and bias; and data processing errors. In a survey of 30 citizen science project leaders, conducted by Freitag et al. (2016), 12 strategies for credibility building in citizen science were identified. Three of these are applied during the training and planning phase, four are applied during the data collection phase, and five are applied during the data analysis and project evaluation phase. The variation in the application of these strategies is due to factors including the number of participants in the project, the focus on group versus individual work, and the time commitment of participants. In this sense, data quality assurance and control must be adapted to the specific citizen science project under assessment. The literature indicates a number of different approaches to data quality assurance and control.

Meek et al. (2014) identify three types of quality assurance models: the *producer model*, the *consumer model*, and the *stakeholder model*. Their data quality assessment is based on seven steps in a workflow:

1. *Location-based services positioning* redirects users towards areas that are of interest to project organisers.
2. *Data cleaning* removes erroneous entries.
3. *Automatic validation* carries out preliminary credibility checks on the data collected.
4. *Comparison with authoritative data* improves the confidence and validity of collected data.
5. *Model-based validation* compares crowd data with data from models or previously validated crowdsourced data.
6. *Linked data analysis* combines the wealth of freely available data (big data) and associated data mining techniques to establish data confidence and quality.
7. *Semantic harmonisation* transforms input data to ensure conformance to or enrichment of an ontology.

All these steps produce inputs for each of the three (producer, consumer, stakeholder) models of quality assurance.

Clare et al. (2019) defined an iterative and adaptive data evaluation process in a six-step sequential framework (see Fig. 8.2). Three steps are about data quality assurance:

1. Define desired data quality explicitly in terms of study objectives grounded in specific analyses or estimates.
2. Estimate existing levels of accuracy or error within the data set.
3. Estimate a requisite level of accuracy or error within the raw data that allows study objectives to be achieved.

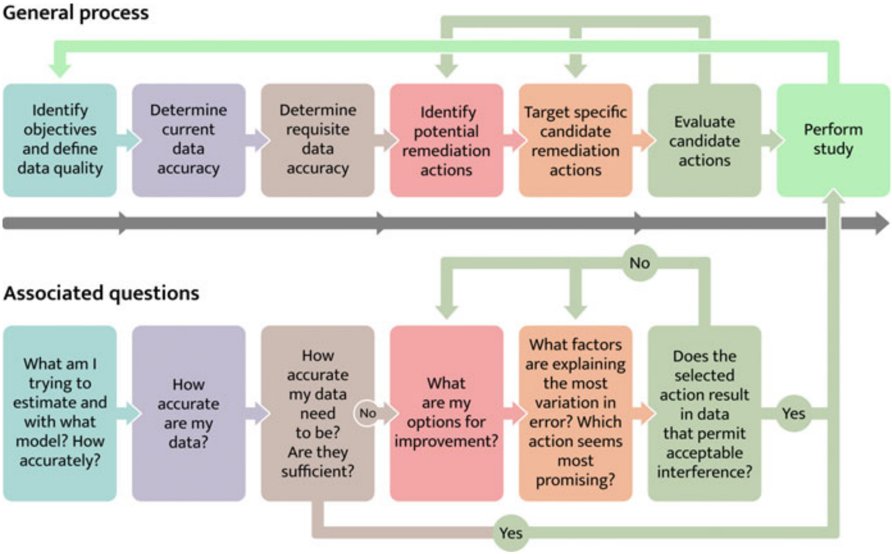

Fig. 8.2 Six steps of data evaluation from Clare et al. 2019

The remaining three steps are about data quality control:

4. Identify possible remedial actions.
5. Explore sources of variation in errors within a data set to target a specific action or set of actions to evaluate.
6. Implement and evaluate candidate actions to determine whether any meets the defined data quality objective.

Data quality assurance and control in citizen science can be conducted using two main strategies: (1) the *upstream* (assuring) strategy, which includes a set of actions that assure the quality of citizen science data to a certain level, or (2) the *downstream* (controlling) strategy, which includes a set of actions that controls the quality of citizen science and learns from earlier failures. Let us now consider some examples of both data quality assurance and control in order to illustrate these concepts more clearly.

Assuring data quality requires a set of criteria that pre-emptively restrict data inputs, such as:

- *Profiling* which assesses the data collectors to understand the quality challenges, including the impact of uncertainty in contributions and how it can be captured or traced.
- *Pre-testing* includes gathering sample data before a citizen science project begins using both expert and beginner contributors. This can help identify unforeseen sources of errors or other problems that can be fixed before the project starts.
- *Standardisation* ensures that expected data conform to quality rules and domain-relevant schemas.

- *On-the-fly data correction or cleansing tools* allow for auto-correction of some errors prior to reporting, for example, autocorrecting geocoding of address data, topology checks, and enforcing selection of an attribute value from a dictionary list.
- *Matching or linking* facilitates aligning or merging similar data records which can help avoid data redundancy.

Controlling data quality includes a set of actions that allow for controlling data quality after the project has started, such as:

- *Triangulation* which combines multiple criteria and methods to ensure data quality (Wiggins et al. 2011).
- *Recursive monitoring* keeps track of data quality over time and generates reports on uncertainties and variations. These reports can be used to maintain or improve data quality as well as provide feedback for project design.
- *Training participants* results in participants understanding data quality and appreciating the minimum data quality requirements for every citizen science project.
- *Protocols and standards for consistency* are followed to make the collected data consistent and homogeneous. Usage of protocols and standards should not adversely affect engagement levels of citizen scientists.
- *Compatible information systems* allow for long-term storage, curation, and archiving of data from citizen science projects.
- *Usage of international standards* such as ISO19115, ISO19157, and ISO8000 is recommended as a point of reference for quality control of citizen science projects.
- *Collect and release data under open science principles and open-access licences* which follow FAIR (findable, accessible, interoperable, reusable) principles. This allows for unrestricted data access and allows the data to be reused. Using FAIR principles maximizes the value of the data.
- *Record and communicate quality assurance practices*, as narrative descriptions of citizen science quality practices are often missing. This information should be provided in the description or metadata of a project or data set so that similar failures can be avoided in the future.

Conclusions and Recommendations

This chapter has discussed data quality in citizen science and approaches to ensure the validity and reliability of data generated by citizen scientists and citizen science projects. Data quality in citizen science has become a crowded and contested landscape in recent years, as various citizen science projects and their stakeholders often claim and seek different levels of data quality. Therefore, the meaning of data quality differs according to the type of project and its stakeholders. We certainly make no claims as to the exhaustive nature of the discussions in this chapter. Our focus has been to consider what data quality is in citizen science and how data quality problems occur and to present some of the most popular and well-accepted mechanisms for assessing and verifying data quality. Most citizen science projects employ multiple mechanisms to ensure data quality. The selected mechanisms are driven in no small part by the resources available, the project type and structure, and the needs of stakeholders. Every project can seek to improve data quality. There are always places where one can improve the process to have better data quality (if it is needed).

Success criteria in citizen science are defined by mission statements that guide projects, which are more likely to emphasise the scientific process than the results (Freitag and Pfeffer 2013). Different disciplines will have different conventions around defining data quality and acceptable measures or levels of data quality. However, many scientific disciplines collect similar types of data but do so in varied ways. Consequently, there is no one-size-fits-all approach. It is this diversity and breadth of application which makes data quality in citizen science such a tantalising subject to tackle. Improving data quality always involves trade-offs. Given that there are many moving parts to any citizen science project, it can require additional resources (time, skills, technology, participants, etc.) to deal with the data quality issues identified. Overall, we find that most studies agree that to improve data quality, several approaches are necessary: adaptable project aims and survey protocols; volunteer training; the use of experts; automated and statistical analyses; and finding an appropriate project structure (e.g. volunteer recruitment and retention, overall management) (Lewandowski and Specht 2015).

With abundant literature and examples of data quality approaches in citizen science projects, how do we proceed in order to meaningfully contribute to the data quality discussion? We believe that problems about data quality are rarely shared between citizen science projects. There is often little scope for new projects to learn from existing projects in terms of best practice approaches. Avoiding the same pitfalls as previous or existing projects can go a long way towards ensuring the data quality goals of a project are achieved and maintained. There are many useful lessons relevant to data quality, for example, unforeseen problems with devices, suppliers, and volunteers or unintended consequences of training methods and use of advanced technologies such as AI. However, not only are these stories unlikely to be published in an environment where future funding depends on demonstrating success, but they are subjective narratives which do not clearly fit into the available structured options for data quality reporting. Unfortunately, this means that the same problems related to data quality continue to be repeated. As well as sharing insights on data quality pitfalls in citizen science projects, there is also a need to convey successful data quality approaches. Ensuring data quality in a citizen science project should not be regarded as a burden; it can enhance the reputation of the project, make the outputs (re)usable for a broad range of end users and applications, and contribute to higher levels of citizen engagement and long-term project sustainability. In addition to establishing credibility and trust, communicating data quality practices can help citizen science collaboration by identifying shared issues and concerns.

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Chapter 9
A Conceptual Model for Participants and Activities in Citizen Science Projects

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Abstract Interest in the formal representation of citizen science comes from portals, platforms, and catalogues of citizen science projects; scientists using citizen science data for their research; and funding agencies and governments interested in the impact of citizen science initiatives. Having a common understanding and representation of citizen science projects, their participants, and their outcomes is key to enabling seamless knowledge and data sharing. In this chapter, we provide a conceptual model comprised of the core citizen science concepts with which projects

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and data can be described in a standardised manner, focusing on the description of the participants and their activities. The conceptual model is the outcome of a working group from the COST Action CA15212 *Citizen Science to Promote Creativity, Scientific Literacy, and Innovation throughout Europe*, established to improve data standardisation and interoperability in citizen science activities. It utilises past models and contributes to current standardisation efforts, such as the Public Participation in Scientific Research (PPSR) Common Conceptual Model and the Open Geospatial Consortium (OGC) standards. Its design is intended to fulfil the needs of different stakeholders, as illustrated by several case studies which demonstrate the model's applicability.

Keywords Participation tasks · Dataset description · Data integration · Project description · Project metadata · Interoperability

Introduction

Every citizen science project is unique in terms of its participants, governance model, scientific methodology, measures of quality control, and campaigns conducted, as well as the data and knowledge it generates. It is necessary to determine the current status and trends of citizen science in order to inform relevant decision-makers and to increase the impact of citizen science projects by coordinating their efforts. It is a significant challenge to collate and analyse the fragmented and diverse citizen science data that is generated (e.g. records and observations). The COST Action Working Group 5, tasked with *improving data standardisation and interoperability*, sought solutions to these challenging tasks. The resulting modelling effort was closely linked to the larger objectives of the international Data and Metadata Working Group of the US Citizen Science Association (CSA),[1] which includes members of the European Citizen Science Association (ECSA), and the Australian Citizen Science Association (ACSA). In this chapter, we introduce a model of core citizen science concepts, which is one of the major outcomes from the COST Action working group. This *conceptual model* is implemented using formal and standardised knowledge representation techniques and allows both human interpretation and computer-based processing.

Such a conceptual model fosters the representation of citizen science globally by:

- Enabling a common understanding of the terminology, for example, for indexing literature, outreach and education, and delimiting the field within the generic domains of IT, scientific projects, and data standards
- Forming a basis for facilitating the alignment and integration of data produced in citizen science projects by fostering standardisation and interoperability (being able to share information seamlessly across activities)

[1] http://citizenscience.org/association/about/working-groups/

- Facilitating the creation of software, database *schemas*, and data interchange formats for the development of new citizen science applications
- Supporting potential project participants and other stakeholders to better understand the tasks involved in a particular citizen science project

This chapter first briefly introduces its approach to a conceptual model for citizen science, the stakeholders concerned, and the methodology used. It also defines the concepts, relations, and constraints (axioms) of a *volunteer participation conceptual model*. It then explores connections between these and a traditional *scientific activity conceptual model* that includes the project, funding, outcomes, datasets, and domain. Next, this chapter provides a detailed description of the conceptual model providing the basic concepts about participants and their activities. The conceptual model links to existing standards by adopting and unifying suitable top-level concepts that appear in those data models. The chapter finally demonstrates the applicability of the conceptual model based on case studies before turning to a roadmap for future use and research.

Towards a Conceptual Model for Citizen Science

A conceptual model for citizen science needs to cover three main aspects (and their corresponding metadata):

- Information about citizen science *projects*
- The *people* involved
- Project *outcomes*, typically data and publications

When we refer to citizen science as a domain, we follow the definition outlined by Haklay et al. (this volume, Chap. 2).

Project metadata includes general information such as project name, aim, runtime, the topic or field of science addressed, a contact person or contact point, the organisations involved, and funding sources. In addition, metadata includes information which is specific to citizen science, for example, about the participants (their motivations, skills, knowledge level, and training undertaken). This also includes information that might be important to interested citizens, for example, how to participate and the type and difficulty level of volunteer tasks required.

In addition to project-related metadata, a conceptual model for citizen science needs to provide descriptive elements for project *outcomes*, which are typically data and publications. Data records are usually bundled into datasets following a certain data schema. Typical information about datasets includes name, license, access rights, geographic coverage, access information, submission date, creator, data quality requirements (see Balázs et al., this volume, Chap. 8), information on how data was collected, by whom and with which skills and expertise, and how quality was assessed and verified. Citizen science projects differ from other types of projects in that they employ novel ways of collecting data (e.g. a mobile app specifically designed for a project) and employ data collection protocols that are not common in traditional scientific research projects.

The major difference between a traditional scientific research project and a citizen science project is the participation of non-professionals in scientific activities. Therefore, our formal description of citizen science projects (project metadata) focuses on the representation of the *people* involved, their motivations and skills, the tasks they perform, how they were recruited, how their privacy is protected, how they collect data, and how the quality of their contributions is assessed.

Stakeholders

The spectrum of stakeholders (as identified by Göbel et al. 2017) who require reliable information about citizen science projects includes:

1. Participants
2. Academic and research organisations
3. Government agencies and departments
4. Civil society organisations, informal groups, and community members
5. Formal learning institutions
6. Businesses or industry

The requirements of the stakeholders listed above vary; for example, a certain level of interoperability is essential for government agencies as well as academic and research organisations. However, in the case of community-driven citizen science projects, the stakeholders are participants or informal groups who do not prioritise interoperability but need data to be provided in a user-friendly format.

Methodology

In this chapter, we define a conceptual model as *a representation of a knowledge domain or system*, with which people can understand the meaning of its underlying concepts and which can be used by computer software to meaningfully process its related data. There are a variety of conceptual models, ranging from simple *mind maps* and *concept maps* (Novak and Cañas 2008) to complex *ontologies* (Simperl and Luczak-Rösch 2014). Commonly, concepts are described in terms of their definitions and the (labelled) relationships between them. In formal models, concepts are often called *classes* (e.g. 'project'), and classes have specific examples, called *instances* (e.g. 'OpenStreetMap'). All those elements can be represented visually (for human understanding) and in formal computer language (for data integration). In this chapter, we apply commonly used techniques from *ontology engineering* and *concept map construction*.

The core conceptual model elements and associated metadata presented here draw on previous research and existing vocabularies. In particular, they utilise the Public Participation in Scientific Research (PPSR) Common Conceptual Model (described in Bowser et al. 2017) and the core requirements in the associated conceptual model PPSR-Core.

The conceptual model developed in this chapter is intended to fulfil the needs of different stakeholders, as shown in several case studies. To address this requirement, we refined core elements of the PPSR model based on existing case studies; these informed the identification of additional core concepts.

The conceptual model presented is not the only model that suits the field of citizen science, but it provides a view of the technical aspects of the discipline in order to help stakeholders understand the domain and foster interoperability across applications. It is an evolving model that is becoming established via an international consensus process.

Related Conceptual Models

Conceptual Models of Projects and Participants

A number of models that allow projects to be described in general and scientific projects to be described specifically have been previously developed outside the citizen science community. Those models aim to represent knowledge about a subject domain such as relevant concepts and relationships between those in a very formal way (e.g. in terms of an ontology) or less formally by means of a controlled vocabulary. The following table gives an overview of these models and summarises which facets of projects and their participants they cover. The models listed were carefully considered when designing our conceptual model for the citizen science domain.

We will now summarise the models listed in Table 9.1. FRAPO describes projects and their outputs in terms of publications and datasets. SCoRO models the roles of project participants and their contributions. It allows the linking of individuals' contributions to project outputs. PROV-O can be used to model projects, their outcomes, and how the outputs are produced and by whom. The Project Description Ontology extends PROV-O and is an attempt to model projects in a domain-agnostic way. FOAF can be used to characterise participants of a citizen science project. The FaBiO model is discussed in the next section.

Table 9.1 State of the art of conceptual models of projects and participants

Conceptual model	Aspects related to projects and participants that are covered by the model
The Funding, Research Administration and Projects Ontology (FRAPO) (doi: https://doi.org/10.13140/RG.2.2.26124.92802) (Peroni and Shotton 2018)	Administrative information related to projects (e.g. budget, project partners)
	Information related to project funding
	Project outputs (e.g. in terms of publications and datasets)
The Scholarly Contributions and Roles Ontology (SCoRO) (http://www.sparontologies.net/ontologies/scoro) (Peroni and Shotton 2018)	Roles of people working together on a project (e.g. data creators/managers/curators, principal investigators)
	Contributions of project participants (e.g. intellectual contributions such as conception and design of experiments)
The Friend of a Friend vocabulary (FOAF) (http://www.foaf-project.org)	Interests of participants
	Information about participants (e.g. name, age, home page)
	Relationships between participants (e.g. who knows whom)
The Bibliographic Ontology (FaBiO) (http://www.sparontologies.net/ontologies/fabio) (Peroni and Shotton 2012)	Project outcomes in terms of published or publishable results (e.g. scientific publications)
The PROV Ontology (PROV-O) (http://www.w3.org/TR/prov-o/)	Provenance information about projects (e.g. which project outcomes were produced by whom, with what information and input, and via which project activities)
Project Description Ontology (https://github.com/dr-shorthair/project-ont)	General information about projects that is independent from a specific application domain

Conceptual Models of Project Outcomes

FaBiO models published or publishable project outcomes such as scientific publications. The Project Documents Ontology (PDO) describes other project-related documents such as minutes and status reports.

A number of models provide descriptive elements for datasets. This includes the World Wide Web Consortium (W3C) Recommendation Data Catalog Vocabulary – Version 2 (DCAT)[2] that enables the description of datasets and data services in catalogues. More general specifications, such as Dublin Core,[3] define elements for the description of arbitrary resources, not just publications.

Several conceptual models have been developed for the formal description of observational data and measurements as common outcomes of scientific projects, for example, in the life sciences and geosciences, but also in citizen science. A number

[2] https://www.w3.org/TR/vocab-dcat-2/

[3] https://www.dublincore.org/specifications/dublin-core/dcmi-terms/

of standards with overlapping semantics have emerged: the Semantic Sensor Network (SSN) Ontology,[4] a joint standard of Open Geospatial Consortium (OGC) and W3C, that specifies the semantics of sensors and their observations, and its proposed extensions;[5] the OGC/ISO Observation and Measurement (O&M) conceptual model;[6] and the W3C Data Cube Vocabulary,[7] focusing specifically on the representation of multi-dimensional data. The data model of OGC's SensorThings API[8] is based on the OGC/ISO O&M model and closely resembles it. Although several ongoing community-driven attempts aim to harmonise the description of observational data in order to facilitate data integration, none of the existing data models have been adopted by a scientific community as a whole. However, attempts have been made to link coexisting models by establishing mappings to align different models, for example, the SSN Ontology offers alignments to the OGC/ISO O&M model. An OGC discussion paper (Simonis and Atkinson 2016) gives a helpful overview of standardised information models with relevance to citizen science data and describes a data model for the exchange of citizen science sampling data based on existing standards.

In parallel, practitioners such as data managers of research data infrastructures have developed their own vocabularies and models that do not rely on existing standards. In the biomedical domain, several domain-specific data models have been developed. Those include the Extensible Observation Ontology (OBOE)[9] (Madin et al. 2007) and the Biological Collections Ontology.[10] There are hundreds of domain-specific metadata standards and data models facilitating the description of scientific data in specific scientific domains, for example, BioPortal[11] currently lists 838 ontologies in the biomedical domain. Finally, the catalogue of the Digital Curation Centre[12] lists numerous disciplinary metadata standards.

The Proposed Conceptual Model for Citizen Science

As a starting point, we considered the top-level model of the CSA report (Bowser et al. 2017) (see Fig. 9.1), which proposed a grouping of the existing attributes into a set of modules. The titles of the modules were adapted by Working Group 5 (see COST Action CA15212 Working Group 5 2018a). The Project Metadata Model

[4]https://www.w3.org/TR/vocab-ssn/

[5]https://www.w3.org/TR/vocab-ssn-ext/

[6]https://www.iso.org/standard/32574.html

[7]https://www.w3.org/TR/vocab-data-cube/

[8]https://www.ogc.org/standards/sensorthings

[9]https://github.com/NCEAS/oboe

[10]http://www.obofoundry.org/ontology/bco.html

[11]http://bioportal.bioontology.org/

[12]http://www.dcc.ac.uk/resources/metadata-standards

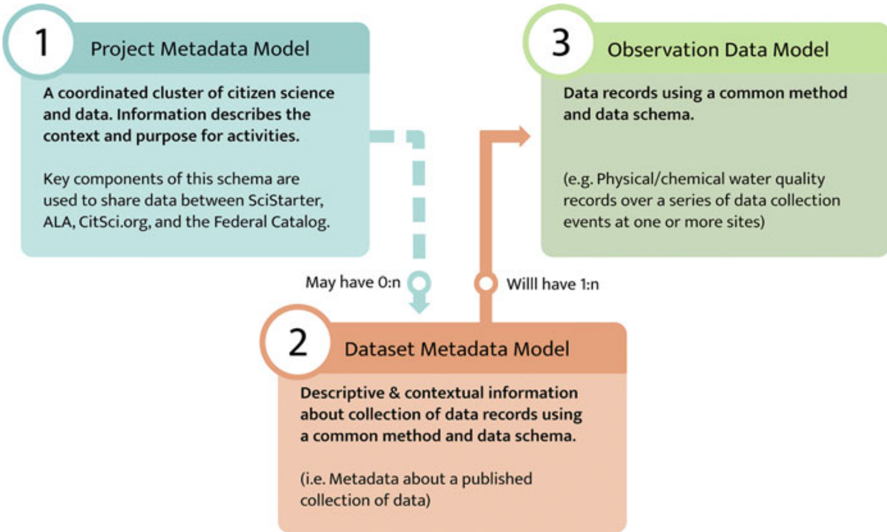

Fig. 9.1 The PPSR-Core conceptual model adapted from the Public Participation in Scientific Research (PPSR) Common Conceptual Model (Bowser et al. 2017). The 0:n (and the dashed arrow) means that a Project Metadata model may have zero or more Dataset Metadata Models. The 1:n (and the solid arrow) means that a Dataset Metadata Model will have one or more Observation Data Models

describes the key components of a citizen science project. The Dataset Metadata Model characterises a dataset as an output of a project and describes its geographic coverage, data collection method, and access rights. The Observation Data Model contains a detailed description of the data elements that are used in a dataset, for example, the meaning of specific sensor observations (such as nitrogen/nitrate concentration in a water quality measurement).

Project Description

The development of the PPSR-Core model was driven by the requirements of the implementations available at the time. As a consequence, it is tied to these implementations, and a conceptual model allowing for better project content representation is still not available. In addition, PPSR-Core still includes some domain-specific properties, especially from the biodiversity domain. Since citizen science activities take place in different disciplines and focus on specific aspects that vary across activities, a model that tries to capture everything in the domain can become complicated and difficult to manage.

In order to exploit the citizen science knowledge encoded in PPSR-Core and, at the same time, overcome the above-mentioned drawbacks, we have developed a

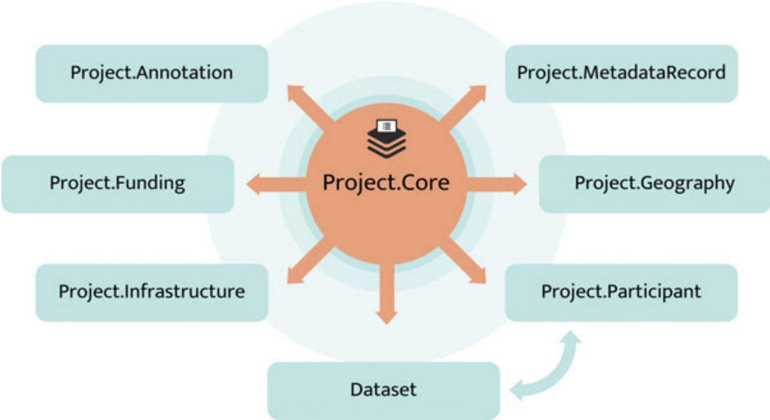

Fig. 9.2 An overview of the structure of the main conceptual model, highlighting the different modules. The arrows indicate the dependency between the modules. The connection between the Dataset and Project.Participant modules indicates that there are relationships between concepts across these modules

modular conceptual model for the representation of citizen science knowledge (see COST Action CA15212 Working Group 5 2018b). This model comprises different modules that are all linked to the Project.Core module that captures essential project information (see Fig. 9.2 for an overview of the structure of our conceptual model). The Project.Core module includes many properties imported from PPSR-Core, like project name, website, start and end date, etc., and unifies the other modules. These modules include:

- The Project.MetadataRecord module, which captures general information about the project, including its provenance
- The Project.Annotation module, which captures information, like tags, used for annotating project descriptions
- The Project.Funding module, which captures project funding information
- The Project.Infrastructure module, which captures information about project infrastructure (hardware, software, services, etc.)
- The Project.Geography module, which captures geographical information about the project
- The Dataset module, which captures information about project datasets
- The Project.Participant module, which captures information about project participants and their activities within a project

Due to the wide scope of the main conceptual model for citizen science, it was developed in phases. In this chapter, our attention is focused on *participation* and *participant activities* in citizen science projects. Related initiatives from CSA, ECSA, ACSA, and OGC are accounted for and the model is tested with case studies.

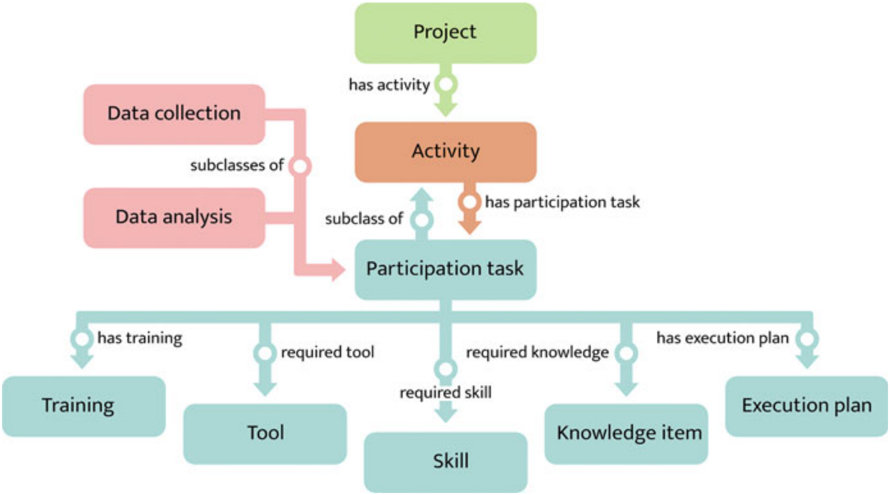

Fig. 9.3 Excerpt (part a) of the conceptual model on citizen participation. The different boxes represent concepts; the arrows represent relationships

Since the role of the citizens as participants is the main difference between citizen science projects and traditional research projects, in the following section, we will discuss the Project.Participant module in more detail.

Together, Table 9.1 and Figs. 9.2 and 9.3 outline all the concepts and relationships in the conceptual model related to the Project.Core and Project.Participant modules. Here, we describe a selection of the concepts; a full list of descriptions is currently under development and available in the model repository.[13]

Participation and Activity Description

At the heart of the Project.Participant module lie the relationships between the participants, their activities, their outputs, and the skills, knowledge, and tools required to perform them. A project has one or more activities, and these are performed by participants with a variety of roles and motivations, during a specified time range.

In the model, the Activity concept (see Figs. 9.3 and 9.4) represents activities that belong to a Project. A general *activity*, such as 'Collecting data about bird migration', may contain a number of tasks. A *task* is an activity with a specific goal and a limited duration (a kind of transaction), such as 'Taking a picture of a bird and storing it in an image collection' or 'Validating a bird identification'. The description

[13]Doi: https://doi.org/10.5281/zenodo.3695444

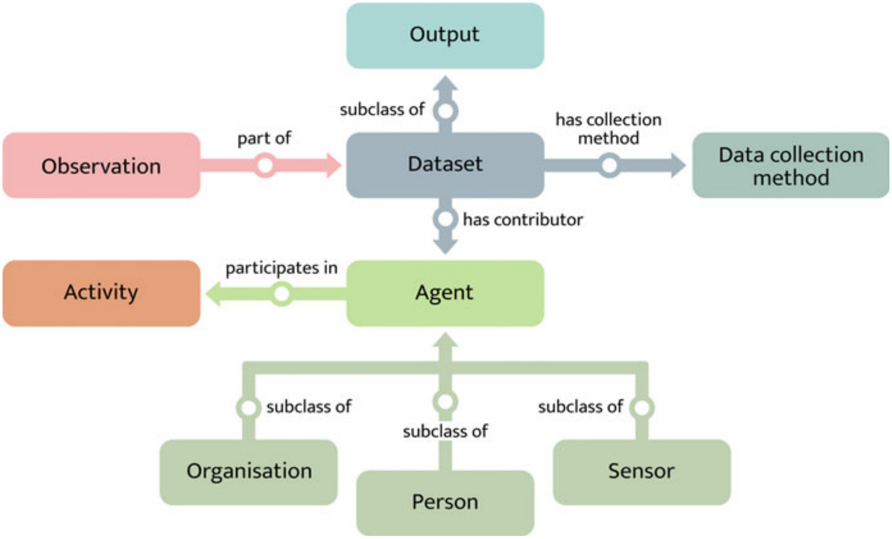

Fig. 9.4 Excerpt (part b) of the conceptual model part on citizen participation

of a task includes details of the knowledge, skills, and tools required as well as the training available and its *execution plan*.

The Agent concept in Fig. 9.3 generalises the idea of participants to groups of people in particular organisations and to machines, such as sensors. An *instance* of the Agent concept represents a type of agent, for example, 'registered Zooniverse user' or 'mapping agency'.

The Activity description includes its output (e.g. dataset, publication, software) that can be composed of a number of *output items*. A project may acknowledge the participation of an actor in the production of an output item. In this case, the description of an output item includes a link to the role played by the actor its production. The description of a Project also includes its participant recruitment technique and its privacy protection policy. The dataset as an entity is handled in our model as a specific type of output. Its details are described in a separate module (see Fig. 9.1), and although they are required for interoperability, they are beyond the scope of this chapter. The same holds true for the semantics of a dataset's content, which is described in the Data Model (Fig. 9.1). Here we make use of existing standards, such as the underlying data models of the SensorThings API (Footnote 8) and the SSN Ontology (Footnote 4).

The concepts depicted in Fig. 9.4 cover participation and its requirements. The model does not claim to be exhaustive, but rather serves as a backbone. Each of the branches, such as tools and skills, can themselves be described by external models. The subclassification is also not exhaustive. Part a (Fig. 9.3) and part b (Fig. 9.4) are connected through the Activity concept.

Application in Case Studies

This section explains how the conceptual model for citizen science can be used in specific case studies, that is, how the different characteristics of a project – its participants, its data, etc. – can be described by using the model. The case studies represent projects with different domains, community sizes, and types of participation in order to demonstrate the breadth of citizen science applications that the model can accommodate. The first sub-section highlights four different projects. Here we demonstrate how they can be described with the help of our model in order to understand project content and metadata. The second sub-section illustrates another use for our model: the application of its concepts and structure for (1) creating project descriptions in a specific inventory and (2) structuring data collection.

Instantiation of Projects

After providing a short introduction to the four selected citizen science projects, we use our conceptual model as a skeleton for each specific project. Where applicable, the concepts (as depicted in Figs. 9.3 and 9.4) have been *instantiated* for each project; see Tables 9.2 and 9.3. In other words, a concept is assigned a project-specific value where possible and applicable. This means that specific projects, their activities, participants, data outputs, etc., are described with the help of the conceptual model. Using this common model allows the projects to be compared and combined, thus increasing interoperability between the projects and their elements. It should be emphasised that in the tables only a few examples are provided and that each entry in the table corresponds to a concept in the model, which is more than just a flat table. For example, a project can have multiple participation tasks, each using different tools; and a project can produce multiple, different datasets, and so on. We will now introduce our case studies.

OpenStreetMap. OpenStreetMap (OSM) is a well-known *crowdsourcing* project in which thousands of volunteers maintain an online map of the world. OSM has all the characteristics of participation and data handling we see in many other citizen science projects. In addition, OSM is an essential geographical reference for many citizen science projects.

Bash the Bug (Zooniverse). The objective of the Bash the Bug project is to improve tuberculosis diagnosis. The task of the volunteers is to accurately determine which antibiotics are effective for each of the collected tuberculosis samples. This is carried out by analysing pictures of plates showing the effects of several antibiotics on the tested sample.

Mars in Motion (Zooniverse). Mars in Motion was created to look for and identify geological changes on the surface of Mars over time by gathering in-depth data on the type of features that are detected. It is part of the i-Mars.eu project, which includes several European partners, and is focused on developing tools and datasets to increase the exploitation of space-based data from the US National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) Mars mission beyond the scientific community.

Table 9.2 Instantiation of the conceptual model with OSM, Bash the Bug, Mars in Motion, and MICS

Concept	Project instantiation OpenStreetMap	Project instantiation Bash the Bug
Activity	OSM mapping event OR data capture facilitation	Assessment of antibiotic effect (a)
ActivityAgentDependency		(a) – (u)
Agent		Zooniverse user (u)
AssociatedPublications		
Consortium		
ContactDescription		
ContactPoint		
DataCollectionMethod	On-screen digitising	Web crowdsourcing (on-screen recognition)
Dataset	OSM change set	Antibiotics sensitivity dataset
Description		
Email		
EndDate		
ExecutionPlan	Mapping campaign, HOT task	
GeographicExtent		
GroupOfAgents		
Hardware		
Initiative		
KnowledgeItem	GIS fundamentals	
Machine		
MeansOfContact		
Motivation	Contribute free map data	
Name		
Observation	OSM feature	
Origin		
OGC:Datastream		
OGC:Sensor		
Organisation		
OrganisationCategory		
Output		
OutputItem	Geometric primitive (point, lines)	Record (infection sample –>sensitivity to antibiotics)
ParticipantAcknowledgment	OSM user id	Authorship recognition
Participation	OSM contribution	
ParticipationTask		Image classification
Person	OSM contributor	
PrivacyProtectionPolicy	Terms of use in signup	https://www.zooniverse.org/privacy
PrivacyProtectionTechnique	Person is behind user id	Zooniverse informed consent
Project	OSM.org	

(continued)

Table 9.2 (continued)

Concept	Project instantiation OpenStreetMap	Project instantiation Bash the Bug
Publication	OSM upload	
RecruitmentMethod	Mapping event invitation, conferences, courses	
Role	OSM mapper; OSM validator	
Sensor		
Skill	Image interpretation	
Software (as tool)	Mobile/web editors	Zooniverse classification web app
Software (as output)		
SpatialAreaofInterest		
StartDate		
Status		
TemporalExtent	OSM mapping event duration	
Tag		
Tool	OSM editor, e.g. iD, JOSM, etc.	
Training	Online self-training, Wiki specs	8-slide tutorial
WebPage		

Concept	Project instantiation Mars in Motion	Project instantiation MICS Project
Activity	Online classification of Martian surface (a)	Online assessment of project impact (a)
ActivityAgentDependency	(a) – (u)	(a) – (u)
Agent	Human (u) and machine	Human (u) and machine
AssociatedPublications	https://doi.org/10.1016/j.jag.2017.05.014	
Consortium	FP7 i-Mars project	Horizon 2020 Project
ContactDescription	Project contact	Project contact
ContactPoint	James Sprinks	Luigi Ceccaroni
DataCollectionMethod	On-screen analysis	On-screen survey
DataSet	ESA Mars Express HRSC Camera	MICS Impact Assessment Corpus of Knowledge
Description		
Email	james.sprinks@nottingham.ac.uk	lceccaroni@earthwatch.org.uk
EndDate		
ExecutionPlan	Project deliverables/timeline	Project deliverables/ timeline
GeographicExtent		
GroupOfAgents		
Hardware	N/A	N/A

(continued)

Table 9.2 (continued)

Concept	Project instantiation Mars in Motion	Project instantiation MICS Project
Initiative	iMars	MICS
KnowledgeItem	Scientific concept	Project outputs
Machine	Change detection algorithm	Impact assessment algorithm
MeansOfContact	Email	Email
Motivation	Contribute to understanding of Martian surface evolution	To understand the impact of their project
Name	Jo Bloggs	Joanna Blogson
Observation	Martian geomorphological feature	Impact measurement
Origin		
OGC:Datastream	N/A	N/A
OGC:Sensor	N/A	N/A
Organisation	iMars project consortium	MICS project consortium
OrganisationCategory	European FP7 Project Funded	European H2020 Project Funded
Output	Martian geomorphological features that evolve temporally	Impact assessment
OutputItem	Distance, speed, typology	Report
ParticipantAcknowledgment	Authorship, acknowledgement in publication	Acknowledgement on website
Participation	Mars in Motion contribution	MICS contribution
ParticipationTask	To detect changes on the Martian surface, through comparison of two images	To evaluate the impact of their citizen science project
Person	Mars in Motion participant	MICS participant
PrivacyProtectionPolicy	Zooniverse privacy policy	MICS privacy policy
PrivacyProtectionTechnique	Zooniverse informed consent	MICS informed consent
Project	https://www.zooniverse.org/projects/imarsnottingham/mars-in-motion/	https://mics.tools/
Publication	Database of Martian feature change	Project impact assessment report
RecruitmentMethod	Online correspondence to existing Zooniverse community	
Role	Project participant	Project coordinator
Sensor		
Skill	Image interpretation	Assessing project processes/output that have impact
Software (as tool)	Web platform (Zooniverse)	Web platform
Software (as output)	N/A	N/A
SpatialAreaofInterest		
StartDate		
Status		

(continued)

Table 9.2 (continued)

Concept	Project instantiation Mars in Motion	Project instantiation MICS Project
TemporalExtent	30 years + of historical data	Unlimited
Tag		
Tool	Online Zooniverse image annotation	Online survey data entry
Training	Online training (compulsory)	Online guidance/ examples
WebPage		

Table 9.3 Instantiation of the conceptual model with the JRC Citizen Science Project Inventory and the Participatory Toponym Handling Project

Concept	Project instantiation JRC Citizen Science Project Inventory	Project instantiation Participatory Toponym Handling Project
Activity		Toponymic data handling OR toponymic field survey
ActivityAgentDependency		
Agent		Citizens, local government, university, Badan Informasi Geospasial (BIG)
AssociatedPublications		doi: https://doi.org/10.3390/ijgi7060222; doi: https://doi.org/10.3390/ijgi8110500
Consortium		
ContactDescription		
ContactPoint		
DataCollectionMethod		Geographic data collection: fieldwork and office treatment
DataSet		Toponymic files and gazetteers
Description	Brief description	
Email		
EndDate	End year	
ExecutionPlan		Workshops (toponymic field survey campaign), citizen science project on toponym, local government project on toponym, HOT (Indonesia) task
GeographicExtent	Geographical extent	West Java province
GroupOfAgents		
Hardware		Tablets
Initiative		
KnowledgeItem		Toponymy
Machine		

(continued)

Table 9.3 (continued)

Concept	Project instantiation JRC Citizen Science Project Inventory	Project instantiation Participatory Toponym Handling Project
MeansOfContact	Contact	
Motivation		Contribute toponymic data, preserve embedded knowledge on toponyms, collect toponyms in their surrounding areas
Name	Name	
Observation		Place names, coordinates, history, pronunciation
Origin	Source	
OGC:Datastream		
OGC:Sensor		
Organisation		
OrganisationCategory	Lead organisation category; project initiator category	
Output		Dataset (toponyms, gazetteers)
OutputItem		Geometric primitive (point), audio (pronunciation of toponym)
ParticipantAcknowledgment		Reward-based approach, incentive, capacity building opportunities
Participation		Local toponyms
ParticipationTask		Providing place name and related information
Person		CitSciTopon contributor, LocalGovt contributor, OSM contributor
PrivacyProtectionPolicy		Terms of use in signup
PrivacyProtectionTechnique		Person is behind user id
Project	Project	
Publication		SAKTI upload
RecruitmentMethod		Toponymic training event invitation, Toponymic survey invitation
Role		Data collector; data verificator/validator
Sensor		
Skill		Interview, communication with local people
Software (as tool)		Mobile/web editors
Software (as output)		
SpatialAreaofInterest	Geographic coverage	
StartDate	Start year	

(continued)

Table 9.3 (continued)

Concept	Project instantiation JRC Citizen Science Project Inventory	Project instantiation Participatory Toponym Handling Project
Status	Still active	
TemporalExtent		National naming authority event programme duration
Tag	Primary environmental domain; primary environmental field; primary category of project	
Tool		EpiCollect, SAKTI application, ODK and OSM OpenMapKit
Training		Training on toponymy, workshops, focus group discussions
WebPage	Website	

MICS. The MICS project provides an integrated platform of metrics and instruments to measure both the costs and the benefits of citizen science. These metrics and instruments consider the impacts of citizen science on the following domains: society, governance, the economy, the environment, and science.

Deployment of the Conceptual Model

In addition to the basic metadata provision outlined in the previous section, the conceptual model can be used as a structure for project-related activities. Two case studies are provided here.

JRC Citizen Science Project Inventory

The European Commission Joint Research Centre (JRC) has developed a multidisciplinary data infrastructure (Friis-Christensen et al. 2017) to facilitate open access to its research data, in line with the recent *open data* trend (Trojan et al. 2019). The JRC Data Infrastructure[14] has helped establish requirements for dataset metadata. The JRC datasets are published in the JRC Data Catalogue and are described by metadata that follow a modular metadata schema. The schema consists of (1) a core profile which defines the common elements of metadata records, based on the reference standards DCAT-AP (ISA DCAT-AP 2015) and DataCite (2016), and (2) a set of extensions, which defines elements specific to given domains (geospatial, statistical, etc.), based on existing metadata standards.

[14]http://data.jrc.ec.europa.eu/

In addition, the JRC Citizen Science Project Inventory has supported the JRC in describing projects. The JRC Citizen Science Project Inventory was initially developed as one of the outcomes of the study *Citizen Science for Environmental Policy: Development of an EU-wide Inventory and Analysis of Selected Practices* (Bio Innovation Service 2018; Turbé et al. 2019). This project was executed by the European Commission (DG Environment), with the support of the JRC. The project also included additional contracted partners: the Bio Innovation Service (France), the Fundacion Ibercivis (Spain), and the Natural History Museum (UK). The main objective was to build an evidence base of citizen science activities to support environmental policies in the European Union (EU). Specifically, the goal was to develop an inventory of citizen science projects relevant to environmental policy and assess how these projects contribute to the United Nations Sustainable Development Goals (SDGs). To this end, a desk study and an EU-wide survey were used to identify 503 citizen science projects of relevance to environmental policy. The resulting project inventory has been published in the JRC Data Catalogue[15] and is updated on a regular basis (it also considers new entries suggested via an online survey).[16]

The Citizen Science Explorer,[17] a dynamic catalogue provided as part of the JRC GitHub space, has been developed to provide more visibility to the JRC Citizen Science Project Inventory and to showcase the opportunities for knowledge sharing and management. The inventory is available in the form of *comma-separated values* (CSVs),[18] JSON,[19] and JSON-LD.[20] Therefore, the conceptual model described in this chapter does not allow us to represent all the information available in the inventory but does allow us to structure its core entities in a standardised way.

There are other initiatives which can be considered as case studies for identifying stakeholders needs. These include activities covered by Earthwatch (e.g. the MICS project, in which the impact of citizen science projects is measured) and COST Actions throughout Europe.

Participatory Toponym Handling Project

One application case where the citizen science conceptual model had a direct influence, and which in turn can be used to shape future developments of the conceptual model, concerns the collection and maintenance of place names (or *toponyms*) in Indonesia.

This particular case study was motivated by the fact that many national mapping agencies (and agencies responsible for the naming of places in databases and gazetteers) have scarce or insufficient resources. At the same time, many citizens

[15] http://data.jrc.ec.europa.eu/dataset/jrc-citsci-10004

[16] https://ec.europa.eu/eusurvey/runner/CSProjectInventory

[17] https://github.com/ec-jrc/citsci-explorer/

[18] https://tools.ietf.org/html/rfc4180

[19] https://tools.ietf.org/html/rfc8259#section-4

[20] https://www.w3.org/TR/json-ld/

have rich local and traditional knowledge of toponyms. Indonesia, in particular, has many regional and local languages and a varied topography. Including local and traditional knowledge is also relevant from a research point of view, because it can, for example, uncover yet unwritten histories.

The Geospatial Information Agency of Indonesia (Badan Informasi Geospasial, BIG[21]) is responsible for toponyms in Indonesia. BIG conducted two pilot projects in 2015 (Yogyakarta) and 2016 (Lombok) on the involvement of citizens in toponym handling. The Indonesian approach includes many stakeholders, combining both *top-down* and *bottom-up* elements: national legislation provides regulations and procedures, while their implementation relies on local actors. However, local governments tasked with the implementation often lack the capacity to provide the required skills and resources.

The pilot projects led to the development of a *participatory toponym handling framework* (Perdana and Ostermann 2018). More importantly for this chapter, the framework adopted several concepts from an early version of Working Group 5's citizen science conceptual model. Thus, although the framework has been subsequently improved and significantly expanded through collaborative learning, including focus group discussions with stakeholders and workshops (Perdana and Ostermann 2019), this example shows the utility of an early version of the conceptual model for designing a project involving citizens.

The concrete participatory toponym handling approach that was developed is also expected to influence ongoing legislation processes. Furthermore, it resulted in three experimental toponym collection projects in late 2018 (their outcomes will soon be published).

Using this chapter's conceptual model, we can describe the participatory toponym handling. The main Activity is the collection of place names, either entirely new ones or updating existing ones. The Agents carrying out this activity are citizens, local government officials, experts from the national mapping agency, and academics/researchers. The DataCollectionMethod is field surveys using tablets, supplemented by office-based processing. The created Datasets are initially forms completed by participants (Observations) with multimedia elements (e.g. audio recordings of pronunciation) and ultimately enriched gazetteers. Therefore, the ParticipationTask is to provide place names and related information. The Motivation is to contribute toponymic data, preserve embedded knowledge on toponyms, and collect toponyms in their surrounding areas.

Roadmap for Future Research and Use

The benefits of using the conceptual model presented in this chapter are twofold: *human understanding* of citizen science project characteristics and *machine processing* of these characteristics. Further technical development and

[21] https://big.go.id/en

documentation of best practices will be required to support the model in use. Humans wishing to discover, evaluate, and contribute to projects will require intuitive visualisation of the conceptual model and well-designed tools for search and query. Machines that use the model for data alignment will require well-designed APIs, and repositories of standards, schemas, and agreed terms, with reliable access mechanisms.

An example of the context in which this conceptual model could be used is the EU Horizon 2020 Framework Programme project EU-Citizen.Science, which aims 'to build a central platform for citizen science in Europe, a place to share useful resources about citizen science, including tools and guidelines, best practices and training modules'.[22] By utilising a metadata schema such as this conceptual model, a greater understanding of data types, their structure, and their relationships can be achieved. Adopting the conceptual model will also ensure that the tools, guidelines, and training developed are as widely applicable and usable as possible.

The following recommendations are designed to foster the uptake of the conceptual model by the citizen science community in order to increase citizen science interoperability:

- Develop procedures to respond to existing regulatory or legal frameworks related to citizen science, such as the implementation of the INSPIRE Directive (in Europe) and the provision of related best practices and tools.[23]
- Involve the ECSA, CSA, ACSA, and the Citizen Science Global Partnership (CSGP) in the definition of an agenda for the model's practical implementation and possibly as hosts for interoperable catalogues of citizen science projects and data. They could also provide guidelines on the use of existing solutions.
- Include a dedicated section on ECSA, CSA, ACSA, EU-Citizen.Science, and CSGP websites to explain the conceptual model and provide introductory information.
- Develop extensions related to more diverse outcomes, such as mathematical theorems, hardware, and policy and societal impacts.
- Develop communication approaches to help practitioners navigate through the various standards and concepts (e.g. a 'choose your own adventure' approach; see also the Digital Curation Centre[24] for additional ideas).

Implementing the proposed recommendations will take some time and also require collaboration across communities. The publication of the conceptual model outlined in this chapter should support this process. In addition, some of the work needed to fulfil the recommendations is already in progress and will ultimately be disseminated through citizen science community channels.

[22] https://eu-citizen.science/about/

[23] https://inspire-reference.jrc.ec.europa.eu/vocabularies/geospatial-standards/sensorml

[24] http://www.dcc.ac.uk/

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Chapter 10
Machine Learning in Citizen Science: Promises and Implications

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Abstract The chapter gives an account of both opportunities and challenges of human–machine collaboration in citizen science. In the age of big data, scientists are facing the overwhelming task of analysing massive amounts of data, and machine learning techniques are becoming a possible solution. Human and artificial intelligence can be recombined in citizen science in numerous ways. For example, citizen scientists can be involved in training machine learning algorithms in such a way that they perform certain tasks such as image recognition. To illustrate the possible applications in different areas, we discuss example projects of human–machine cooperation with regard to their underlying concepts of learning. The use of machine learning techniques creates lots of opportunities, such as reducing the time of classification and scaling expert decision-making to large data sets. However, algorithms often remain black boxes and data biases are not visible at first glance. Addressing the lack of transparency both in terms of machine action and in handling user-generated data, the chapter discusses how machine learning is actually compatible with the idea of active citizenship and what conditions need to be met in order to move forward – both in citizen science and beyond.

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Introduction

The combination of human and machine learning, wherever they complement one another, has a lot of potential applications in citizen science. Several projects have already integrated both forms of learning to perform data-centred tasks (Willi et al. 2019; Sullivan et al. 2018). While the term *artificial intelligence* (AI) is generally used to refer to any kind of machine or algorithm able to observe the environment, learn, and make decisions, the term *machine learning* (ML) has been defined 'as a subfield of artificial intelligence that includes software able to recognize patterns, make predictions, and apply newly discovered patterns to situations that were not included or covered by their initial design' (Popenici and Kerr 2017, p. 2). ML algorithms are currently the most widely used and applied, for example, in image and speech recognition, fraud detection, and reproducing human abilities in playing Go or driving cars. In scientific research, they find many applications in different fields such as biology, astronomy, and social sciences, just to mention a few (Jordan and Mitchell 2015). Although AI is not new to citizen science (Ceccaroni et al. 2019), the convergence of advanced computing, availability of data, and learning algorithms can introduce something dramatically new in this area. The opportunities are many, and in some cases not yet foreseen, but so are the challenges, including the need to advance the explainability, accountability, and fairness of algorithms from the perspective of ML research and from that of citizen scientists using the applications.

We address two main questions here: (1) *what tasks are citizens being invited to perform in citizen science projects through the use of ML?* and (2) *what are the main risks and opportunities of using ML in citizen science?* The majority of citizen science projects are centred around data provided, for example, by satellites, cameras, or, more generally, sensors (Neal 2013). Collecting, analysing, and interpreting data are some of the most common activities that participants carry out, depending on their level of engagement in the scientific research process (Bonney et al. 2009). Similarly, ML makes sense in a variety of stages of the data–science life cycle through algorithms that perform tasks like classification, regression, clustering, and association, especially when dealing with huge amounts of data.

Many research problems are still considered computationally intractable and need human cognitive skills. For example, machines cannot yet match a person's ability to identify certain objects, and it is unclear to what extent they will ever succeed. Conversely, manual classification or identification of a large data set can be made more efficient in combination with ML approaches. Even so, the participation of citizens and the collective intelligence that emerges from it becomes fundamental to perform certain tasks, such as the creation of data sets with correctly tagged data to feed algorithms (Torney et al. 2019). The Galaxy Zoo project and the classification and identification of galaxy morphological shapes is a good case in point (Fortson et al. 2012; Walmsley et al. 2019). This procedure of combining cognitive skills and technical assignments is also called human computation. It is moreover an approach that has also been successfully tested in areas other than science (e.g. Google Maps). Human computation is used when it comes to the handling and classification of large, partly user-generated amounts of data.

Data has always been an intrinsic part of science, and a rigorous methodology is needed to ensure data quality (see Balázs et al., this volume, Chap. 8), a topic extensively studied and discussed in the context of citizen science (Lukyanenko et al. 2019). With the advent of *big data*, not only is scientific resolution increasing, but so is the ability to automate certain routine and repetitive tasks. The application of ML algorithms in the stage of data collection offers guidance in the subsequent analysis – identification and classification tasks – minimising errors and maximising data quality (Lukyanenko et al. 2019).

In other cases, the use of ML algorithms is applied once the data has been modelled, with the objective of analysing the model, extracting information, and giving responses to research questions. Standard statistical analysis, but also supervised and unsupervised learning (see below), is used to find causal relationships in the observations or look for patterns in the data collected (Vicens et al. 2018; Poncela-Casasnovas et al. 2016). At this point it is also possible to implement ML algorithms to detect biases in the data, such as location biases (Chen and Gomes 2018), or to analyse the influence of different explanatory factors in the model (Bird et al. 2014).

These introductory remarks indicate that the application of ML is associated with various functions for science and for citizen science in particular. The aim of this chapter is, first, to give an overview of the application of ML in citizen science and, building on this, to explore the relationship between humans and machines in knowledge production. In the next section, we will present the current learning paradigms associated with ML, illustrated by sample projects, followed by a discussion of the main ethical challenges for citizen science that arise from the opacity of the algorithm from outside and how this imbalance can possibly be overcome. In the discussion section, we use these recent developments to identify the opportunities and challenges arising from collaboration between humans and machines in citizen science in the long run.

Learning Paradigms in ML

To examine the tasks citizens are being invited to perform in citizen science projects through the use of ML, we need to see the learning paradigms associated to it. Currently, in the field of machine learning, three main learning paradigms can be distinguished: supervised, unsupervised, and reinforcement (cf. Sathya and Abraham 2013). *Supervised learning* is based on training or teaching an algorithm using sample data – also called training data – already correctly classified by an expert. After that, the machine is provided with a new set of examples (data) so that a supervised learning algorithm can analyse the training data (set of training examples) and produce a solution from labelled data. *Unsupervised learning* is based on training a machine using unclassified data and allowing the algorithm to act on that data without any guidance. Unlike supervised learning, no classifications are provided which means no training is given to the machine. Therefore, the machine itself has to derive the hidden structure in unlabelled data. *Reinforcement learning* entails taking a suitable action to maximise rewards in a particular situation. It is employed by a variety of software and machines to find the best possible behaviour or path to be taken in a specific situation. While in supervised learning the algorithm is trained on data containing the correct answers, in reinforcement learning there is no answer, but the reinforcement agent decides what to do to perform the given task. In the absence of a training data set, the algorithm has to learn from its own experience. A form of ML that can use either supervised or unsupervised algorithms is *deep learning*. Deep learning can help solve certain types of difficult computer problems, most notably in computer vision/computer hearing and natural language processing (NLP). Computer vision or hearing defines a subset of AI which automatically extracts information from image, video, and audio data using algorithms (see Ceccaroni et al. 2019). The ‘deep’ in deep learning refers to the many layers that are built into a model, which are typically neural networks. A convolutional neural network (CNN) can consist of many layers of models, where each layer takes input from the previous layer, processes it, and outputs it to the next layer, in a daisy chain fashion. The probably most famous example of CNN is the one developed by Google’s DeepMind team, which beat the human world champion of the ancient Chinese game of Go.

Examples of ML in Citizen Science

To provide some examples for our conceptual discussion, we reviewed a small sample of nine citizen science applications using ML (Table 9.1). While we do not consider these projects to be representative of the entire population of ML applications in citizen science, they still offer some interesting indications.

Most of the projects in Table 10.1 are examples of supervised learning in which algorithms are used that do not have a priori recognition abilities and, thus, need external training. Therefore, they usually start with a *golden set* of data labelled by domain human experts (e.g. Mindcontrol). Untrained citizens are then involved to use those labels for annotating a larger set of data, and, at the end, this larger data set is utilised to train a supervised machine learning model that automatically labels the entire data set.

Most projects in our list involve supervised learning by using image recognition software in the realm of computer vision. Computer vision is used on citizen science data and camera trap data to assist or replace citizen scientists in fine-grain image classification for taxon/species detection and identification (plant or animal) (Ceccaroni et al. 2019). A good example is the project Wildlife Insights (Ahumada

Table 10.1 Examples of ML in citizen science projects

Project name	Category of task	Types of AI – purpose	Field	Machine learning paradigm
Galaxy Zoo	Classification	Computer vision – recognise shape and structure of galaxies	Astronomy	Supervised learning and use of CNN
Human Protein Atlas	Classification	Computer vision – combination of pattern recognition and classification of images for large-scale classification of protein localisation patterns in microscopy images	Life sciences	Supervised learning
iNaturalist	Classification	Computer vision – classification of images or acoustic data for species identification	Environmental science	Supervised learning
Machine learning Assisted Image Annotation (MAIA)	Classification	Computer vision – image annotation method for environmental monitoring and exploration	Oceanography	Supervised learning
Mindcontrol	Classification	Computer vision – scaling expertise in neuroimaging. Semi-automated replacement for manual coding of neuroimages through a mixture of crowdsourcing and machine learning. Citizen scientists are trained	Neuroscience	Supervised learning and use of CNN
'Nature through the eyes of many'	Classification	Computer vision – preselection of animals trapped in camera trap databases and learning the species by citizen scientists' inputs	Environmental science	Supervised learning
Observation.org	Classification	Computer vision – classification of images of species identification	Environmental science	Supervised learning

(continued)

Table 10.1 (continued)

Project name	Category of task	Types of AI – purpose	Field	Machine learning paradigm
SciStarter	Prediction	Automated reasoning – use of recommendation algorithms to predict users' interests based on their past interactions with SciStarter, a portal of 3000 global citizen science projects that aims to help users to find suitable projects	Citizen science platform	Unsupervised learning in most cases, generally based on the project listed in the platform
Snapshot Serengeti	Classification	Deep learning on structured data – automatic animal identification using deep learning to identify, count, and describe the behaviour of animal species captured with camera traps	Environmental science	Supervised learning

et al. 2020) covering images from camera trap databases. Another example is a prototype called 'Nature through the eyes of many' as a utilised output from the project 'National database of photo trap records' ('Informační systém pro správu záznamů z fotopastí') (Lehejcek et al. 2019). Camera traps are commonly used in environmental monitoring, geography, and beyond (Trojan et al. 2019). Millions of pictures are collected throughout the extensive network of camera traps every day. This project combines pictures from various camera trap databases and serves as a management tool for the collected images. Like in the project Snapshot Serengeti (Swanson et al. 2016), machines are not always successful in identifying the proper animals in the collected pictures. In this case, citizen scientists in the role of spotters identify the animals and serve as teachers for the AI algorithms. Firstly, the AI will run the automatic classification of the picture. If the animal is detected with a certain probability, spotters come to the scene. AI offers a primary classification (animal recognition) to the spotter (also the trapper who uploaded records can pre-classify the image). A spotter validates/invalidates the pre-classification, and the image is not considered as validated until there is at least a 75% consensus (which can be adjusted in a certain project) among all the spotters involved. This is the input for the ML algorithms. The simplified schema of the whole process is visualised in Fig. 10.1, in which the parameters of the ML process are suppressed and generalised. However, the example using a camera trap database could be analogically used in other ML in citizen science.

Although there are technical issues related to ML mechanisms, they can be utilised for gamification purposes increasing spotters' motivation levels and making participation for citizen scientists more attractive. Every spotter builds up their

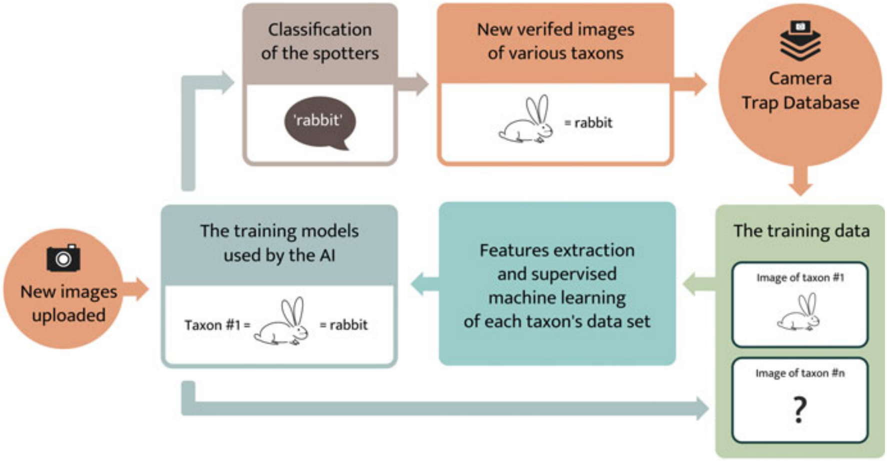

Fig. 10.1 The interaction between spotters and ML processes during image classification within the camera trap database

credibility. Spotters who tag pictures with greater consensus get higher weighting for their future votes; spotters who do not classify records well or who want to spoil the system are automatically weighted lower. The process of image classification involving AI/ML and citizens ends back with the trappers, who upload their camera trap data into the database. Trappers benefit from both AI and citizen science approaches and can easily manage their data within the database. The systems combining these methods in one place are in high demand, which can be substantiated by the support of big technology companies like Google (see the case of the Wildlife Insights project, Ahumada et al. 2020). For instance, national agencies for nature conservation and landscape protection using a significant amount of data from several remote camera trap repositories could manage the records in one place.

Challenges and Opportunities of Using ML

In the most applied ML paradigm – supervised learning – solutions are inferred directly from the data following the mathematical rules used to create such a paradigm (Sathya and Abraham 2013). Applications using this paradigm embed an idea of learning as acquisition or enhancement of knowledge to improve predictive accuracy or make more effective decisions (Blackwell 2015). This idea of learning builds on the strengths of machines, including performing tedious and repetitive tasks, fast processing of huge amounts of data, recognising complex patterns, and making predictions under uncertainty (Dellermann et al. 2019). Therefore, training ML models at high speed while maintaining accuracy and precision remains a vital goal for science. However, the application of ML in citizen science produces both epistemic and ethical challenges. Both have to do primarily with the opacity of the machine, whose operations and outcomes are largely obstructed by concrete human comprehension. Whether and how transparency can be created will be briefly discussed in the following section.

Epistemological and Ethical Challenges

The extended use of AI, particularly ML, has initiated a general debate on the different forms of opacity (Burrell 2016) and bias (Mehrabi et al. 2019) that it promotes. Drawing on Burrell (2016), we use opacity to describe the difficulties encountered by a user of the output of an algorithm (e.g. a classification decision) to make sense of how or why that particular classification has been arrived at from inputs. We use the term bias to refer to any prejudice or favouritism toward an individual or a group based on certain characteristics (Mehrabi et al. 2019).

The issues connected to opacity and bias in ML have brought to light the need for more transparency in the designing of algorithms and the data used for training in order to prevent or mitigate adverse effects. This consideration transcends citizen science and unequivocally affects every area in which ML algorithms are applied. However, the very nature of citizen science projects and their possible biases mean that citizen science researchers devote much attention to ensuring data quality, a task which is even more important when using ML approaches.

Opacity in ML takes many forms but one of the most recently scrutinised is the *black box* effect. In general, a black box is a system in which we can observe the inputs and outputs but not the internal process. ML algorithms like neural networks and deep learning are so intrinsically complex that it is virtually unworkable to get to the bottom of their operations and internal decision-making processes. Those algorithms are designed to achieve the best performance possible given particular metrics; thus they are very useful when the cost of an error is low (Rudin 2019). This, for instance, happens when the consequences of unacceptable results are not significant or when the results are studied and validated in real applications (Doshi-Velez and Kim 2017). Nevertheless, the black box effect can cause biases and unfairness that impact human lives deeply. In those cases, it is advisable not to use opaque systems in high-stakes decisions regarding justice, healthcare, and employment, to mention just a few (Rudin 2019).

Making ML More Transparent

To achieve further and sustained progress by the implementation of ML, explainable, interpretable, and comprehensible algorithms are needed to reduce biases (such as gender and racial biases), produced in both the design of the algorithms and the data used to train them.

Concepts such as explainability, interpretability, and transparency are widely used in the AI literature, and, in some cases, they have even been used interchangeably. Gilpin et al. (2019) state that an *explanation* can be evaluated in two ways: 'according to its interpretability, and according to its completeness' (p. 2), where *interpretability* describes the internal mechanisms of a system in a way that is understandable to humans and *completeness* describes the operation of a system in an accurate way. Doshi-Velez and Kim (2017) define interpretability in machine learning as 'the ability to explain or to present in understandable terms to a human'.

Therefore, the idea behind explainable AI radiates from the implementation of algorithms that are understandable to a human expert who can discern the internal mechanisms and understand what is happening. This idea is in contrast to black boxes. In a similar way, interpretable algorithms are the ones that allow the observation of the cause and effect in a system and predicting what is going to happen if there are changes in the input or in the algorithmic parameters.

In some citizen science projects, an explanation may not be required unless there is a decision-making process envisaged by the outcome. For instance, if we want to classify images that contain a whale and images which do not, in principle it is acceptable to use black box models. However, if from this outcome we need to make critical decisions, or we want to know how the decision-making process to detect whales works, then we would need an interpretable model. This is particularly critical in the context of citizen social science where we work with sensible social data; thus inferences in the analysis can have a direct impact on societal concerns. In this case, the generalisation bias means not only that data does not represent the whole context but, moreover, that data represents and reproduces situations of social injustice or prejudices. Transparent systems to avoid intentional bias (Burrell 2016) in projects that involve sensitive data, such as biometric and genetic information, political opinions, and sexual orientation, need adopting mechanisms to ensure principles and guidelines regarding ethics: transparency, justice and fairness, non-maleficence, responsibility, and privacy (Jobin et al. 2019; Floridi and Cowls 2019).

From these concerns about unfairness in ML emerges the 'right to an explanation', which basically states that a decision should not be based solely on automated decision-making, but also provide an explanation about the outcome of the decision-making process (Edwards and Veale 2018). The application of this principle in science is very interesting in the sense that the scientific understanding needs not only the outcome of the systems but also the process leading to this outcome in order to extract knowledge from the procedure and be able to interpret it (Doshi-Velez and Kim 2017), let alone the possibility of replicating the results.

There are useful methods for explaining black box models (Guidotti et al. 2018) that can be applied to citizen science projects (for a more generalised way of differences between black box projects and transparent projects, see Fig. 10.2). The open research culture of citizen science is a perfect context to promote transparency within AI. The first step should be transparency of the forms of

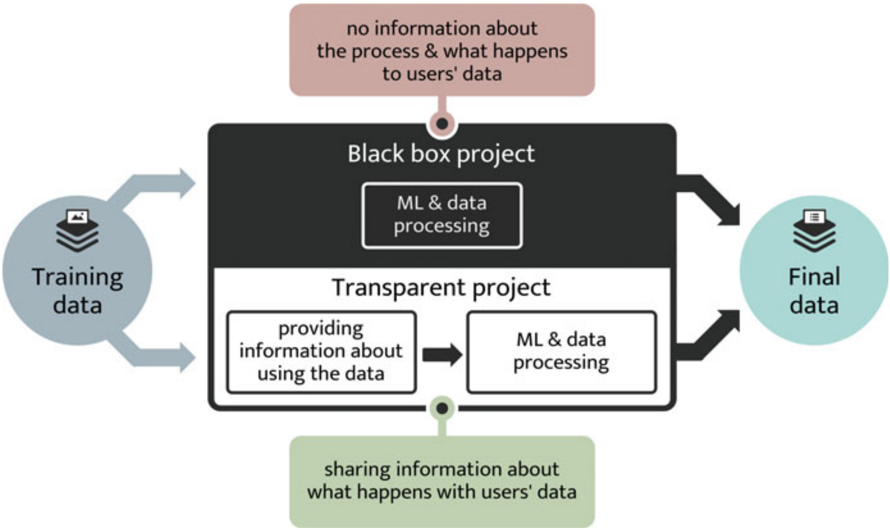

Fig. 10.2 Differences between black box and transparent projects

collaboration between humans and AI in citizen science. The main reason most humans are willing to give time and money (through energy consumption and use of their computers, e.g. in online citizen science) is to help science and scientists build knowledge and therefore act for a better world. The implicit contract of citizen science builds on the premises of collaboration with scientists – not with artificial agents programmed to make use of data provided by human volunteers. However, citizen science projects do not always communicate clearly which use they make of the inputs of the volunteers. A minimum ethical requirement of online citizen science is therefore to make the process of human–AI collaboration explicit.

Conversely, this ethical issue is also an opportunity to introduce AI to the participants of citizen science projects: through participating in hybrid intelligence activities and platforms that connect human intelligence and artificial intelligence to advance scientific knowledge, volunteers might get first-hand experience and better understanding of how AI works, and what are its requirements and limits, especially regarding the quality of structured data needed for the algorithms to be useful, the corresponding lack of relevance of AI to ambiguous problems, and the complexity of the black box and need to control it if AI is to contribute to decision-making on important social and medical matters. This opportunity to learn about AI is not widely shared; therefore citizen science can play a limited but critical role in helping citizens learn about algorithms. We could even imagine citizen science projects which would explicitly aim to help citizens learn about AI. In some projects (e.g. in Eyewire), volunteers can contribute as ML experts not only to use but also to design the project. The combination of a concrete experience of collaboration with AI, measuring its benefits and limits, and opportunities for social learning in the field of AI through citizen science projects is a promising path to spreading a democratic understanding of AI.

Lessons Learnt

The use of ML continues to grow, but scholarly reflection and discussion on the role of ML in citizen science are still in their infancy. In other words, a solid research overview on this topic is complicated by the fact that not only is citizen science research not settled science, as Ceccaroni et al. (2019) argue in their review essay, but also by the fact that 'AI is not settled science either; it inherently belongs to the frontier, not to the textbook' (p. 8).

To further explore this topic, we have therefore selected the aspects that appear most relevant to us from the recent research literature, without claiming to be exhaustive. These include, firstly, the *approach to machine learning*, which is inscribed in the various citizen science projects in different ways. Secondly, it was important to explore more closely the way in which humans and machines work together, as established through the use of ML. From a technical–scientific point of view, this is expressed by the term *human computation* based on the concept of distributed intelligence. The central question therefore is: *what is the division of labour between humans and machines?* In contrast to conventional cooperative relationships in research, however, it means that the actions of the machine remain invisible, from which special challenges are derived for citizen science that aims to increase transparency, algorithmic de-biasing, and fairness. One of these is the approach of *fair machine learning*, which we have discussed in the section on making ML more transparent as a possible solution to ML opacity. This example moreover shows that the plea for more transparency in algorithms is neither limited to citizen science nor to science as such. Algorithms today affect all areas of social life and here lies a sociopolitical challenge as to how the interplay between humans and machines will be shaped in the future.

However, the main issue that arises when citizen science is considered in the context of ML is whether the machine should actually be regarded as a cooperative partner or rather as a competitor to human research activities. Currently, it is emphasised, and this is often part of the initial call for participation in citizen science projects, that certain tasks can be performed better and more efficiently by humans than by computers. Above all, however, in projects built around monitoring issues, in which the role of the citizen is primarily that of the human sensor (Haklay 2013) or in projects based on classifier-based models (Haklay 2013; Lintott and Reed 2013), the question arises to what extent these activities cannot be completely automated sooner or later, thus rendering superfluous not only citizens but also professional scientists (Franzen 2019). If the machine learns to perform more and more tasks reliably, the question is where to look for the role of the citizen (and the human) in the future.

One possible response would be to involve citizens in scientific research for even more demanding activities, which is in line with the normative expectations of citizen science. In Haklay's typology of citizen participation, ranging from participatory sensing to collaborative science, this would mean allowing non-scientists to participate in higher levels of citizen science other than crowdsourcing, up to the generation of having their own research projects by defining research problems (Haklay 2013). Particularly in view of today's increasingly data-driven research landscape, participation in citizen science would then not only depend on the *digital literacy* of the participants (with regard to the use of smartphones and apps, such as many of the citizen science projects provide) but would also require *code literacy* in order to actually exploit ML for this type of bottom-up research in citizen science.

In the context of human computation, however, there is another reflexive component, which is named analogously as *data literacy* but is rarely discussed in the discourse on citizen science. Volunteers should at least be aware that as soon as they participate in data-driven citizen science projects, they themselves become data that might be processed further. For the purpose of increasing data quality, user performance is not only recorded automatically in the systems but is also partly used as a weighting factor in classification projects (e.g. Galaxy Zoo) or as information about the participant, in order to keep him or her on their toes, depending on the required commitment profile (cf. Lintott and Reed 2013). Since citizen science is primarily designed to advance collective knowledge, it is important to enlighten potential participants about the handling of user-generated data as it is demanded in all other areas of an increasingly datafied society (see, e.g. the 'manifesto' for the 'public understanding of big data', posted by Michael and Lupton 2015).

We should therefore remember that learning has a double meaning in this context: through the classification activities mostly carried out in large-scale citizen science projects, not only can the participants possibly learn something about science but the machine also learns something about human actions in order to imitate them first and possibly exceed them sooner or later.

Future Trends, Recommendations, and Conclusions

The processing power and sophistication of algorithms have improved at previously unimaginable levels, and some ML techniques have already outperformed or at least parallelled human capabilities. Google-owned AI specialist, DeepMind, claimed a new milestone in being able to demonstrate the usefulness of AI to help with the task of predicting 3D structures of proteins based solely on their genetic sequence. Google's new algorithm AlphaFold showed at the last biannual protein-folding olympics that it is more efficient than humans in predicting protein structure based on amino acids (Sample 2018). In Galaxy Zoo, the use of CNN to classify galaxies led to impressive results in a task previously considered performed better by humans. Despite these remarkable achievements, there are still problems that machines cannot solve alone, such as those involving creative tasks or using expertise in decision-making (Dellermann et al. 2019).

As Watson and Floridi (2018) pointed out, ‘We cannot be certain just what scientific developments the future holds in store, but we can be confident that many of our next great discoveries will be made thanks to some complex partnership of minds and machines’ (p. 760). We must not forget that we are thus dealing with the question of development of science and society as a whole, even if we discuss the question of ML here using the example of citizen science. Recourse to the normative foundations of citizen science is, then, helpful in providing concrete indications for the thrust and democratic design of a socially desirable sociotechnical development in the age of AI. Precisely because citizen scientists are volunteers who donate their time to ‘help science’, compliance with research ethics guidelines in the handling of personal data is a top priority. At the same time, however, citizen science projects might become forerunners in the drive to break down the opacity of algorithms as far as possible in favour of education and enlightenment. Whether approaches like local-interpretable-model-agnostic explanations (see Ceccaroni et al. 2019, p. 8) are already sufficient to increase model transparency should be further discussed, not only in academia but also with citizens. For developers of future citizen science projects in the context of AI, the crucial question is therefore how to involve and motivate citizens not only in the processing of data but also how to educate them and reward them for their work. With regard to volunteer monitoring projects, Ceccaroni et al. have summarised the concern as follows: ‘How do we acknowledge, respect, and reward the people whose data and expertise have helped to train the computer-vision algorithms?’ (2019, p. 2). While these dimensions correspond to the normative structure of science, the question arises to what extent the principles for dealing with data and self-learning algorithms can or should be applied to other social sectors, especially if the aims are to be used for commercial or political/regulatory goals.

This kind of reasoning is part of a sociopolitical debate that needs to be conducted on a broad scale, because, with all the promises associated with AI, an informed view of the risks must not be neglected in order to shape sociotechnical development for the common good. This addresses the scientific responsibility, not only of computer scientists and IT developers but also of other (social) scientists and citizen science researchers, when it comes to applying ML to scientific knowledge production.

The rapid progress in the development of computing capacities – see Google’s major breakthrough with its new quantum computer (Arute et al. 2019) – means that we run the risk of being unable to keep up with the reflexive consideration of its significance and impact on science and society. This brings us to our last point: the success of citizen science and ML in citizen science therefore depends on the technical and financial resources available now and in the future for this type of research.

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Chapter 11
Participation and Co-creation in Citizen Science

Enric Senabre Hidalgo, Josep Perelló, Frank Becker, Isabelle Bonhoure, Martine Legris, and Anna Cigarini

Abstract Citizen science practices have different frames to general scientific research – the adoption of participatory methods in research design has long been pursued in citizen science projects. The citizen science research design process should be inclusive, flexible, and adaptive in all its stages, from research question formulation to evidence-based collective results. Some citizen science initiatives adopt strategies that include co-creation techniques and methodologies from a wide variety of disciplines and practices. In this sense, the will to collaborate between researchers and other stakeholders is not new. It is traditionally found in public participation in science, including participatory action research (PAR) and the involvement of civil society organisations (CSOs) in research, as well as in mediatory structures, such as *science shops*. This chapter critically reviews methodologies, techniques, skills, and participation based on experiences of civic involvement and

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co-creation in research and discusses their limitations and potential improvements. Our focus is on the reflexivity approach and infrastructure needed to design citizen science projects, as well as associated key roles. Existing tools that can be used to enhance and improve citizen participation at each stage of the research process will also be explored. We conclude with a series of reflections on participatory practices.

Keywords Civil society participation · Research design · Reflexivity · Facilitation

Introduction

Citizen science projects and initiatives allow non-professional researchers to contribute to a variety of usually large-scale research processes. The collaboration process is often facilitated by information and communication technologies (ICT). However, a series of questions must be considered about the participatory design of research processes. This goes beyond a purely contributory vision of citizen science – that is, of data collection by citizens. Lessons can be drawn from a long tradition of related practices such as participatory action research (PAR) and the involvement of civil society organisations (CSOs) in research (see also Göbel et al., this volume, Chap. 17). This chapter discusses the importance of co-creation and participation in citizen science research and describes some existing projects and approaches. A range of research approaches are considered, including participatory science, open science perspectives, ethics of collaboration, as well as alternative viewpoints. The case studies exemplify the involvement of a diversity of stakeholders in the design and execution of research initiatives and shed light on key issues of communication, participatory design techniques, and facilitation principles. The chapter aims to provide a series of methodological and participatory design principles to support the development of successful co-created and participatory citizen science initiatives in the future.

Articulating Citizen Co-creation in Research

Over the past 30 years, the idea and practice of *laypersons* or representatives of civil society participating in processes of research and innovation has gained increasing significance. A milestone in this debate was Epstein's study (1996) that demonstrated how AIDS activism in the USA had an important impact on the process of research, including setting the research agenda. The influence was effective with regard to research outcomes but also disruptive in relation to the scientific research process itself, by blurring the boundary between science and the public. In this sense, a vast number of studies have been carried out with respect to the role and impact of non-academics in the field of scientific research (Rabeharisoa and Callon 2004). A similar dynamic can be observed when involving individuals in the early stages of knowledge generation, where it is akin to the idea of open innovation (West and Bogers 2017). As participation of civil society actors is seen as a key resource for

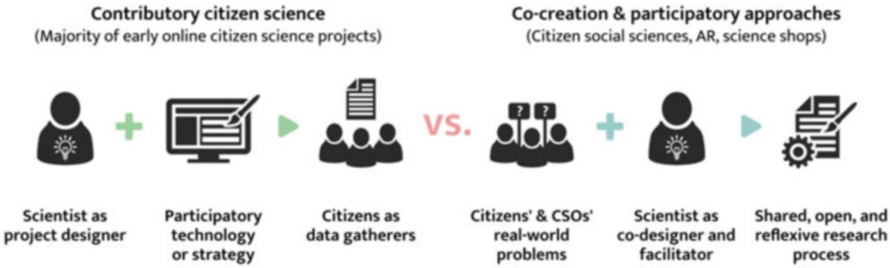

Fig. 11.1 Contributory and co-creative approaches in science: citizen social science, action research (AR), science shops, and civil society organisations (CSOs)

improving processes of research and innovation, these debates are grouped under the terms *upstream engagement* (Escobar 2014) or even *citizen science* (Irwin 2002). All these ideas represent typologies that highlight interaction between research (or researchers) and civil society actors as the core feature (Fig. 11.1).

Traditionally, literature on research design focuses on how to practically define a scientific process. Recently, this has moved on to how to implement, for example, more visual or digital methods (Rogers 2013); however, this is usually from the perspective of the principal researcher as the main decision-maker. This also applies in scientific teams, where crucial research design steps are usually informally negotiated. There is significant literature discussing collaboration between civil society as well as CSOs and the scientific community. This literature, mainly based on the analysis of case studies, challenges specific aspects of collaborations, such as the 'expert–lay divide' and the issue of *undone science* – which refers to areas of research sometimes left unfunded, incomplete, or ignored, for not being of interest to the political and economic elites but that social movements and CSOs identify as worthy of investigation.

Some authors suggest that increasing the involvement of CSOs in research corresponds with improved research results, especially with regard to embedding contexts and wider society (Hickey et al. 2018). In parallel, originating in the design sphere (Sanders and Stappers 2014), *co-creation approaches* are increasingly being extended to the political, social, cultural, and scientific spheres, in line with increasing public participation in *collective decision-making* processes. Regarding citizen science practices, for example, in the context of health-related and environmental science, fully *co-created projects* are still rare: the majority of citizen science projects rely on participation only for the collection, and sometimes the analysis, of large-scale observations, in order to overcome the capacity of current research structures (Kullenberg and Kasperowski 2016). While not all citizen science projects are intended to achieve in-depth public participation, evidence suggests that research results can be significantly shaped by the degree and quality of public participation in project design (Shirk et al. 2012). At the same time, recent studies highlight a motivational framework for volunteers that exceeds data collection, where the wider social impact and cognitive, affective, social, behavioural, and motivational dimensions are all relevant (Phillips et al. 2019).

The motivational framework also relates to *participatory action research* (PAR) and other *community-based research* practices, where a diversity of non-professional and nonacademic researchers can be fully involved in the investigation process. Participants can then collaborate with researchers in practical or pressing issues at the local level, representing the needs of different organisations and communities (Reason and Bradbury 2001). Citizens or CSOs can also take the initiative and lead the research in collaboration with the researchers, as seen in some recent citizen science projects. Here, citizens are not considered qualified research assistants but rather *coresearchers*; they are able to design and implement, jointly with scientists or in an autonomous way, valid and robust research processes (Kimura and Kinchy 2016). In order to implement these approaches, inclusive processes must be used in conjunction with the development and adaptation of robust methodologies, allowing for the social concerns of citizens and local communities to be specified and expressed (Senabre Hidalgo et al. 2018). This requires integrating these problems and challenges into the research cycle at its onset and then facilitating the participation of groups of citizens or CSOs in all phases of the research process. It also demands adequate participatory infrastructures, for example, *science shops*, as intermediaries between civil society groups (e.g. trade unions, consumer associations, non-profit organisations, social groups, environmentalists, consumers, residents' associations, etc.) and the scientific community.

Throughout the research process, a participatory and social impact-oriented research cycle needs to follow specific iterative and reflexive steps from a co-creation and participative perspective (Fig. 11.2).

The four case studies that follow reflect how co-creative and participatory processes unfold in different social contexts, local settings, and *communities of practice*.

Case Study 1: OpenSystems – Participatory Design in Citizen Social Science

An emerging practice, termed *citizen social science* (Kythreotis et al. 2019), serves as our first case study to provide insights on whether and how co-creation should be adopted in research design. Citizen social science (see also Albert et al., this volume, Chap. 7) can be understood as co-created research that builds on participatory social sciences approaches or social concerns expressed by diverse groups of citizens (Bonhoure et al. 2019).

Citizen social science is intended to facilitate participants' contribution to research. Their unique expertise comes from everyday experiences, including of their neighbourhoods, health (Cigarini et al. 2018), gender discrimination (Cigarini et al. 2020), and climate action (Vicens et al. 2018). Following a horizontal approach and a *distributed expertise model* (Nowotny 2003), participants can be considered

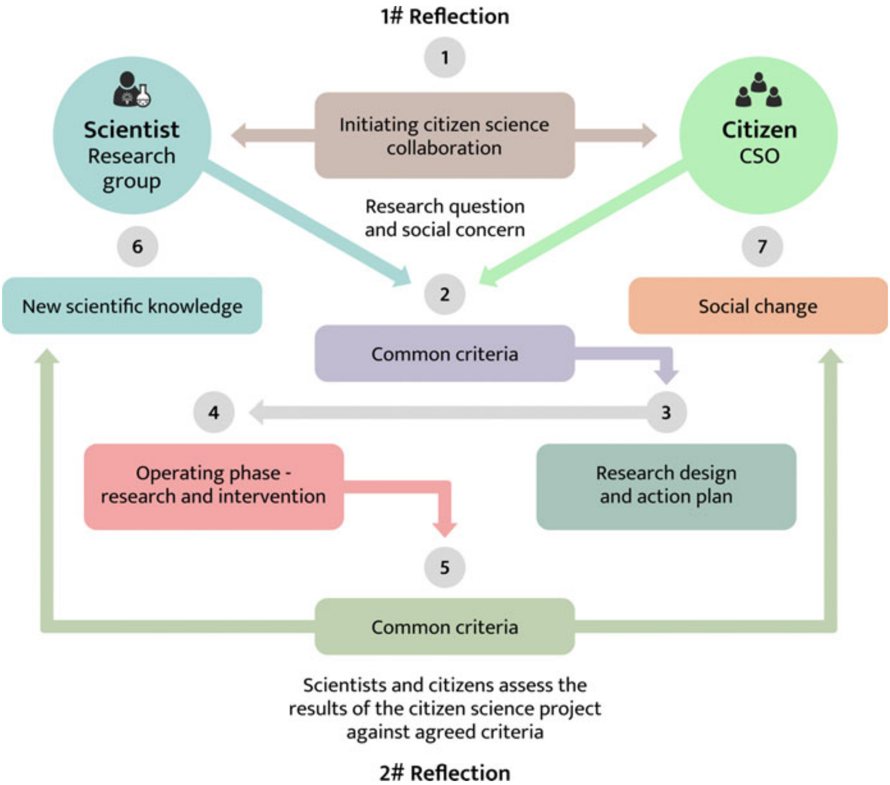

Fig. 11.2 Global view of a co-creation and reflexivity approach for the social impact of citizen science, connecting scientists with citizens and civil society organisations (CSOs)

competent in-the-field experts and therefore able to produce socially robust knowledge.

In order to enact co-creation in citizen social science, it is key to establish a process and associated tools that combine materials and instructions, in order to facilitate the participatory design of projects (Senabre Hidalgo et al. 2018). OpenSystems developed tools for knowledge generation, each associated with a reflexive research stage (see Fig. 11.3). The tools were tested and refined during six co-creative processes using a series of activities based on alternate phases of divergence and convergence, a fundamental principle of research design (Sanders and Stappers 2014).

1. The first sequence generates ideas and possibilities in a participatory way; the sequence of divergence is normally enacted through the formation of subgroups.
2. In the second sequence, the participants jointly select options; the sequence of convergence is enacted through pooling and decision-making mechanisms, as reflected in Fig. 11.3.

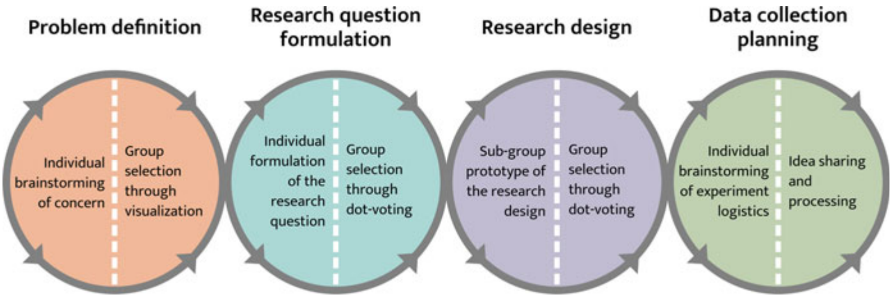

Fig. 11.3 A conceptual map of the citizen social science co-creation approach, showing phases of divergence and convergence

3. During the convergence steps, collective decision-making is achieved through *dot-voting*, or *dotmocracy*, and *thermometers of concepts*.

Accessibility was emphasised with the aim of making the tools clear and attractive to a diverse public. In particular, the visual language was kept as simple as possible, and easy-to-understand icons were used. Gamification strategies were also integrated, based on feedback from participant focus groups.

This approach to citizen social science was developed by OpenSystems from the Universitat de Barcelona in different research contexts. The first was STEM4youth, a project from the European Horizon 2020 research and innovation programme (2016–2018) to encourage young people to study science and pursue technology careers. A series of co-creation experiences were organised to design citizen science projects with 4 groups of teenagers (128 teenagers in total) attending secondary schools in Barcelona, Spain, and Athens, Greece. The same approach was used in the project Neighbourhood Water, which engaged a group of youth members from the Itaca Association in early 2019. This association, located in the Collblanc-La Torrassa district in Barcelona (one of the most population dense and diverse in Europe), is aimed at providing youth social education. Finally, this co-creative strategy was used in the framework of a Barcelona Public Libraries Network initiative to reformulate the role of librarians and public libraries in local communities. Building on the idea of libraries as *community hubs*, librarians acted as mediators for a co-created research design, with a community of library users (45 on average) acting as coresearchers. Adopting these co-creative processes resulted in a number of behavioural projects being undertaken with engaged communities of citizen scientists (Perelló et al. 2012).

Case Study 2: Kubus Science Shop at Technische Universität Berlin (TUB)

Science shops provide independent, participatory research support and carry out scientific research in a wide range of disciplines. They are often, but not always, linked to or based in universities. If university based, research is often carried by students as part of their curriculum, under the supervision of the science shop staff and other associated university members (as in the Boutique des Sciences Lille Science Shop). Science shop facilitators are experts in the field of *cultural translation* and reflexive practices. Through their local, national, and international contacts, science shops provide a unique antenna function for society's current and future demands on science.

Two of the most pressing issues of our time are the reduction of resource consumption and greenhouse gas emissions. The growing use of electronic equipment in everyday life and the waste derived from consumer goods result in significant social and environmental costs worldwide. The term *throwaway society* addresses this negligent, yet socially normalised, attitude towards resource consumption. On the other hand, cities are a focal point for social innovations, such as in the *repair* and *do-it-yourself* (DIY) movements (Frick et al. 2020), which offer a practical solution. Citizens can (re)gain the ability to handle their consumer goods competently and learn what they need to do in the event of either repair or programmed obsolescence. In this sense experts, hobbyists, and amateurs are all looking for solutions to global technological production and consumption problems. This can take place via specific online forums, or in face-to-face groups, such as *repair cafes* (Keiller and Charter 2016), FabLabs, *hackerspaces*, and *makerspaces* (Becker and Zacharias-Langhans 2014). In these social and technical contexts, it is important to generate robust knowledge about reduction in environmental impact as part of community empowerment (Scheumann and Becker 2014).

There are more than 40 such initiatives in Berlin alone. In 2015, Kubus, the Science Shop of Technische Universität Berlin (TUB), supported the founding of the Repair Café Brunnenviertel in the district of Wedding. In addition to meeting a shared need and interest in repairing electronic tools, hardware, and other types of machines, repair cafes are places where social networks can be strengthened and social capital can be developed (Keiller and Charter 2016). In this context, diverse communities emerge that can explicitly or implicitly promote a new appreciation of resources and their efficient use, quality, and longevity, encouraging sustainable consumption in the long term. Kubus initiated a collaboration between UTIL (the TUB Environmental Technology Integrated Course) and the Repair Café Brunnenviertel. They adopted a co-creative and participatory approach that sought to facilitate aspiring environmental engineers to provide life cycle assessments of CO_2 savings, focusing on repair groups of 3–5 students each summer semester. Integrating university students and citizens from the repair community, the first group showcased their research results at the Repair Café Christmas party, providing concrete insights on how to evaluate CO_2 savings. This type of research-based

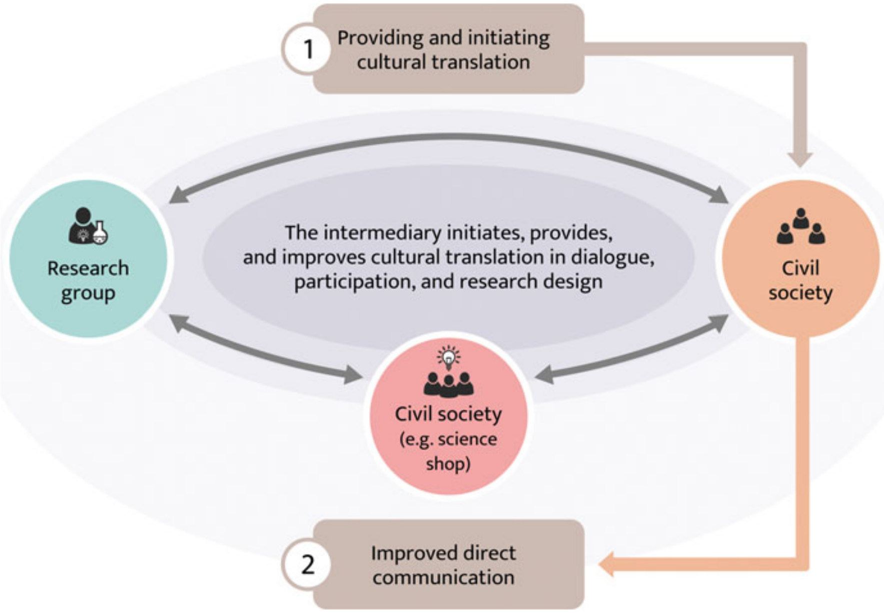

Fig. 11.4 Diagram reflecting the participatory co-creation approach utilised by Kubus and the Lille Science Shop

service learning (Becker et al. 2018), as part of a student-organised course, enables students to engage in transdisciplinary participatory research (Fig. 11.4).

With these practical experiences, Kubus allows a knowledge-based dialogue on teaching everyday skills and competences, which makes it possible to address the social responsibility of academic education on two levels: first, in the 'here and now' of pragmatic cooperation between students and civil society actors and, second, in the experiential education of aspiring engineers and scientists participating as students in these courses. Kubus sought to improve approaches to *hands-on* academic education. Their participatory approach helped students to self-organise explorative and research-oriented learning, encouraging them to present and discuss their project designs not only with their teachers but also with the repairer community.

Case Study 3: Procomuns – PAR and Co-creation of Public Policies

Procomuns, led by the Dimmons research group from the Universitat Oberta de Catalunya (Spain), focused PAR on citizen participation in policymaking in the fields of *social and solidarity economy* and the *platform economy*. Procomuns was a 3-year explorative study, between 2016 and 2019, analysing how co-creation dynamics in the social sciences can contribute to the participatory definition of public policies and agendas in a local context. Project participants (more than 400 people from diverse backgrounds and perspectives) were involved in a co-creative policymaking process that resulted in 87 policy measures. The central topic of research was the platform economy (also called the *sharing economy* or the *collaborative economy*). This refers to the collaborative consumption and production of capital and labour among distributed groups supported by a digital platform. Examples range from shared vehicles to food delivery to home sharing. Several questions were raised about which public policies to adopt, and how policymaking with a citizen science approach can adapt to, take advantage of, and respond to the platform economy, its effects, and potential.

In this regard, the goal of Procomuns was threefold: first, to develop a state of the art on the topic of platform economy, which is an emerging issue in the academic literature on policymaking; second, to generate new knowledge interchange dynamics with reference to Barcelona regarding socio-economic challenges; and, third, to develop co-created policy recommendations based on PAR approaches that could have a positive impact on the city from different perspectives (sustainability, work rights, data ownership, etc.). For this, a series of mechanisms and channels of co-creation were established based on diverse approaches, such as the *digital commons* (Senabre Hidalgo and Fuster Morell 2019), *open design* (Boisseau et al. 2018), and a temporary *policy design lab*.

In the first participatory design phase, a strategic analysis was carried out among a small group of 12 representatives (from civil society, digital entrepreneurship, politics, and academia) from the platform economy and social and solidarity economy. The aim was to evaluate the strengths, weaknesses, opportunities, and threats of the platform economy in the Barcelona context, following SWOT analysis methodology (Martin and Hanington 2012). In the second phase, members of the initial work group and additional participants drafted an online document with possible approaches for new policies. This collaborative text collected draft proposals and specific policy measures to guide the platform economy promotion activities of Barcelona City Council. In the third phase, a face-to-face co-creative session adopted a *theory of change* model (Martin and Hanington 2012), in order to generate concrete proposals for long-term change, and the steps needed to achieve them. A key priority in this phase of participatory generation of policies was to establish a thematic clustering of proposals with a card sorting technique, used in the fields of *knowledge management* and *user experience design*.

In the fourth phase, the project expanded the collaboration process by holding a celebratory Procomuns community event on the platform economy. It was conceived as a co-creation meeting beyond the conference format, including local associations, relevant city actors, international experts, political leaders, and citizens. Collaborative working sessions covered themes, including general regulatory measures, technological developments, tourism, mobility, housing, social inclusion, health and care, and job conditions.

In the final phase, the list of public policy proposals was uploaded, discussed, and voted on online, coinciding with the broader public consultation process to define Barcelona's Municipal Action Plan (PAM) via the Decidim online platform (Aragon et al. 2017). This gave additional visibility to Procomuns outputs via social networks and importantly provided refinement and social filtering of co-creative results, generating additional public engagement.

Case Study 4: The Duchenne Project – When a CSO Leads the Research Process

An example of CSOs and community-based forms of collaboration is a technology development project that focused on orthoses, more specifically on the correction of limb disorders to support the movement of the upper limbs of children with Duchenne. Duchenne is a type of muscular dystrophy which only affects boys and significantly reduces life expectancy.

The project was driven by the French National Association of Parents of Duchenne Sufferers. The CSO collected funds to set up a foundation to prepare proposals to undertake research that would help patients to regain some movement of their upper limbs. Upon successful creation of the foundation, the CSO managed to attract further co-funding from other related CSO. It then managed to work with relevant scientists to produce a proposal for a national funding call. The CSO was the driving force behind the project, assembling the key actors, notably a leading scientist who served as the guarantor of the scientific quality of the project. The social interaction within the project went far beyond this, however, enabling formal interactions at the project review stage and, arguably more importantly, frequent informal interactions in the form of meetings, telephone conversations, and so on.

The project design was clearly aligned with the aim of producing practical outcomes in the form of technologies that could be used by patients. This vision of the project as highly practice oriented was clearly communicated to all partners. This was accepted and reflected by everybody interviewed for the case study. The choice of participants was driven by this practice-oriented ethos, as well as agreed with the researchers. The CSO not only initiated the project but had a pervasive influence on its development and culture.

As an indicator of the CSO's impact in terms of knowledge production, it is important to underline that the research agenda was identified and informed by the CSO's local knowledge. There is an enormous amount of research that has been undertaken to alleviate the suffering of Duchenne patients. The vast majority of this research focuses on the medical condition itself and aims to develop drugs that extend the lifespan and improve the quality of life of patients. The CSO, as an association intimately involved in the day-to-day lives of patients, identified the fact that for the Duchenne sufferers themselves, the loss of movement of their arms can be perceived as worse than their reduced life expectancy.

One notable aspect of this project was the CSO's prior engagement in research and its experience of being able to influence research that was better targeted to the interests of Duchenne patients. The CSO had been involved in pharmaceutical research for Duchenne patients which, at the time of the project's launch, had resulted in a clinical study that had attracted several hundred million euros in research funding. This success arguably provided the CSO with the confidence to engage in the next step and drive through a research agenda collaboratively defined for the benefit of the patients.

The main advantage of a participatory approach was that the process of doing research together not only produced a co-created result that was widely shared and implemented. It improved the living conditions of patients and created new knowledge for medical support.

Core Principles and Practices

While the four case studies differ in their conceptual frameworks, areas of application, and disciplinary fields, there are several common aspects that point to key characteristics that are important to consider when planning, facilitating, and accompanying participatory citizen science projects.

Co-define and Address Real-World Problems

A key consideration in all citizen science and participatory research projects that aspire to integrate citizens and other representatives of civil society into their development is the importance of addressing real-world problems and issues (Phillips et al. 2019). It is also necessary to establish mechanisms for co-defining these problems and issues from the outset (Senabre Hidalgo et al. 2018). This can be through the generation, review, and discussion of specific research questions (e.g. STEM4youth and its participatory design approach) or through using PAR principles to undertake a cultural translation process (e.g. science shops, involving students and *makers* in sustainability issues). Iterative validation mechanisms for the results of each phase (e.g. Procomuns generating and voting on public policy proposals) and how the research agenda itself can be identified and promoted by the local knowledge of a CSO (e.g. the Duchenne dystrophy study) are also key strategies.

The methodological approach should focus on addressing real-world problems which, regardless of its potential academic impact (on journal papers, scientific conferences, etc.), are broadly shared by the participants. This approach is not yet widely used in citizen science projects, but it is clearly reflected in our four case studies that address social issues. In the science shops and citizen social science examples, their approaches have in common the idea that research and action must be done *with* people and not *on* or *for* people. They aim to solve concerns and problems via a *hands-on* approach, combining scientific knowledge, and in different societal spheres (the economy, environment, science, culture, etc.). Many citizen science projects are designed to address scientific questions or align to specific educational objectives. Co-created citizen science projects that address real-world problems have great potential to impact public understanding (Pandya 2012).

Another key consideration regarding the early stages of participatory problem identification is how co-creation and participatory research can often point to 'wicked', 'systemic', or 'multifaceted' problems. In this sense, every involved actor (from a wide spectrum of 'amateur' to 'professional' scientists) carries with them their own creative potential and prejudices. Each actor represents a valid expert but also a layperson in relation to the wider field of knowledge. Rather than avoiding the conceptual and theoretical complexities resulting from diversity, co-creation techniques enable a common arena where everyone contributes based on their own expertise. This facilitates the use of a variety of perspectives on real-world problems. Even if only a limited number of real-world problems can be addressed during a citizen science research process, the mere formulation and collection of additional ones can always inform further research and additional action-oriented interventions.

Shared Language and Visual Thinking

When integrating the collaboration of researchers from other disciplines, especially nonacademic participants and communities of interest, it is important to start with facilitation strategies that integrate simple and affordable ways to communicate concepts which are often complex or specific to the scientific world (Richter et al. 2019). A progressive approach and familiarisation between participants based on a shared language, rather than conceptual theories or sophisticated academic discourses, can help to discuss the problems, methods, and solutions to be addressed from a citizen perspective (Mattor et al. 2014). Reflexivity and visual and systems thinking contribute to a methodological starting point that helps channel the perspectives of multiple stakeholders, in order to establish the alignment of interests and participation roles in open science (Ravetz and Ravetz 2017). This approach usually employs diagrams, icons, storytelling, and other techniques derived from participatory design (Sanders and Stappers 2014).

Among the possible methodologies, co-creation techniques and materials are a good starting point (Senabre Hidalgo et al. 2018), where some authors highlight the value of participatory design and its potential to 'allow more transparent, accountable, and democratic modes of knowledge production, learning and governance' (Qaurooni et al. 2016, p. 1825). This requires a visual design approach to address wicked problems (climate change, poverty, pollution, etc.), using diagrams, canvases, and gamification techniques to channel citizens' social concerns and needs into the research process. While acknowledging the power imbalances and continuous negotiations inherent in any collaborative setting, visual materials and facilitation mechanisms in co-created research designs can provide opportunities for people lacking a voice to use science to reveal otherwise hidden or contentious societal problems (like in the case of the Barcelona Public Libraries Network).

The science shop experience also highlights the importance of this aspect, especially the need to invest time to enable the recognition of explicit values and interests of partners that emerge during the initial phases of a project. It is necessary, while translating the problem into a research question, to leave as much information as possible in a shared physical space (permanent or temporary) and capture results of discussions, even on flipcharts, printed posters, or sticky notes. This can visually represent the flow of the project during the research process (Senabre Hidalgo and Fuster Morell 2019), as interests can diverge. A key consideration is that a diversity of actors must find a way to translate their different values and perspectives into a common research goal (e.g. librarians and users of libraries; municipality policymakers and CSOs; and education settings with professional researchers). If the same research questions and their accessible translation in a shared or visual language uses physical artefacts (or online collaboration tools), participants can have continued discussions and iterations regarding new questions, even when they share the same preliminary outputs.

Building the Research Community: Frameworks, Ethics, and Collaborative Decision-Making

These participatory methodologies should consider the importance of discussion and decision-making mechanisms, in order to enable the research process to achieve cooperative governance. For instance, are all partners equal? How do researchers change their usual routines to integrate other stakeholders' agendas and habits? Furthermore, how can the research team be reflexive? Is it useful to be able to take a step back and evaluate how each other's expectations are reached? This usually implies trust; otherwise it can be difficult to tackle problems and issues. Talking about implicit expectations leads to questioning one's values and ethics. Writing down common rules about governance and knowledge sharing can be a first step. Collective decision-making processes usually face the question of how do I understand my counterpart? This is fundamental in all the case studies presented. Participation issues can emerge because participants (laypersons, as well as academics) believe they already know how problem-solving works and how a given problem 'has to be solved'. Therefore, the challenge in these approaches is to allow mechanisms for each actor to understand their interlocutor and for the project's early development to actively create the space for a decision-making process (where some uncertainty can help to challenge the respective levels of individual routines and self-assurance).

In the experiences reflected here, and the further studies and literature we refer to, several simple coordination mechanisms can be adopted to draw out conflict and agreement – from simple brainstorming techniques, such as using sticky notes to summarise early concerns, to varied research methods or tools (which can be voted on with coloured dots or other mechanisms), to ad hoc agreements in small groups between researchers and citizens when doing collective data interpretation of preliminary outputs. This was demonstrated in the Neighbourhood Water and Duchene projects. Small groups can help to establish a common vision among coresearchers on what to do with the project results (publication, actions, productions, media releases, etc.). In the Neighbourhood Water project, for example, it was decided to produce a poster for a window in a crowded street of the neighbourhood public library. And in the Duchene project, patients gained improved quality of life. In another citizen science case study on mental health, a dissemination-oriented report was produced and shared widely to reinforce the importance of caregivers in mental healthcare provision.

The Role of Mediation and Participatory Meetings

When activating participatory processes in research, another key factor is including a diversity of voices and perspectives. As pointed out by the literature on co-creative PAR and CSO-related approaches to research activity, it is essential that someone is responsible for carrying out a well-planned, independent, and neutral facilitation during group sessions. Whether or not they have a complete understanding of the research topic or questions, a facilitator can create the necessary conditions for equitable and free speaking. They can also support collective decision-making mechanisms during intense participant meetings, ideally in face-to-face interactions.

A facilitator is in charge of suggesting the materials and dynamics in advance and discussing it with participants. They need to have a script for the co-creative sequence that is going to take place. During each session, a facilitator explains what is going to be done, clarifies doubts, and controls the time needed for each co-creation phase. The facilitation role can also be a turning role, or even be delegated to a small number of people who are outside the research group. This role needs to be flexible, considering how the group moves forwards in the different research phases by facilitating agreement and adapting development strategies. Facilitation, understood as one of the main activities of intermediation (e.g. in science shops), requires intensity and effort, agility and reflexivity, as well as some moderation experience and personal empathy. For these reasons, if the role is performed by two facilitators or even a small group, it can improve the efficiency and quality of the outcomes.

This also relates to the importance of space and infrastructure for face-to-face collaboration. This is reflected in the science shop practices, the temporary policy design lab concept from Procomuns events, the community hubs in the citizen social science libraries, and how the CSO leading the Duchene project operated outside of the usual medical settings. The way rooms are furnished, or what kind of spaces are available as meeting points (sometimes having a symbolic value), can ease or hinder the practice of facilitation. For instance, meeting in the town hall might prevent some participants from attending (depending on citizens' sociocultural backgrounds or political orientations, etc.). Participatory design thinking usually includes a view on the meeting rooms and materials to be provided in order to align with the meeting's objectives and participants. In contrast to the restricted conditions of laboratories in universities and research institutes, considering infrastructure and facilitation can become crucial to achieving flexibility and transparency when orienting research in a participatory and inclusive way.

Participation Tools and Channels

A series of common considerations on the tools and channels used for wider and more efficient participation are closely related to the focus on real-world problem-solving, a shared visual language, decision-taking mechanisms, and the importance of facilitation and physical infrastructure for face-to-face interactions. Similar to the approach described in the Procomuns and citizen social science case studies (integrating the participation of different stakeholders through a long iterative process), co-creative participatory research also requires adequate communication and interaction channels, from project coordination to progressive validation of results (Sanders and Stappers 2014). When defining an incremental process of idea generation, discussion, and selection of proposals in a participatory manner, the approaches described here provide valuable elements to consider. One of them is the importance of combining physical or *analogic* materials (visual canvases, collage diagrams, posters about results, etc.) with online mechanisms and tools, such as in collaborative writing applications and democratic participation platforms (Aragon et al. 2017).

This combination should facilitate the sequencing process from robust proposals, generated in face-to-face participatory design dynamics, to the online integration of diversity with as many points of view as possible. When systematising results, the mechanisms for guiding analyses should be open, reliable, and verifiable. The three main components of *participatory science* (Kimura and Kinchy 2016) are (1) production of knowledge from empirical data, (2) commitment to an objective of decision-making for the action, and (3) cooperation with civil society actors stemming and other stakeholders. These point to the constant need to consider, adopt, and adapt new tools and research design channels that allow collective decision-making and shared access to outputs. The emergence and 'natural selection' of ICT for communication and collaboration represents an opportunity to select the appropriate ones for project facilitation. However, different criteria should be considered with regard to ICT and digital channels, such as ease of use and acceptance levels of tools (especially if participants have low levels of *digital literacy*). To what extent tools serve the intended aim of accessibility and openness should also be evaluated.

Projects can provide ICT training and also produce online and physical *boundary objects*, such as toolkits, guidelines, manuals, etc. (Star and Griesemer 1989), to make co-creation strategies and interactions more effective and scalable. The objectives of a given co-creative approach and the roles of the involved actors should be viewed as co-shaped with other actors and institutions over time. For example, the

3-day training sessions with librarians as citizen science facilitators were proposed during the project for the participants in order to discuss and learn how to work collectively. This proved to be complex, as it threatened librarians' social status and professional identity. This type of training on co-creative methods and tools can also provide opportunities to review research designs and to develop new research avenues.

Discussion

Co-creative processes and experiences in PAR, CSOs, citizen social science, and science shops need to be considered to enhance active, inclusive, and wide participation in citizen science projects. The concerns of citizens, as coresearchers, should be placed at the centre of the research cycle, as argued in this chapter. This way coresearchers can engage in all stages of the research cycle. However, when articulating co-creation methodologies in citizen science projects, a number of challenges emerge.

A focus on real-world problems requires balancing social and scientific interests and impacts. Research design and question formulation need to be guided by the different levels of knowledge and techniques of negotiation among the participants. This was evident in the negotiations of the CSO and researchers for the benefits of patients in the Duchenne case study and in the Procomuns process for generating public policy recommendations via a bottom-up approach. In the context of citizen science, collective data interpretation and evidence-based analysis of social change impacts are less common and studied in comparison to the initial stages of research (Shirk et al. 2012). In our opinion, this reflects the need to explore and analyse more case studies, especially successful examples reflected in both robust academic references and practices from participatory research studies in the social sciences (Heiss and Matthes 2017). Also reflecting the value of wider participatory approaches in citizen science is the fact that, due to the increased complexity of real-world problems and societal challenges, no meaningful solutions can be achieved without inclusive co-creation approaches and reflexive decision-making processes. It is also important to consider that sometimes citizen science approaches can be abused or misused by drawing citizens into projects with hidden agendas.

Another important challenge identified is the need to further develop and adopt facilitation roles, especially in an independent manner. Ethics and reflexivity can combine *peer-to-peer* and internal evaluation criteria to build up a collaborative governance of projects (Böschen et al. 2020). Accessible visualisation tools can provide a better understanding of participatory research processes and outputs in terms of scientific data, as well as open online platforms for public deliberation on the interpretation of scientific results. Reaching consensus from citizens and CSOs regarding derived actions and policies can also benefit from such designs (Aragon et al. 2017). Digital tools can bring additional layers and complexities to the face-to-face co-creation process when supporting future citizen science practices. In our opinion they represent another key factor to improve and 'close the loop' of co-creative work on real-world problems in relation to the type of practices described here.

In considering how co-creation and participation can articulate the basis for new citizen projects, the role of the facilitator is key. However, this requires a specific type of personal attitude, background, and know-how which cannot be easily defined and taught. From our perspective, based, for example, on the experience of science shops, facilitation usually requires more than *communicative and dialogical* translation work, since the knowledge and expertise from such intermediaries can influence in many ways the effectiveness of a participatory approach. For this, one possible way to consider the necessary training and scale of facilitation roles for citizen science is to combine practical and theory-based knowledge for specific types of *research facilitators*. This means activating and improving facilitation by learning first-hand about specific *how-to guides* like the ones mentioned here (such as design thinking, collaborative project management, and other *learn by doing* approaches), in combination with existing methodologies and practices from the social sciences (especially in relation to social movements, organisational learning, and PAR). This way, intermediaries and facilitators can pinpoint methodological mistakes, misunderstandings, and even abuse.

Finally, some of the key principles and values regarding shared decision-making, governance, and openness, reflected here, point to how the articulation of communication and open research outcomes can provide the basis for the necessary levels of trust among all the involved actors. In this regard, the key elements of collaborative work and regular communication with participants, articulating comprehensible timeframes and rules for participation, as well as digital channels to discuss issues around policies at any given moment, can be seen as a starting point for even more ambitious ways of doing science in the future.

Further Reading

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Chapter 12
Citizen Science, Health, and Environmental Justice

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Abstract This chapter considers the interface of citizen science, health, and environmental justice. We review citizen science research undertaken by civic educators, scientists, and communities that aims to broaden scientific knowledge and encourage democratic engagement and, more specifically, to address complex problems related to public health and the environment. We provide a review of the current state of existing citizen science projects and examine how citizen science, health, and environmental justice impact each other, both positively and negatively. Specific challenges that relate to these projects are discussed, especially those that are not obvious or applicable to more traditional citizen science projects.

Keywords Review · Controversies · Social responsibility

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Introduction

This chapter considers work undertaken by civic educators and scientists together with citizen communities to advance health and medical research, to foster scientific literacy, and to encourage democratic engagement. This allows society to deal scientifically with complex modern problems related to human health and environmental justice.

Citizen science has been defined in previous chapters and elsewhere as *voluntary engagement in science* (Ceccaroni et al. 2017; Robinson et al. 2018; Haklay et al., this volume, Chap. 2) and has been primarily undertaken in the environmental domain. As citizen science is a relatively young field, it is necessary to define *health-related citizen science* and *environmental justice* in order to understand the relationships between the three concepts.

Few research domains are as meaningful to the public as *human health*, which should, therefore, be well-positioned for citizen engagement. Health research encompasses a vast range of potential inquiry, much of which is becoming newly accessible, thanks to technology, especially mobile technology. From air-quality testing to DNA sequencing, the opportunities for citizen contribution have grown exponentially (Wiggins and Wilbanks 2019).

Controversies at the Interface of Citizen Science and Health

Initiatives investigating human health (physical or mental) can be challenging to assess via employing citizen science approaches and employing the ten principles of citizen science (Robinson et al. 2018). Defining projects as citizen science can also be controversial; below we highlight some of the contributory factors – from most controversial to least controversial (Haklay et al. 2020).

- *The level of active engagement*. If engagement or participation is passive, for example, consisting of citizens either as patients or wearing digital sensors, projects tend not to be classified as citizen science.
- *The purpose of knowledge production*. If the goal is mainly commercial (e.g. the development of a drug), projects tend not to be classified as citizen science. Of course, the purpose of knowledge production should never be solely commercial but also related to health improvement.
- *The level of expertise required to participate*. If projects mainly target experts, they tend not to be classified as citizen science.
- *Data sharing*. If data are collected by a commercial enterprise or not shared, projects tend not to be classified as citizen science. While in other domains sharing personal data is sometimes problematic, in the health domain, it is often a prerequisite to participation.
- *The organisational context*. The same activity (such as a trial of a treatment) can be undertaken by a public hospital, a public university, or a commercial actor and

assessed by citizens as citizen science if it is conducted by a public organisation, but not if undertaken by a commercial organisation. This assessment is often not justified because attitudes and aims of public and commercial organisations are not necessarily different in practice. As an example, the following is an extract taken from a 2020 public university trial of the ChAdOx1 nCoV-19 vaccine: 'The results of this research study may be presented at scientific meetings or conferences and published in a scientific medical journal. If you contact the researchers in the future, you can obtain a copy of the results. You will not be identified in any report or publication. The de-identified data from this study will be shared with the collaborating partners who are organising and funding this research work. *Data from this study may be used to file patents, licence vaccines in the future or make profits in other ways* [emphasis added]. You will not be paid for any part of this' (University of Oxford 2019).

- *Involvement of commercial activities in industry and academia*. Project ethics can be influenced by whether a non-profit or a commercial entity controls the project. While a level of scepticism exists towards business involvement in citizen science, some observe that the sector has made positive and impactful contributions towards advancing the tools and application of citizen science as well as in providing volunteers through campaigns that engage their employees. Finally, organisations from any sector can undertake citizen science projects that do not follow the *ECSA 10 Principles of Citizen Science* (Robinson et al. 2018).

Environmental Justice

Environmental justice can refer to both the *natural environment* and the *social environment*, with the latter covering aspects of social, economic, and political justice, as well as racism and classism. In this chapter, we analyse both kinds of environment. In relation to the natural environment, environmental justice refers to how ecological degradation (including pollution), landscape destruction, and massive biodiversity loss have the most significant impacts on people on low incomes. An example is when people on low incomes can only afford to live in areas with high levels of ecological degradation or pollution, such as where landfills are located. *Environmental injustice* can take many forms: at a basic level, it includes an unequal burden of environmental hazards (such as landfills, incinerators, polluted sites, industrial livestock production) and unequal access to environmental amenities (such as parks) across geographies, communities, and populations. Environmental injustice most strongly impacts communities of colour (Abara et al. 2012; Wilson 2009).

Environmental justice is not confined to the geographic and demographic distribution of hazards and amenities. It also includes critical political and social processes by which communities can either control their environmental fate or be deprived of control (Holifield 2001).

In this chapter, we consider the fields of citizen science and health (including *public health* and *population health*) with particular reference to the effects on environmental justice. Related work can be driven either by communities or by entities such as universities, public bodies, and commercial organisations. To this end, the chapter begins by considering the relationships and interplay between the fields of citizen science, health, and environmental justice and how they can influence each other both positively and negatively. A review of the current state of play regarding related citizen science projects is then presented, described through a typology that considers tasks, research focuses, and participatory models. The chapter concludes by acknowledging some of the challenges faced by projects that bring together these three disciplines and reflecting on their relevance, trends, and future opportunities.

The Relationships, History, and Development of Citizen Science, Health, and Environmental Justice

The links between citizen science, health, and environmental justice are complex. We illustrate these relationships in Fig. 12.1, before providing examples from the literature to substantiate the claims the links represent. We aim to facilitate a better understanding of the role of citizen science, the different ways it enacts this role, and the repercussions for health and environmental justice.

The central 'ring' shown in Fig. 12.1, which represents the environmental justice and citizen science concepts and their influences, can be described as a feedback loop, which can be either positive or negative.

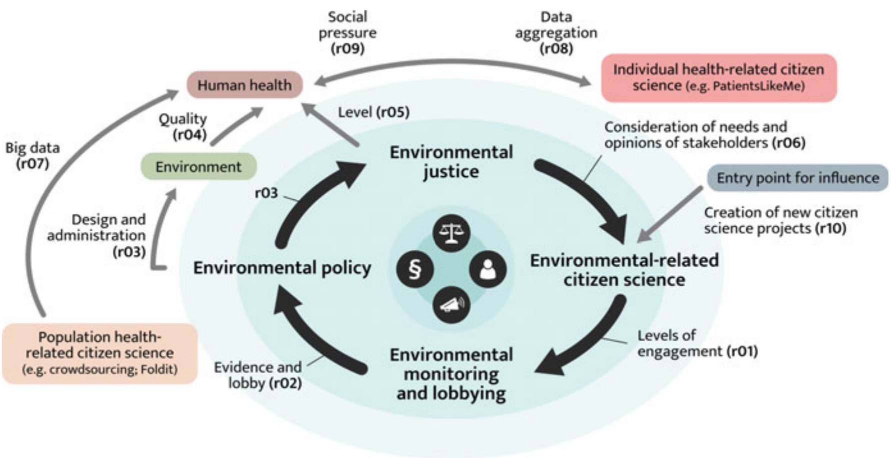

Fig. 12.1 Interactions between citizen science, health, and environmental justice. Relations (rXX) are defined in the text

In a *positive feedback* scenario, higher levels of engagement in environment-related citizen science activities (**r01**) can lead to increased monitoring of, and lobbying for, environmental issues (Nascimento et al. 2018). The resulting evidence and lobby (**r02**) can lead to new, positive, and measurable environmental policies. Well-designed and well-administered environmental policies can have a positive impact (**r03**) on both the environment itself and environmental justice (Bullard and Johnson 2000). For example, through the fair treatment of all people with respect to the development, implementation, and enforcement of these policies, both a better environment (**r04**) and an increase in environmental justice (**r05**) can have a positive impact on human health (Taylor et al. 2006). Environmental justice, by considering the needs and opinions of a diverse range of stakeholders (**r06**), can further increase engagement and improve the outcomes of environment-related citizen science activities (Shirk et al. 2012). Health can be positively influenced (**r07**) by citizen science initiatives focusing on population health (Candido dos Reis et al. 2015). Health can also exert its influence on (**r08**) as well as be influenced by (**r09**) individual health-related citizen science projects, such as PatientsLikeMe, the world's largest personalised health network that helps people find new treatments, connect with others, and take action to improve their outcomes (Wicks et al. 2010). By making society 'fairer' (**r06**) and by creating new citizen science projects related to environmental issues (**r10**), it is possible to increase environmental citizen science engagement. This can, directly and indirectly, improve the environment, environmental justice, and human health.

A *negative feedback* scenario can also be observed. The absence or reduction of environmental justice can lead to reduced levels of engagement in environment-related citizen science (**r06**). Lower levels of participation in environment-related citizen science (**r01**) can lead to decreased monitoring of, and lobbying for, environmental issues by those directly affected by them (**r02**). This can result in environmental policies that are poorly designed, poorly administered, and inadequate for addressing the needs of the community (**r03**). Inadequate environmental policies can harm both the environment itself and environmental justice (**r03**). Both a compromised environment (**r04**) and an absence of environmental justice (**r05**) can harm human health (Pearce et al. 2010) and, further, can decrease engagement in environment-related citizen science (**r06**). They can also increase engagement, as citizens might be motivated to change the situation. Potentially, then, making society less 'fair' not only impairs citizen participation and empowerment but directly and indirectly degrades the environment and human health.

The 'Entry point for influence' shown in Fig. 12.1 represents the impact that citizen science can have within these feedback loops. Citizen science can contribute to these relationships in a positive manner. This can be achieved through increased and improved citizen empowerment, data accessibility, public transparency, research relevance, and knowledge production (English et al. 2018).

However, this positive influence is not a given, with issues including lack of engagement, data accuracy, and potential bias constituting barriers that can have a negative impact (Kosmala et al. 2016). Taking a broader definition of environmental justice into account, which includes political and social processes, also reveals potential issues. Questions exist regarding who owns the data (Kish and Topol 2015) and the credentials and motives of who is coordinating the effort (Boulos et al. 2014). These raise issues around misuse of trust and selective inclusion that can be barriers to environmental justice.

The Relationships Between Citizen Science and Health

Figure 12.1 shows how health can be positively influenced (**r07**) by citizen science initiatives focusing on population health and can affect (**r08**) – and be influenced by (**r09**) – individual health-related citizen science projects, such as PatientsLikeMe and War on Cancer. For example, the War on Cancer project, through an app launched in 2016, offers a safe space where anyone affected by cancer can share stories. Importantly, by collecting this narrative evidence, it can accelerate the search for a cure. The industry has difficulty in obtaining self-reported data on how patients are coping and feeling and how they are responding to treatment. However, most patients are willing to share these data if they understand the purpose. War on Cancer makes money by building tools that allow patients to share their data with researchers and pharmaceutical companies and, crucially, keep the patients informed about the results of that research. There are many patient communities whose activities resemble citizen science or are a form of citizen science. For example, work by the Precision Medicine Initiative (Collins and Varmus 2015) is targeting patient engagement in research and using the 'citizen science' label for large-scale research.

The Relationships Between Citizen Science and Environmental Justice

It is difficult to disconnect environmental justice-related citizen science projects from health. Even if health is not considered to be a central aim of such projects, any engagement in citizen science (be it for the natural or social environment) can be linked to improvements in mental health, through a feeling of purpose and belonging as well as self-actualisation and empowerment (O'Brien et al. 2010). The natural environment itself can have positive effects both mentally and physically when it is the setting for citizen science projects. This connection between environmental justice and health is represented in Fig. 12.1, whereby the central environmental ring and external health concepts are distinct but inextricably linked.

The Current Landscape

Health-related citizen science projects that address environmental justice are the primary focus of this chapter. Several models exist that reflect the relationship between citizen science, community-engaged research, and research in environmental and public health (Wiggins and Wilbanks 2019). Related activities can be classified depending on the *task type* (data collection or data processing), *research focus* (observational research or interventional research), and *participation models* (including N-of-1 and N-of-we, as defined later in this chapter). We present examples from the literature of how citizen science projects investigating health also relate to environmental justice, using the classification system described by Wiggins and Wilbanks (2019).

Task Type

Though Wiggins and Wilbanks (2019) admit that having just two categories of task type – *data collection* and *data processing* – somewhat oversimplifies the range of activities that citizen scientists may engage in, this classification is sufficient within the scope of this chapter.

Data collection citizen science projects include observational studies of personal health data, the human microbiome,[1] and pollution. Pollution includes sensory pollution which causes adverse sensory effects in humans by stimulating the senses.

Sensory pollution can be used as a proxy of environmental contamination (Wargocki 2004) and integrated into environmental justice programmes by using environmental sensors. An example is the A Day in the Life programme – a collaboration between the University of Southern California Community Engagement Program on Health and the Environment (USC CEPHE) and three environmental justice organisations – which focuses levels of personal exposure to air pollution and youth engagement. Across California, people of colour are more likely to live near facilities that emit *fine particulate matter* (particles <2.5 μ in diameter, $PM_{2.5}$), a pollutant which increases the risk of cardiovascular disease, respiratory disease, and neurological disorders. Johnston et al. (2019) note that, by providing youth participants with portable personal $PM_{2.5}$ monitors, citizen science can 'build upon principles of community-driven participatory research, which seeks to deconstruct traditional power dynamics, provide information about environmental hazards important to residents, and democratise knowledge'. This democratisation of knowledge exemplifies how citizen scientists collecting health-related pollution data can address environmental injustice.

[1]The human microbiome is the aggregate of all microbiota that reside on or within human tissues and biofluids, along with the corresponding anatomical sites in which they reside.

Technology can act both as a facilitator and as a barrier to environmental justice in health-based citizen science. In the above instance, the development of a low-cost, low-tech sensor facilitated the creation of an inclusive citizen science project.

Online *data processing citizen science* projects have often relied on gamification approaches to make repetitive tasks more enjoyable, therefore motivating and sustaining participation (Eveleigh et al. 2013). Mechanisms such as league tables, badges, and scoring systems have been used to sustain the engagement of some volunteers; however, others can be alienated by the competitive aspects (Iacovides et al. 2013). As discussed by Newman et al. (2012), while such games and new technologies can appeal to some participants, dependence on them can inadvertently widen the *digital divide* between participants willing and able to adopt the technology and those unwilling or unable to do so.

Data processing and analysis formed the core research activity of the Southern California Environmental Justice Collaborative (SCEJC), an initiative between Communities for a Better Environment, Liberty Hill Foundation, and a multidisciplinary academic research team established to promote environmental health and social justice issues. The SCEJC had two main goals: firstly, to improve environmental health in low-income communities of colour, by conducting citizen science research on air quality, and, secondly, to build the capacity of community-based environmental justice advocacy through training opportunities. The SCEJC applied a citizen science approach to conduct research using *secondary data sources*. This avoided the potential for (misguided) criticism from the scientific community regarding primary data collection quality conducted by citizen scientists. By analysing the data gathered by the government, the SCEJC determined where patterns of environmental injustice existed and which communities suffered potential health impacts as a result. As a result, they were able to demonstrate the effects of cancer-causing air pollutants on communities of colour and to campaign to tighten the standards (Petersen et al. 2006).

Research Focus

Health-focused citizen science research can be *observational* or *interventional*, while both research types can positively address the issue of environmental justice.

Observational studies, in which citizen scientists observe a situation or organism and collect data about it, form the basis for most established citizen science projects. In one observational study, *Tools for Community-based Health Monitoring and Health Impact Assessment – Exploring 'Citizen Science' Approaches* (Den Broeder et al. 2017), the perceived impacts of participation in a public health citizen science project on the citizen scientists themselves – in a disadvantaged neighbourhood in the Netherlands – were investigated in order to address environmental injustice. Citizen scientists characterised by low income and educational level were trained to interview fellow residents about health-enhancing and health-damaging neighbourhood features. Observations showed that citizen scientists perceived participation in the project as a positive experience, resulting in acquisition of a broader understanding of health and its determinants and knowledge about healthy lifestyles.

Interventional studies, in which an intervention is made during the study, can take the form of citizen science in health and biomedical sciences but are rare in citizen science approaches in other domains. One interventional study (Linking Breast Cancer Advocacy and Environmental Justice) had both political and educational aims. At the *political level*, the study aimed to inform local decisions regarding a nearby oil refinery, state policies regarding chemicals, and political decisions regarding *endocrine-disrupting compounds* (EDCs)[2] in consumer products. At the *educational level*, the project aimed to inform community members about the determinants of their indoor and outdoor air quality, strategies to reduce their exposure to pollutants, and the potential implications of contaminants on community health. The study resulted in increased environmental health education, which subsequently stimulated further public involvement and changes in community behaviour. Moreover, and most noteworthy, the project resulted in a legal victory that blocked the expansion of the oil refinery. This decision not to expand the refinery was considered a *public health intervention*, supporting our ontology: lobbying for the environment via citizen science initiatives leads to increased environmental justice and improved public health (Fig. 12.1, **r02**, **r03**, **r04**).

A second example of interventional health-related citizen science addressing environmental justice is the Our Voice initiative, led by Stanford Medicine, which empowers communities to make a positive impact on their local environment. Our Voice works with research institutions and community-based organisations around the world to (1) encourage citizen scientists to discover which aspects of their surrounding environment have an impact on healthy living; (2) support them to discuss their findings with other citizen scientists; and (3) enable them to change their community (including natural and social environments and health) for the better. In one such partnership with GirlTrek – a civil rights-inspired health movement encouraging African American women to adopt a daily habit of walking as a way to reclaim their neighbourhoods – citizen scientists across eight cities were trained in the Our Voice Discovery Tool mobile app. This resulted in 230 photographs being analysed to assess neighbourhood features that improve walkability. As a direct consequence of the project, sidewalks were repaved around an elementary school, and the length of time for pedestrians to cross the road at a crosswalk was increased from 20 to 40 seconds.

[2]EDCs are compounds which affect the endocrine system, which is responsible for metabolism, growth, and development in humans.

Participation Models

The participation models considered in this chapter are *N-of-1* and *N-of-we*. While there are other models discussed by Wiggins and Wilbanks (2019), these two lend themselves most naturally to health-based citizen science initiatives related to environmental justice.

N-of-1 In medicine, an N-of-1 trial is a clinical trial in which a single patient is the entire trial or case study. Examples are data collection of one's daily actions, the possible analysis of those actions, and the observation of outcomes in response to interventions. N-of-1 can include *self-tracking*: individual-driven, personal experiments sparked in part by the growing ease of collecting data, reporting data, and analysing data. An example is using wearables to track heart rates. *Generalised N-of-1* is a project in which a single citizen collects or analyses scientific observations of any kind, not necessarily about themself. These studies are more individualistic than other citizen science projects. Since citizen science is primarily associated with collective models of participation, generalised N-of-1 studies are less likely to be recognised as citizen science unless they become visible through coordination or sharing of results.

In this sense, one of the most famous examples of generalised N-of-1 environmental justice studies related to health involved the collection of landfill data. The study found that, between the 1930s and the 1970s, 80% of all the waste in the Houston area was dumped in neighbourhoods predominantly made up of communities of colour. This practice was neither random nor isolated to Houston, with targeted and widespread injustice demonstrable across the southern states of the USA. There is evidence to suggest that living within 5 km of a landfill is associated with increased mortality from lung cancer and respiratory disease. Thus, environment-based citizen science, to monitor the natural environment and improve environmental policy to ease environmental injustice, also feeds into human health.

Environmental injustice can be subtler than the placement of landfills and oil refineries; it can manifest itself as negligence. The lack of action can lead to the development of less 'walkable' locations. At least in the USA, such locations are related to less-active residents, who are more likely to be obese, with increased risks of high blood pressure, high cholesterol, heart disease, and stroke. While public health studies have linked socioeconomics and race to the risk of obesity, these studies do not take factors such as marginalisation and disinvestment (issues of environmental justice) into account.

N-of-we In N-of-we models, N-of-1 data sets are connected to form a more general knowledge base. The work related to these models is often community driven or public driven. One example is the citizen science project Mosquito Stoppers, funded by the National Science Foundation in the USA, that studies the exposure to mosquito-borne pathogens. Effective control of mosquito populations and of the diseases they carry requires explicit spatial knowledge about their habitat; citizen science projects can provide this knowledge. Project leaders established four priorities: (1) making open spaces healthy and appealing; (2) alleviating the burden of mosquito exposure in disinvested communities; (3) reinvestment in disinvested communities with substantial participation by residents; and (4) improvement of city sanitation services. The first priority could arguably be seen to also address mental health, as spending time outside has been demonstrated to improve health and well-being.

In communities facing environmental injustice, unmanaged infrastructures, a lack of redevelopment, and the often-associated build-up of waste (due to limited waste collection services through disinvestment) contribute to higher adult mosquito density because they provide a more favourable habitat. These communities have lower health levels and are less likely to be engaged in citizen science.

To promote the co-management of the project, citizen science leaders were recruited from within the community; citizen knowledge was incorporated via two channels (mosquito population data collection and qualitative citizen science experience data); and the results were disseminated at neighbourhood meetings. Community members were encouraged to contact city services using data on waste issues throughout their neighbourhoods ('calling to report trash and request the city to clean it up'), as part of translating data to on-the-ground outcomes (Sorensen et al. 2018).

On paper, this health-related citizen science project directly addressed environmental justice to drive action and change. Nevertheless, even such a well-conducted and well-meaning project is not without its challenges. It was noted that many participants began to express fatigue, as they felt increasingly frustrated that they kept noticing, and reporting, the same piles of waste and the same abandoned buildings, but nothing was ever done by the authorities. The problem of those in power not acting on the data generated by those lacking power is one of several challenges we encountered while working on this chapter. These challenges are the focus on the next section.

Challenges

Addressing Health Disparity

Health disparity, the gap between the health of the rich and the health of the poor, is a significant issue. If the rich use their superior health to enrich themselves further, and if more money can buy them enhanced bodies and brains, with time, this gap will only widen. Soon, the wealthiest 1% might own not only most of the world's wealth but also most of the world's health. Factors to consider are the reduction in government spending on public health, the shrinking investment in the treatment of diseases that hit the marginalised in society, as well as the cost of diagnostic tests and procedures. As discussed in a prior section, health-related citizen science projects do not always directly address environmental justice. Are, then, current health-related citizen science projects that do *not* directly address environmental justice unwittingly raising barriers to inclusion, and, if so, what can be done to remove these barriers? To make an already problematic situation even worse, as the masses lose their economic and political power, the state has less incentive to invest in their health. This can be observed in the laissez-faire response from the UK government in March 2020 to COVID-19 (ICD-10 B97.2 and U07.1), a disease killing mainly those with low levels of economic and political power (Bialek et al. 2020).

When scientists are confronted with this scenario, their standard reply is that many medical breakthroughs begin with the rich but eventually benefit the whole population and help to narrow rather than widen social gaps. For example, vaccines and antibiotics initially profited mainly the upper classes in the Global North, but today they improve the lives of humans globally. However, the expectation that this process will be repeated in the twenty-first century may be just wishful thinking, for two crucial reasons. First, medicine is undergoing a *conceptual revolution*. Medicine in the Global South (e.g. in China or in most of Africa) aims to heal the sick, while medicine in the Global North increasingly (e.g. in the UK) seeks to enhance the healthy. For example, a report suggests that life expectancy in the UK has stalled for the first time in more than a 100 years and is in decline for the most deprived women in society (Marmot 2020). Second, medicine in the Global South benefits the masses because the Global South is home to the masses. Armies in the Global South need healthy soldiers, and the economy requires healthy workers. These needs do not exist in the Global North, or else will soon no longer exist.

Nevertheless, citizen science programmes on, for example, air pollution can lead to policy measures to improve air quality, from which everybody will benefit, not only the rich.

Gaps in the Ability to Volunteer

We also need to consider that citizen science is volunteer based and how that relates to *time poverty* (the idea that discretionary time is class based). Kimura and Kinchy (2019) discuss the dilemmas related to the class stratification of *volunteerism* (which has become popular under neoliberalism) in more detail.

Neoliberal Transfer of Responsibility

Furthermore, we should consider if citizen science practices reinforce the *neoliberal transfer of responsibility*. Citizen science needs to be situated in the broader dynamics of neoliberalism, where accountability for health and well-being is increasingly individualised. Indeed, it is not a coincidence that the growth of citizen science coincides with lower governmental spending on environmental monitoring, health, and scientific research. Citizen science is effective in providing fine-grained data that considers local/personal knowledge. Yet, such personal-level attention can shift the scale at which health or environmental problems are conceptualised, from social/ structural to individual. Citizen science needs to navigate the challenging situation in which collecting data can sometimes reinforce the neoliberal transfer of responsibility to citizens (Kimura 2016; Kimura and Kinchy 2019).

Privacy

Health-related citizen science projects often face challenges around *privacy*. Health information is very sensitive, so health-related citizen science initiatives should bear this in mind and explore appropriate modes of data governance.

Interoperability

Communication (multilingual and interdisciplinary) is another challenge that health-related citizen science projects face. The use of international standards and vocabularies is essential to cover a global perspective and allow data from different countries to be aggregated, studied, and compared. In health, some of these standards and concepts are promoted by the World Health Organization (WHO):

- International Classification of Diseases (ICD)[3]
- International Classification of Functioning, Disability, and Health (ICF)
- International Classification of Health Interventions (ICHI)
- Anatomical, Therapeutic, Chemical Classification System (ATC)[4]
- Disability-adjusted life year (DALY)[5]

Even when collecting interdisciplinary data according to international standards, health-related citizen science projects can face challenges in addressing environmental injustice. Quantifying the health risks of exposure to a single toxic compound is inherently problematic in terms of being able to isolate its effects from other environmental factors. Thus, while there are established correlations between environmental exposure to particular chemicals and particular diseases, the levels of exposure (in terms of concentration and duration) and how best to measure these are continually disputed. This makes deriving solutions from such data even more problematic.

While providing answers to such issues is beyond the scope of this chapter, we recognise the importance of organisations putting pressure on governments and

[3] The latest versions of the ICD, ICF, and ICHI are available from the WHO: https://www.who.int/classifications/en/

[4] https://www.whocc.no/atc_ddd_index/

[5] https://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/

other institutions to include under-represented groups and interests in health-related citizen science projects. We recommend that all citizen science projects seek opportunities to reach citizen scientists from different classes. We will discuss inclusivity further in the final section of this chapter.

Defining the interplay between the three (not immediately obviously related) concepts of citizen science, health, and environmental justice is challenging. Despite the use of citizen science since the 1990s, its utility in health research is relatively novel, health-based citizen science as a way of addressing environmental justice even more so. Interdisciplinary environments are themselves challenging. Experts from several disciplines need to work together to reach a common goal; apart from using the same vocabulary, they need to share knowledge, processes, and best practices.

The definition of environmental justice itself has proven controversial. While we have predominantly focused on the natural environment in this chapter, we acknowledge that environmental justice is also a social issue that extends to the economic and political contexts. Citizen science, if used *to empower additional people to join the debate about the future*, undoubtedly has a role to play in driving the changes necessary to facilitate social and political environmental justice. However, citizen science is naturally suited to research on the natural environment, more so than to issues such as the economy.

Disparity and Power Imbalance

It is important to consider the specific challenges for citizen science in the Global South, where citizen science might be driven by foreign international organisations as a part of their data gathering or development work.

First, *who asks the questions?* Whether the scientific questions to be addressed by a citizen science project come from citizens themselves or civic educators (including scientists, professional researchers, and their institutions) needs to be interrogated. Is it reasonable to expect communities to initiate and drive a socio-environmental-justice movement? Is it overambitious to assume that they *can*? Does suggesting that they *cannot* indicate a level of institutional and structural racism? Empowering people includes enabling them to initiate citizen science projects. Nevertheless, in most cases an external organisation is the initiator. In the field of health-related science, the history of modern Western medicine connects seamlessly with that of European colonial expansion in the nineteenth century. Quinine enabled European armies to enter previously forbidden terrains. Medical officers helped to sanitise dangerous spaces and environments but also subjected Indigenous populations to European rule. Today, as in the past, efforts to curb epidemic and pandemic diseases such as plague, smallpox, cholera, and COVID-19 lead to attempts to discipline the routines, diets, and movements of citizens. Effective medical interventions and vaccination programmes help to maintain a healthy labour force (Keller 2006). In this context, scientific questions are asked by people in power: only their knowledge counts, and the science, while presented as a benefit to the citizens, is used as an effective means for control. Ultimately, science is for the people in power, not the citizens. Therefore, whenever science is being conducted in the Global South, it is pertinent to additionally consider:

- Whose knowledge counts when asking the question?
- How is science being used?
- Who, ultimately, is the science for?

Second, *does citizen science marginalise Indigenous knowledge?* Whether citizen science inadvertently cements such historical dynamics of marginalisation is a question that needs to be investigated. A considerable part of environmental justice science deals with the *colonisation of science*: the disproportionate legacy of white European thought and culture in science. Modern Western science is inextricably linked with colonialism, especially British imperialism. The scientific successes of the West were used to allege that non-Westerners were intellectually inferior and so deserved and needed to be colonised. Although colonialism has formally ended, these attitudes have not yet wholly disappeared. Academic journals are dominated by Western papers, stemming from the top-ranking universities, because the scoring system is Western. A study of papers produced by central African countries revealed that 80% of the region's output was produced in collaboration with a partner from outside the area, with 35% in partnership with past colonial rulers (Boshoff 2009). Attitudes expressed by academics from the Global North towards academics from the Global South are sometimes alarming. They suggest that attitudes expressed by academics from the Global North towards mere citizens from the Global South could be even worse (Dahdouh-Guebas et al. 2003).

Third, *does citizen science have a significant impact on justice?* Environmental justice is not focused on documentation and observation but on action, and citizen scientists investigating their environments (natural or social) do not need academics or researchers to validate the science they undertake. Though scholars and other professional scientists are undoubtedly interested in the issues of environmental justice, and are keen observers, they are generally not as motivated to drive improvements in unjust environments as the communities themselves. Therefore, there is a lack of focus on generating science that translates results into action, indicative of the issues of power and control.

Fourth, *does citizen science drive democratisation?* A key challenge is how to democratise science, whether it be science for health or science for environmental justice. Citizen science needs to acknowledge the diversity of participants in terms of language and literacy and address the issue of *who conducts science?* For example, the Northern California Household Exposure Study, by encouraging women and people of colour to present the results of their study at community meetings in both English *and* Spanish, was able to at least challenge (if not change) ideas about who conducts science.

Relevance, Future Trends, and Recommendations

Relevance and Future Trends

Citizen science, health, and environmental justice are closely linked. For example, pollution has a disproportionate effect on the health of minorities: unequal environmental quality exacerbates social inequality.

Research led by patient communities is an excellent example of user-driven studies and the power of citizen science. If the success of these initiatives can also be adopted in other fields for truly co-created citizen science projects, this will facilitate innovation in science and at the science–society interface.

Understanding how engagement in citizen science itself can provide health benefits – either through (1) experience of self-efficacy and sense of purpose; (2) actual or virtual social contact and cohesion; or (3) being in natural environments – is to date unexplored and presents an essential further avenue of research.

The global environmental changes facing us today are increasingly being recognised as critical, so are issues of environmental justice, as future trends in population growth are linked to food and health equality and to the overuse of the environment. In the Global North, there is a trend towards more individual health-related citizen science. For example, Project Baseline aims to make it easy and engaging for citizens to contribute to the map of human health and participate in clinical research. Together with researchers, clinicians, engineers, designers, advocates, and volunteers, the project contributes to building the next generation of health-care tools and services. Citizens can contribute through clinical research, surveys, and focus groups. They are the first to know when *studies matching their preferences* are launched. They can test new tools, technologies, and treatments and shape the future of health care. In addition, citizens can learn about their own health and simultaneously help improve health for all.

Recommendations

Barriers to inclusion are a concern in citizen science in general (Paleco et al., this volume, Chap. 14) and particularly in health-related citizen science. Therefore, we recommend incorporating *inclusivity* into health-based citizen science project design. Some projects give citizens a great deal of control, while others give credentialed scientists the lead, relegating citizens to a prescribed role. The degree of community involvement varies and changes over time, and project partners need to consider whether the limits placed upon citizen involvement are justified. Moreover, 'citizens', 'communities', and 'local people' are not homogenous. Participants in health-related citizen science are overwhelmingly well-educated, wealthy, and of European ancestry (Greshake Tzovaras and Tzovara 2019). Whether participants genuinely reflect the diverse opinions and lived experiences of those experiencing environmental and health struggles needs to be considered. Citizen science is in a strategic position to ensure the following challenges are addressed. How can we make sure that those with less power, women, and minorities are among those who are asking the questions? Is the science being conducted by a diverse group of people? Is it being analysed by a diverse group of people, using technology that does not discriminate?

Additionally, there are pervasive *biases* in health data; the different types of biases are outlined in the Catalogue of Bias established by the University of Oxford (https://catalogofbias.org/). Citizens and scientists who are analysing collected data must be made aware of these explicit and implicit biases. We recommend that citizen science projects take specific measures to ensure that the data they work with are unbiased and that the algorithms they use are *fair by design*.

In terms of the *role of the business sector*, we note that there is an increasing awareness about the use of citizen science for public relations. Given citizen science's appeal as a community-based participatory endeavour, there is the possibility that commercial actors will deploy it in a way that enhances their public image, softens community health concerns, and obfuscates, rather than clarifies, their environmental or health impacts. Partnering with the commercial sector also raises issues about the ownership of data and equitable profit sharing. We recommend undertaking research in order to understand the role of the commercial sector and the way it engages with citizen science.

Also, we recommend a citizen science approach that welcomes questions asked by those who are under-represented or lacking in power. Appropriate questions asked by the commercial sector can have positive effects on health-related citizen science projects.

We recommend using citizen science to *empower* additional people to join the debate about the future. Citizen science projects should allow communities that might otherwise be overlooked to drive both the design and the implementation. To ensure the project is genuinely community led, open discussions should be held on how the tools used should function, how they will be used and managed by the community, how the data will be stored, and what the expected outcomes will be. In the case of environment-related citizen science projects, benefits to mental health are apparent, even before data are collected, if empowerment within the community is evident. Community-initiated projects demonstrate that professional scientists are not a prerequisite for science to be conducted and that there is value in empowering citizens to lead scientific endeavours.

Interestingly, citizen science itself could also be seen and evaluated as a health intervention, if it is empowering and thereby engendering a sense of community, social cohesion, as well as self-efficacy. These outcomes could have a salutogenic effect on mental health and well-being for the participants. This effect may, of course, not only apply for health-related citizen science projects but also for citizen science projects in general.

We recommend taking into account *Indigenous and local knowledge* in citizen science projects. While scientific knowledge is validated through peer review by other scientists, other knowledge systems can have different validation approaches which should be considered.

Finally, we recommend considering how international health-related *standards and vocabularies* can be incorporated in a user-friendly way.

We hope this chapter provides a basis for discussion for all those interested in health-related citizen science which aims to address environmental justice and pointers on how to strive for equality and promote positive, sustained impact.

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Part II
Citizen Science in Society

Chapter 13
Participants in Citizen Science

Anne Land-Zandstra, Gaia Agnello, and Yaşar Selman Gültekin

Abstract The most important factor that defines citizen science is that non-professional scientists contribute to scientific research. Therefore, it is important to recognise the perspectives and experiences of these participants. Projects may provide ways for participants to contribute to scientific research at different stages of the scientific process according to different levels of engagement. Understanding what motivates citizen scientists to engage in a project, and subsequently matching the project to these motivations, will help project leaders to recruit and retain participants. In addition, it is important to understand what benefits participants gain from engagement in citizen science projects. For individual projects, this will help ensure that scientists as well as participants benefit. For the wider field of citizen science, this will provide evidence of the potential impact of citizen science on participants. However, participants may also encounter challenges during their engagement with citizen science projects. Project leaders and scientists should plan in advance to address these challenges and ensure that relevant expertise is present in the project team.

Keywords Citizen engagement · Participant motivation · Participant experiences · Learning outcomes · Participant benefits · Recruitment

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Introduction

The feature that most distinguishes *citizen science* from other forms of science is that non-professional scientists are involved in the scientific process. These non-scientists, the 'citizens' in citizen science, can collaborate with scientists in all stages and aspects of the scientific process, but, in most projects, they contribute to data collection and data analysis. The terminology used to describe participants in citizen science varies across the field, like the definition of citizen science in general (Haklay et al., this volume, Chap. 2). Eitzel et al. (2017) explored terminology in citizen science and found a range of terms, including hobbyist, amateur, citizen scientist, collaborator, human sensor, and participant. Many of these terms have a negative connotation, and some do not cover what participants in citizen science projects actually do. For example, *citizen* may have a negative connotation for people who do not have citizenship in the country they live in. The term *volunteer* may be too general and does not encompass the fact that most citizen science projects strive to provide benefits to the non-scientists involved. Eitzel et al. (2017) propose that scholars and practitioners in citizen science choose their terminology deliberately and explain their definitions of the terms chosen. In this chapter, we will use the terms participant and citizen scientist to incorporate anyone within a citizen science project who is not part of the project coordination team.

The field of research about participants' experiences in citizen science is new and borrows from many other fields. For example, although the use of the term volunteer for participants in citizen science can be problematic, much of the research regarding participants borrows from the field of volunteer research in social science and health. Motivations for volunteering in general are similar to motivations for participation in citizen science. Research and theory from other fields such as education, psychology, and social science are also applied to the study of citizen science participation.

In this chapter, we will discuss several aspects that are important to consider when analysing the perspective of participants. First, we will describe how scrutiny of the role of participants and their perspective has grown. Then we will discuss participants' motivations to engage with citizen science. Understanding why citizen scientists engage with a project can help project leaders with retention of participants. Next, we will discuss the benefits participants gain from their engagement with citizen science. These outcomes are ideally aligned with participant motivations and with the goals of project leaders. Lastly, we will discuss the challenges both participants and project organisers face in citizen science projects in relation to participation and recommendations for resolving these challenges in practice.

Increased Scrutiny of Participants

The field of citizen science has been professionalising over the last few decades (see also Haklay et al., this volume, Chap. 2; Vohland et al., this volume, Chap. 3). As part of that process, there has been an increased scrutiny of the viewpoint of the citizen scientist. Kullenberg and Kasperowski (2016) determined that there is a growing trend in the number of scientific papers about citizen science. One of the clusters of publications they found was on the social science of citizen science in journals such as *Public Understanding of Science*. These papers include the experiences of citizen scientists. In addition, the *ECSA 10 Principles of Citizen Science* (ECSA 2015) includes no less than five principles explicitly addressing the citizen scientist's perspective.

Taking the knowledge, skills, and expertise of citizens as collaborators in scientific research seriously fits into a larger trend towards public participation in several other areas. For example, within the field of science communication, there has been a shift from one-way communication towards more interaction between science and society (Smallman 2018). In addition, many local governments organise public dialogues and public consultations for decision-making processes. Similarly, the field of health care has also increasingly included the voice of the patients and the public (Ceccaroni et al., this volume, Chap. 12; Tritter 2009). In all these fields, the assumption is that involving the public in science, policy, and health will make for better outcomes and decisions and that by making use of the public's knowledge and ideas, these decisions will also be supported by a broader audience.

In citizen science, scrutiny of the role and viewpoint of participants has increased because, in addition to developing and providing clear procedures and protocols to ensure data quality (see Balázs et al., this volume, Chap. 8; Hidalgo et al., this volume, Chap. 11), making sure that participants' expectations and needs are satisfied also influences the quality of scientific outcomes. Since most citizen science projects have project goals regarding benefits for participants, it is also necessary to understand their experiences in order to measure outcomes. Further, increased understanding of participants' experiences is necessary to make claims about the overall benefits of citizen science for participants and society.

Involvement of Citizens

Levels of Engagement

In general, citizens can engage in different levels of the scientific process: development of research questions and hypotheses, data collection, data analysis, drawing conclusions, and disseminating data. In all of these stages, engagement can be top-down (directed by the project leaders) or bottom-up (directed by participants themselves). Bonney et al. (2009) developed an often-used categorisation of citizen science projects. Their framework defines *contributory* projects as projects where scientists design the project and participants are involved in collecting and analysing data according to predefined protocols. In *collaborative* projects, participants may also be involved in adjusting protocols, drawing conclusions, and proposing new directions for research. Finally, *co-created* projects include citizens in all stages of the scientific process; scientists and citizens collectively design and develop the project. Another categorisation that is often used in the field of citizen science is the levels of participation coined by Haklay (2013): *crowdsourcing*, *distributed intelligence*, *participatory science*, and *extreme citizen science*. Here, levels range from 'citizens as sensors' (crowdsourcing) and 'citizens as interpreters' (distributed intelligence) to levels where participants are more involved in problem definition and collection protocols (participatory science) or are even part of the entire development of the scientific process (extreme citizen science).

In both of these categorisations, participant engagement will look different according to the type of project involved. Most citizen science projects are contributory or crowdsourced/distributed intelligence projects. In these projects, participants are recruited to contribute to a certain scientific cause, and they then register with a project that fits their motivations and interests and start contributing according to a fixed protocol. Most of the projects listed on platforms such as Zooniverse and SciStarter are contributory projects, and many participants are excited to be able to contribute to science in this way. The development and growth of the Internet and mobile technologies have enabled many people to contribute to science from the field or from their own homes (Silvertown 2009). One disadvantage of these large online contributory projects is that often a large portion of participants only contribute once and then leave the project; the majority of the work is done by only a small number of participants (Sauermann and Franzoni 2015).

In collaborative and co-created projects (Bonney et al. 2009) and participatory science and extreme citizen science projects (Haklay 2013), participants have a more active role in the development of the project itself. They can be involved in sessions where the results of the project are being discussed and interpreted. They can also contribute to the dissemination of the results to other stakeholders, such as local municipalities. For example, in the *Co-click'eau* project in France, farmers, water policymakers, and other stakeholders collaborated to determine and assess the consequences of different scenarios to comply with EU freshwater regulations. In some regions, using this approach to citizen science results in co-designed action plans and collaborative learning (for a case study, see Bio Innovation Service 2018).

Although many participants may be satisfied with a minimum level of engagement in a citizen science project, in general it is better to provide opportunities for participants to become more involved in a citizen science project if they want to be (see, e.g. ECSA 2015). Many projects have opportunities available to become more engaged, for example, through interaction in an online forum, by becoming a moderator or trainer, or in small-scale workshops on data interpretation or policy involvement. Sometimes these opportunities evolve within a project because participants request them. An example is the Dutch project *Schone Rivieren* (Clean Rivers). In this project, participants were trained to monitor waste along the riverbanks of two large rivers in the Netherlands. After several participants offered to do more, the project started to organise *hackathons* and *maker days*, allowing engaged participants to help with other aspects of the project, such as a national conference, improving training material, and community building. As a result of the initiative of these active participants, the project itself is now working on a more embedded way for others to also increase engagement. The preference of participants for a certain level of engagement depends largely on their motivation to participate.

Motivation to Participate

Motivations for participating in citizen science projects vary between individuals. In order to attract participants and keep them engaged in a project, it is important to understand what drives them to participate and why they stick with a project or leave it. The frameworks for studying motivation in citizen science participation come from research conducted on volunteerism in the social service sector, aimed at understanding the psychological and social processes that initiate and sustain volunteerism (Clary et al. 1998; Finkelstein 2008). Clary et al. (1998) proposed the Volunteer Function Inventory (VFI), a measure of six motivational functions for volunteering (*values*, *understanding*, *social*, *career*, *ego protection*, *ego enhancement*) based on the psychological theory of functionalism (Katz 1960) – according to which people display similar attitudes in response to psychological functions that serve individuals' needs.

Studies about motivation in citizen science often use social science research methods such as *surveys* and *interviews* (see Schaefer et al., this volume, Chap. 25). In surveys, participants generally indicate how strongly they agree with a list of statements about their motivation (e.g. 'I participate in this project because I like to contribute to scientific research') or they indicate the motivations that are most important to them. Often several of these questions are then combined within categories of motivation such as *contribution*, *intrinsic motivation*, *extrinsic motivation* (e.g. West and Pateman 2016); others divide motivations into how much they serve a person's own interests or the interests of others (e.g. Rotman et al. 2012). Several studies have been conducted to unpick citizen scientists' motivations (Curtis 2015; Land-Zandstra et al. 2016a; Raddick et al. 2013; Rotman et al. 2012; Wright et al. 2015; Agnello et al. 2020). In many of these studies, participants are motivated by the fact that they are contributing to 'real science', or to the overarching goal of the project (e.g. the environment, health, biodiversity, astronomy). For example, in the *Galaxy Zoo* project, almost 40% of the people that took part in a survey about their motivation picked the statement 'I am excited to contribute to original scientific research' as their primary motivation for participation, making it by far the most important motivation (Raddick et al. 2013).

Another important motivation is often an intrinsic interest in the particular topic of the project, such as birds, galaxies, plants, language, etc. For example, many bird monitoring projects attract people who already are interested in spotting birds or who are interested in nature (Wright et al. 2015; Sullivan et al. 2009). Health-related citizen science is often strongly linked to a personal interest as it may provide people with a certain disease or illness a way to contribute to research towards a treatment or a cure (Wiggins and Wilbanks 2019). For example, in the Dutch air quality project, *iSPEX*, many people stated that they contributed because they themselves or a family member had asthma (Land-Zandstra et al. 2016a).

Other common motivations are related to enjoyment, recreation, and social interaction; participants often look for enjoyable activities or a way to become part of a community of like-minded people. For example, *BioBlitzes* (see Rüfenacht et al., this volume, Chap. 24) provide an opportunity to collect biodiversity data in the field, working in groups where people meet each other face to face. Asah and Blahna (2012) found that people who want to converse and interact with like-minded people are more likely to participate in citizen science projects. Other studies have shown that face-to-face interactions with leading scientists can positively influence the level of participation in a project (Havens et al. 2012). The motivations to socialise and for recreation drive outcomes such as the level of personal investment and the willingness to advocate for the programme (Agnello et al. 2020). Other projects offer communication channels on their website, such as a forum, or organise separate events where participants can meet each other and project leaders offline and share their experiences. For example, in the citizen science game *Foldit*, players use their problem-solving skills to come up with ways proteins can be folded. In this project, participants revealed in interviews that the fact that they could collaborate in the game with a diverse community who shared a common goal was one of the things they enjoyed most (Curtis 2015). In cases where citizen science has been 'gamified' (i.e. turned into an online game), competition also sometimes serves as a motivating factor.

Although research on motivation in citizen science is increasing, much of it involves case studies which makes it hard to compare across projects. In order to work towards a more universal framework for assessing motivation for citizen science, Jeanmougin et al. (2017) conducted a systematic literature review[1] of articles that studied citizen scientists' motivations. They proposed a framework based on existing theory of basic human values (Schwartz et al. 2012). Levontin et al. (2018) used Schwartz's universal human values to develop such a framework, supplemented with motivations that are unique to citizen science (based on the literature review). They then developed an extensive questionnaire to measure these motivations in citizen scientists. Table 13.1 shows the motivation categories, the definition of each category, and an example in each category. The assumption is that if an assessment of motivation to participate in citizen science is based on this overarching theoretical framework of basic human values, using the questionnaire, then it will become easier and more reliable to compare different projects

[1]This work was conducted as part of the COST Action CA15212 *Citizen Science to Promote Creativity, Scientific Literacy, and Innovation throughout Europe*.

Table 13.1 Categories of motivation, based on Levontin et al. (2018)

Motivation category	Definition in terms of motivational goals	Example
Self-direction	Independent thought and action – choosing, creating, exploring	'I want to learn'
Stimulation	Excitement, novelty, and change	'I strive to challenge myself'
Hedonism	Pleasure and sensuous gratification	'I want to have fun'
Achievement	Personal success through demonstrating competence according to social standards	'I am seeking fame'
Power	Power through exercising control over people and material and social resources	'I want to gain recognition and status'
Face	Security and power through maintaining one's public image and avoiding humiliation	'I want to enhance my reputation'
Security	Safety, harmony, and stability of society, of relationships, and of self	'I want to live in secure surroundings'
Conformity	Restraint of actions, inclinations, and impulses likely to upset or harm others and violate social expectations or norms	'Other people I know are participating'
Benevolence	Preservation and enhancement of the welfare of people with whom one is in frequent personal contact	'I am happy to help'
Universalism – social	Commitment to equality, justice, and protection for all people	'I want to improve our society'
Universalism – nature	Preservation of the natural environment	'I want to help wildlife'
Routine	Everyday, ordinary, and regular	'I was doing this activity anyway'
Belongingness	One's feeling of being secure, accepted, included, valued, and respected	'I want to socialise with other people'
Help with research	Contribution to science	'I want to contribute to science'
Teaching	Providing an educational opportunity to others	'I want to share my knowledge and experience'

(e.g. biological versus astronomical; online versus offline) and different participant groups (e.g. children versus adults).

In addition to learning more about motivations to participate in citizen science projects, it is also important to understand how motivations change over the course of a project. Several studies have focused on changing motivation over time and different levels of engagement (Crowston and Fagnot 2008; Eveleigh et al. 2014; Land-Zandstra et al. 2016b; Rotman et al. 2012). Crowston and Fagnot (2008), for example, suggest that, initially, participants are mainly motivated by curiosity about a project, while long-term participants also include social obligation, a shared ideology, and a feeling of satisfaction as motivating factors. Rotman et al. (2012) found that, in their sample, new participants were generally guided by egocentric motivations, while long-term participants were more motivated by helping others. Similarly, Land-Zandstra et al. (2016b) found that participants who had been involved with the flu-tracking project *The Great Influenza Survey* for a while identified with contribution to science as a motivator in greater numbers than newer participants. However, comparing new and long-term participants is not the same as measuring a change of motivation over time within the same cohort. This kind of longitudinal research on participants' motivation, which is rarely conducted in citizen science projects, should be encouraged.

Benefits and Outcomes for Participants

Participants in citizen science derive a variety of benefits and outcomes. From the individual participant's perspective, these benefits are related to, for example, scientific literacy, health benefits, opportunity to socialise, and empowerment (Blaney et al. 2016, Haywood 2014, King et al. 2016). For example, Moore et al. (2006), researching community involvement in conservation groups, looked at the benefits of participation and found higher health and well-being in participants engaged in land management. A correlation between participation in environmental work and benefits relating to physical, spiritual, and social health was also found in a study involving people suffering depression (Townsend 2006). Another study categorised the benefits perceived by participants as *altruistic*, *individual*, and *organisational* (Agnello et al. 2020).

In addition to the scientific impact of citizen science, projects can and should seek to ensure benefits for participants which, in turn, can be drivers of outputs and outcomes, such as the level of personal investment and willingness to advocate for the programme. For example, a study surveying different citizen science projects in the south-east of England found that participants who perceived individual benefits dedicated more time to the programme, got involved in additional activities within the same organisation, visited more sites, and attended more training sessions. Moreover, both altruistic and individual perceived benefits predicted participants' willingness to advocate for the programme (Agnello et al. 2020).

Benefits are often connected to the motivations that participants have when contributing to a project. For example, when someone takes part in a project to learn more about butterflies, then increased knowledge and understanding would be an expected benefit. Or, if someone engages in a citizen science project because he or she is concerned about an environmental issue in his or her neighbourhood, the outcome for the participant might be empowerment to be able to address the issue with the local municipality or other stakeholders.

In addition, project leaders may have certain goals in mind with regard to outcomes for participants, often in terms of learning outcomes, increased awareness about an issue, and behaviour change. Alongside the lack of coherent research about motivation of participants, participant outcomes are not often studied or, if they are, it is hard to draw overarching conclusions for citizen science projects in general.

Phillips et al. (2018) reviewed intended outcomes of citizen science projects in the USA and Canada and found that the goals that were most often identified by project leaders were improving research skills, increasing content knowledge, and increasing environmental stewardship (e.g. protecting water quality). In a follow-up online survey of project leaders, Phillips et al. (2018) found that around half of the respondents measured the outcomes of their project. The most reported outcomes were *interest or engagement in science* (46%), *knowledge* (43%), *behaviour change* (36%), *attitude change* (33%), and *research skills* (28%). Interestingly, there was a discrepancy between the most commonly stated goals of the project and the outcomes that were measured.

Subsequently, Phillips et al. (2018) proposed a framework of common citizen science outcomes to be used for the formulation of clear project goals and for the evaluation of a project's impact based on those outcomes. They supplemented the aforementioned outcomes with *self-efficacy* (confidence in one's ability to participate in science), *behaviour and stewardship* (new actions as a result of the participation), and *motivation* ('goal-driven inclination to achieve a science behavior or activity'). We will discuss each of these outcomes with examples.

Often the most obvious outcome that project leaders aim for is increased knowledge and understanding among participants about a specific topic or science literacy in general. Even though this is often not the most important motivation for participants, they can still achieve knowledge gains (either measured or self-reported). For example, in a citizen science project conducted by the US National Institute of Invasive Species Science (NISS), participants showed an increased level of knowledge about invasive species (Crall et al. 2012). However, their knowledge about the scientific method did not increase; this type of general science literacy may be harder to impact.

Related to an increase in scientific knowledge, citizen science projects can have an impact on participants' research skills. In particular, participants may learn to conduct certain data collection protocols such as identifying species of bees or birds, or measuring variables such as air pollution or water quality. These increased skills are beneficial for the participants but also for project leaders, since increased research skills also generally increase project data quality.

Many citizen scientists start contributing to a project because they have a pre-existing interest in the project's topic. People can also become even more interested in the topic once they engage with it further. For example, in an online transcription project where participants had to transcribe sixteenth- and seventeenth-century handwriting, a small group of participants chose the more difficult task of deciphering sixteenth-century handwriting in preference to the easier task of deciphering the seventeenth-century handwriting (De Moor et al. 2019). Although prior interest is more often assessed as a prerequisite for participation in citizen science, more research on increased interest as a result of participation would be interesting.

Self-efficacy, the confidence about one's ability for a certain task or behaviour, is not often measured as an outcome of citizen science, even though Phillips et al. (2018) reported that it was mentioned by project leaders as an intended outcome.

However, participation in a citizen science project may show participants that they are able to perform science, even if they did not previously think of themselves as scientists.

In many environmental and health-based citizen science projects, the motivation of organisers as well as participants may be to produce scientific knowledge and have an impact on issues such as water quality, air quality, and health. Changing behaviour of participants, and, indirectly, of other stakeholders, may be one of the goals. For example, in the *Clean Rivers* project, participants reported having changed their behaviour in terms of their plastic use and their waste disposal behaviour. In projects that are initiated by citizens, for example, because they want to improve their environment with regard to air pollution, the results that they obtain with citizen science may empower them to challenge local government. However, real evidence of these types of impacts is hard to quantify and the results are often mixed (Phillips et al. 2018). More research is needed to determine how citizen science can change participants' behaviour.

The last outcome that Phillips et al. (2018) identify, motivation, can be seen as a factor that influences a person's decision to participate in a project as well as an outcome of the project, similar to interest. We have already described motivation as input for engagement in a project. Motivation as an outcome includes the motivation to continue engaging with a project, to become more active in a project, and to become engaged in other, related, activities.

Participants' Challenges and Recommendations for Project Leaders

As may have become clear from the discussion of participant experiences, motivations, and outcomes, complying with the individual personality traits, values, emotions, and interests of participants in citizen science is a complex task. These aspects determine the motivations, expectations, and barriers of the target audience, which can differ at each phase of the project and the participant experience. In this section, we will focus on some of the challenges that limit participant engagement throughout the project life cycle along with practical recommendations for resolving these – see Table 13.2 for an overview (based on Agnello 2014).

The way project goals, tasks, and recruitment messages are communicated represents a key factor. Initially, willingness to engage with citizen science can be affected by the extent to which the *communication strategy* (the message, wording, and media) is inclusive and matches the motivation of participants. For example, 'skill level' may not be the correct phrasing to use during recruitment as the distinction between 'skilled' and 'unskilled' participants can discourage participation. Potential participants without the required skills in terms of qualifications or with no prior experience, but whose enthusiasm and knowledge can be built over time, may feel excluded. Moreover, certain aspects of project design, such as data

Table 13.2 Challenges to participation in each phase of citizen science projects and recommendations for project leaders

Phase of project management	Phase of the participant experience	Challenge or barrier to participation	Recommendations for project leaders
Recruitment	Motivation to join a project	Communication is not inclusive	Develop communication strategies based on your target audience
		Project goals are not clearly communicated to tap into motivations	Understand what motivates participants in citizen science
	Early stages of engagement	Finding the right task that fits participants' interests, skills, and time availability	Conduct a preliminary assessment of motivations, expectations, availability, and barriers of participants
		Understanding how one can contribute to the project	Communicate clearly tasks for participants, explain aims of the project and the meaning of participants' work
		Not feeling integrated in a well-established group	Plan for welcome of incomers
Retention	Perceiving benefits and satisfaction	Motivations are not met	Conduct longitudinal research about motivations throughout the participant experience
		Costs of participation	Identify participants' perceived benefits, assess satisfaction, and ensure benefits exceed the costs
	Continued engagement	Lack of efficiency in data flow	Data collected by citizens must be shared and used
		Not feeling accomplished	Communicate results and impact of contribution
		Not feeling appreciated	Understand how to reward different types of people (training, give responsibility, reward, recognition, feedback)
		Not feeling acknowledged	Acknowledge contribution, giving adequate recognition of achievements on the website
Evaluation and wrapping up	Overall experience and role in the wrap up	Feeling that expectations have not been met	Ask for feedback and for unresolved issues to set more realistic expectations for future projects
		The project is archived	Give open access to the documentation produced during the project
		Accessibility of data	Provide access to data to the wider audience
		What's next?	Guide participants to new projects

collection and submission, are potential barriers to participants; project design should take into account different abilities and age groups.

From the early stages of engagement, it is important to communicate clearly the different ways participants can contribute to a project. Project leaders need to make sure participants are aware of how they can make a difference through citizen science by doing something interesting, feasible, and achievable for them. If participants are expected to do a complex and effort-intensive task without being reimbursed for their time, project leaders need to clearly define the tasks involved to complete the project and justify why they are seeking public help; otherwise participants may feel it is the government's or the scientists' responsibility to pay participants. Communication strategies (see Rüfenacht et al., this volume, Chap. 24) and inclusiveness (see Paleco et al., this volume, Chap. 14) must be carefully addressed when planning citizen science projects to make sure that diverse groups of participants are engaged, regardless of their skill level, education level, age, gender, ethnicity, and socio-economic status. Also, it must be acknowledged that participants' availability is a potential limiting factor; therefore, project planning should tackle this issue by giving participants the opportunity to contribute when they are able, for example, on the weekends.

Participants dropping out of projects after a short time are often a big challenge. Some of the causes are linked to the dynamics of participation in a community which are determined, for example, by culture, age, and similar factors that can make it difficult for people to feel integrated or involved in a project. For example, a homogeneous group (e.g. made up of all retirees or of a particular ethnic group) can be intimidating and also a barrier to new participants feeling integrated. Therefore, welcoming new participants when they become part of a citizen science community is essential and must be planned for, including offering orientation, explaining how the project functions and key roles in the team, as well as offering opportunities to be introduced to the project community. For example, informal conversation can help to create a positive experience that helps participants to feel welcome and become aware of the ways to ask for help or how to improve their skills; this also enables the project leaders to find out more about their interests and barriers. In order to build an inclusive and effectively engaged community, the project team must ensure a common understanding of data quality among participants and provide constructive feedback, being careful about correcting participants without demotivating them.

Another factor that influences the decision whether or not to continue engagement is how well a project matches participants' motivations and expectations. When there is a mismatch, participants may become very frustrated. For instance, participants whose motivation to join a project is to feel like they are contributing to something important generally expect that information they provide is useful and that data are being utilised in a conscientious and effective way. If there is a lack of efficiency in the data flow – when data collected are not shared or are delayed – this can demotivate participants. Research conducted on the social and psychological traits of participants in citizen science, focusing on the importance of assessing motivations for participation, has developed frameworks for use by project leaders.

By understanding what motivates participants, the project team can work towards meeting expectations and increase the possibility of sustaining commitment in the long term (Bruyere and Rappe 2007; Measham and Barnett 2008; Wright et al. 2015; Agnello et al. 2020).

Assessing what determines participants' satisfaction is crucial to retention (i.e. keeping participants in the project). How satisfied or dissatisfied a participant is depends on factors such as feeling appreciated, feeling rewarded, and the perception of the benefits generated through participation in citizen science. Understanding how to reward and encourage different types of people and how to give adequate recognition can help project leaders to increase project engagement satisfaction. Identifying the benefits people perceive as a consequence of their experience can be useful in order to cultivate them. It is also important to keep in mind that citizen science activities require time and effort from participants. Travelling to the project venue, or simply having to juggle work and family life, inevitably leads people to weigh up the opportunity costs – the potential benefits missed when choosing to dedicate time to a project. Hence, it is important to ensure that the overall benefits people derive from participation exceed any costs they may incur.

The time of project closure and handover is usually a stressful one for project leaders. Among the many tasks that have to be completed, they must pay attention to not overlook the needs of the participants, ensuring that their role is taken into account even in the wrapping up phase. This is the final opportunity to impress a positive memory on the participants about their experience with citizen science and the project. The latter is very important when reporting to donors and if a follow-up project has to recruit new participants or re-engage with previous ones. Participation in citizen science has the potential to start a ripple of positive impact whereby action that successfully gives back to the community encourages others to also get involved. Transparency about the outputs is a right of the participants, and project leaders must ensure clarity whether or not the project's main goal has been achieved. It is of crucial importance to discuss unsuccessful aspects of a project from both the participants' and project leaders' perspectives in order to facilitate future improvements. Finally, having developed a good understanding of the participant cohort, project leaders can provide recommendations to participants on how to continue their involvement in citizen science, for example, by directing them to similar projects that fit their motivations or by discussing the possibility of co-creating a follow-up project.

Conclusion

In this chapter we have discussed the role that participants play in citizen science and different aspects of their experience that are important to take into account, such as providing different levels of engagement, the motivations that bring people to a project and keep them engaged, and the outcomes and benefits for participants. In each phase of a citizen science project's life cycle, these aspects provide certain challenges for both participants and project leaders.

Of course, there is not one typical citizen scientist, so project leaders should investigate the motivations, benefits, and barriers of the participants of their specific projects. In addition, they should plan in advance to address these issues. Often providing different ways to get engaged in a project can help to cater for diverse participants. For example, some participants may be satisfied contributing to a project individually without any interaction with fellow participants, while others are looking for ways to get in touch with a community. Learning more about citizen scientists often means borrowing insights and methods from fields such as social science, psychology, and education. Project teams should make sure that they have the expertise within the team and the funds allocated to address and assess participants' motivation, benefits, and challenges. We recommend building a multidisciplinary team, for example, including a science educator or communicator and a social scientist or a community manager, and providing training to scientists to enhance their skills for interacting with participants.

Throughout the chapter we have discussed research on the motivations and experiences of citizen scientists. Increasingly, project leaders include evaluation and participant research in their projects. On the one hand, this helps individual projects to understand and address their specific group of participants. When project leaders understand the most significant motivations of their participants, they can ensure that communication about the project or activities offered within the project matches those motivations. Additionally, when a project has defined certain goals with regard to participant outcomes (e.g. increased scientific literacy, empowerment, behaviour change), project leaders should include measures to assess these goals. On the other hand, ideally, combining research across many different projects will help the field to understand how motivation for citizen science works in general and how participation in citizen science may impact participants and society. However, in order to reliably combine research outcomes, it is important that results from different projects are comparable. Using overarching frameworks such as the motivation framework, provided by Levontin et al. (2018), or the participant outcomes framework, developed by Phillips et al. (2018), can help compare results across projects. The chapter on evaluation in this volume will discuss further details on how to conduct evaluation and research on citizen science (Schaefer et al., this volume, Chap. 25).

In conclusion, within the field of citizen science, scrutiny of citizen scientists and their experiences is growing. There is an increased understanding of what motivates them, what benefits they may get out of their participation, and what challenges they face. The area of participant experiences will benefit from sustained scrutiny and more overarching conclusions.

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Chapter 14
Inclusiveness and Diversity in Citizen Science

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Abstract An 'inclusive citizen science' practice encourages engagement from all members of society, whatever their social status, sociocultural origin, gender, religious affiliation, literacy level, or age. In this chapter we will first address the question of inclusiveness in citizen science and how this is tackled. We will analyse the current situation of a number of projects and initiatives within the Citizen Science COST Action CA15212 and the Horizon 2020 SwafS programme, examine the data, and discuss the main factors that encourage or hinder inclusiveness. We will offer recommendations for a possible plural participation in citizen science activities and reflect on how research is improved when diverse citizens are used as in-the-field experts. We will demonstrate how research questions can be fine-tuned and how research impacts are enhanced through citizen participation, with a focus on gender representation. Bottlenecks can occur when considering inclusiveness in citizen science, including in data interpretation, tasks that require long-term participation, and tasks that have specific language and intermediation requirements.

Keywords Communities · Democratisation · Gender · Inclusion · Minority · Representation · Inclusiveness · Opportunities · Equal · Targets · ECSA · DITOs · D-NOSES

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Introduction

Citizen science is a way to democratise science by including diverse groups of participants in the different stages of the research process (Hecker et al. 2018). It provides a particularly striking opportunity to rethink questions of inclusiveness in knowledge production: 'citizen science poses questions about who participates in science, what it means to participate in science, who gets to decide what scientific questions to investigate, and even what kind of knowledge and practice count as science' (Pandya et al. 2018). The aspirations and advantages of many citizen science initiatives are *openness*, *accessibility*, and *citizen-driven participation* (Fiske et al. 2019). Through the introduction of new and diverse groups to the scientific community, new perspectives on research questions, interpretations, and methods can develop (Bang et al. 2007, in Pandya 2012). Studies have shown that *diversity* benefits all learners, not just those from minority communities (Gurin et al. 1999, in Pandya 2012). Bonney et al. (2016, p. 12) conclude that 'if the field of citizen science is to truly contribute to democratizing science, then it must strive to reach a wider range of audiences and participants'. This is why *inclusiveness* (in terms of participation) is a core part of citizen science and should be examined along different axes such as gender, ethnicity, socio-economic and sociocultural status, location, and educational level, alongside how these axes intersect to define hierarchies and power relations. For this, an intersectional perspective can be useful (see Okune et al. (2018)). More specifically, with regard to gender, different organisations have developed in their toolkits and principles (ECSA 2015)[1] good practices for balancing the composition of citizen science teams and ensuring that women assume leadership roles in citizen science projects (Puy and Angelaki 2019).

This chapter introduces inclusiveness approaches and trends developed in different international contexts and then leads to three subsections that focus on inclusiveness more particularly within the EU research framework programmes, tackling policies, projects, and practices, including equal opportunities and gender representation within COST Action CA15212 *Citizen Science to Promote Creativity, Scientific Literacy, and Innovation throughout Europe*[2] and citizen science projects. The chapter demonstrates the added value and improvements that inclusiveness can bring to citizen science projects and research. To conclude, recommendations, challenges, and future trends in this area are addressed.

[1] An example can be found at https://www.rri-tools.eu/

[2] http://www.cs-eu.net

Inclusiveness in Citizen Science: Gaps and Trends

In this section, we will identify the many different profiles of participants involved in citizen science activities and then outline the most important developments in the evolution of inclusiveness in citizen science so far. In addition to general reflections on participation (Land-Zandstra et al., this volume, Chap. 13), this chapter adds insights on diversity issues among participants and volunteers. There has not yet been a nuanced, detailed analysis of who participates in citizen science activities (Haklay and Francis 2018), or a formal meta-analysis of representation in citizen science (Pandya et al. 2018). Only a few analyses have been undertaken that emphasise the different demographic characteristics of participant volunteers, mostly in the US and UK contexts. Some of them are summarised below:

- Pandya et al. (2018, p. 159) suggest that 'participation in citizen science, at least in the United States, does not reflect the demographics of the population, and that this schism hurts both citizen science and underrepresented groups. Individuals from groups that have been historically underrepresented in science (e.g. African Americans, Latinos, American Indians) participate less than majority groups and affluent participants outnumber less-affluent participants'. The US National Academies of Sciences, Engineering, and Medicine in an analysis of training camps for volunteer and field experience, also indicate the over-representation of generally older white females with above average education levels (Pandya et al. 2018, p. 160; Frensley et al. 2017, p. 3).
- In the online US citizen science aggregator platform SciStarter 2.0, the majority of 653 SciStarter profiles completed by the end of 2017 were female (64%) in the 35–44 age range (female median, 41; male, 47) (Pandya et al. 2018, p. 160).
- In biodiversity citizen science projects (Theobald et al. 2015; Burgess et al. 2017), 125 of the demographic profiles of participants in 329 projects were white (88.6%), while 6.1% were Hispanic and 4.6% were Asian, including Asian Americans, while Wright et al. (2015), in their study of the Second Southern African Bird Atlas Project, found that volunteers were overwhelmingly older white males with high levels of education and income.
- In two ornithology citizen science projects in the UK, studied by Edwards et al. (2018), 83% of respondents were male, and 67% of respondents had a university-level qualification. However, the links between volunteers' prior level of educational qualifications and disciplines studied are not uniform across citizen science projects.
- A report by OPAL[3] showed parity in terms of participants' gender (51% female). The number of non-white participants was also relatively high (23% in comparison with the total population in the UK of 16% non-white UK or Irish). People with disabilities, however, were fewer: only 9% of the participants, compared to 18% of the total population.

[3] https://www.opalexplorenature.org/reports-updates

- Groups, such as low-income people, people with disabilities, and people of colour, are traditionally under-represented in environmental volunteering (Ockenden 2007).
- Most surveys show who are more highly qualified and from higher socio-economic backgrounds are most likely to participate as volunteers in citizen science projects (e.g. Garibay Group 2015).

Due to these reported trends, specific actions and efforts are needed to expand the diversity of participants in citizen science projects. As projects in citizen science grow, the number of volunteers will increase in turn. However, there should be a major research interest in the motivations of voluntary participation if we take into account different axes of discrimination. Just as motivations differ between individuals, they also may differ for the same person at different times (Clary et al. 1992; Ryan et al. 2001). In other words, it is necessary to understand the cultural, social, economic, and natural barriers that currently stand in the way of volunteering involvement (Roy et al. 2012). Using inclusive approaches, which are at the core of the citizen science movement, could be a solution. There is already an observable shift in the field from the focus on participation per se to the importance of inclusive participation.

It is proposed that encouraging more diversity of participants in citizen science projects will benefit scientific outcomes by delivering them to a wider population and growing *science capital* (Edwards et al. 2018). One evolution that can be observed in this area is that more communities are devising and leading their own citizen science projects (Ballard et al. 2018; Mahr et al. 2018) providing practitioners the opportunity to support grassroots community involvement throughout the research process. This has brought with it new trends, for example, the organisation of ThinkCamp events to harness the potential of creative collaboration and support inclusive, co-creation approaches to citizen science (Gold and Ochu 2018).

At the European level, in 2018, the European Citizen Science Association (ECSA) set up a working group – Empowerment, Inclusiveness and Equity[4] – to establish collaborations with other approaches as *community-based research* (CBR), *transdisciplinary research*, and *participatory action research*. The goal is that more people from diverse backgrounds can participate in citizen science and other activities with collaborative approaches, shape them according to their wishes, and generate impacts that address their needs.

[4]https://ecsa.citizen-science.net/empowerment-inclusiveness-equity

Inclusive Approaches in European Commission Research Initiatives

Inclusiveness is one of the principles that guide the European Commission's (EC) work. In recent years, the EC has intensified the consultation process with stakeholders that benefit from the research programme funding, inviting them to take part in the drafting of these work programmes.

While citizen science is already linked to multiple organisations, grassroots groups, and associations (Göbel et al., this volume, Chap. 17), an inclusive approach has been developed within a number of European Union research programme initiatives. In this section, we will outline three case studies to show how inclusiveness can be addressed, starting with the COST Action Programme.

When funding agencies started to include citizens as stakeholders within projects, the added value of citizen science was emphasised, and the involvement of citizens through citizen science activities increased. The 'Science with and for Society' (SwafS) programme helped integrate citizen science policies within the EC research funding mechanisms, although they are now mainstreamed in the *open science* activities through the Horizon 2020 programme.[5] Two of the main EU projects funded under the SwafS call supporting citizen science are D-NOSES and DITOs. The first proposes a model to tackle inclusiveness within stakeholder engagement, and the second achieves deep public engagement in science and technology in Europe through the implementation of innovative and inclusive participatory events. We will review both projects.

Multifaceted Inclusiveness in the COST Action Programme

The COST Action Programme[6] has developed an *inclusiveness policy* around three main elements: geographical spread, career stage (involving early career investigators), and gender balance.[7] The geographical spread is focused on less research-intensive countries, termed Inclusiveness Target Countries (ITCs) or widening countries. According to ERDYN Consultants and the Centre for Social Innovation (ZSI) recent impact assessment study, respondents from ITCs appear to receive greater career impact from COST Actions than their non-ITC colleagues (Knecht et al. 2019). They also notably benefit from the fact that COST Actions usually have larger consortiums (9.1% added value for ITC, compared to 2.9% for non-ITC) than other programmes and that COST meetings are held more regularly. The respondents also confirmed a change to research networks via COST Actions – they

[5]https://ec.europa.eu/programmes/horizon2020/

[6]https://www.cost.eu/

[7]https://www.cost.eu/who-we-are/cost-strategy/excellence-and-inclusiveness/

expanded in general and specifically included significantly more ITC participation (Knecht et al. 2019).

Cost Action CA15212, which will be examined in detail below, aims to harness research capacity across Europe to investigate and extend the impact of the scientific, educational, policy, and civic outcomes of citizen science with stakeholders from all sectors concerned (e.g. policymakers, social innovators, citizens, cultural organisations, researchers, charities, and non-governmental organisations). The goal is to gauge the potential of citizen science as an enabler of social innovation and socioecological transition. In total, 37 countries participated in this Action – 20 were characterised as ITC (54%). This is reflected in the Management Committee (MC), where 37 out of 68 MC members were from ITCs (54%).

In terms of gender, there was a balance with 35 female and 34 male MC members. The distribution of gender within ITC members is also well balanced (Table 14.1).

Cost Action CA15212 had a policy to include all European countries and developed some special tools for ITC members to increase inclusiveness. One important measure was to run workshops, training schools, and MC meetings in ITCs. This helped to increase the number of participants from these countries and the opportunity for local stakeholders to participate.

It is not easy to determine the configuration of the active Cost Action CA15212 community. For example, some members of the MC do not attend meetings. Others are very active, but have no formal role, or self-fund their participation in workshops and are therefore more difficult to track administratively. Up to April 2020, 795 participants had contributed to 50 workshops, training schools, and MC meetings (Table 14.2). While at the MC meetings (the key annual meeting and decision-making forum) around 40% ITC participants were represented, at the workshops the number decreased to 25%. The percentage of female participants was about 50% but

Table 14.1 Distribution of MC members from ITCs and their gender

ITC	Female	Male
Yes	19	18
No	16	16
Total	**35**	**34**

Source: Cost Action CA15212, 27.4.2020

Table 14.2 Number of events, event type, and number of participants by gender and ITC (data from 2017 to April 2020)

Number of events	Event type	Number of participants	Number of female participants	Percentage of female participants	Number of ITC participants	Percentage of ITC participants
5	MC meeting	209	106	50.72%	86	41.15%
4	Training school	78	38	48.72%	29	37.18%
41	Workshop	512	265	51.76%	128	25.00%
50	**Total**	**799**	**409**	**51.19%**	**243**	**30.41%**

differed depending on the topic. Events that were linked to the social sciences were dominated by females, while events dealing with more technical aspects, such as data quality, data standards, and ontology models, typically had more male participants (Table 14.3).

Another gender-related aspect is the impact of Cost Action CA15212 on both female and male participants. Knecht et al. (2019) highlight that the positive impact is more indirect for female participants, as they strengthen their reputation by participating in Cost Action activities. This would be a strong argument for women's participation. Since many are held back in their careers by personal choices made to maintain the family-work balance, they could compensate by being active player in COST Actions. The greatest added value is seen by female participants in personal development, such as increased self-confidence and knowledge acquisition, which male participants did not report.

Under Cost Action CA15212, two workshops were organised specifically to increase inclusiveness: the first on Citizen Science and Gender[8] and the second on Inclusiveness in Wikipedia Publishing.[9] Both workshops have highlighted women's under-representation in (citizen) science. The first one, in March 2019, did so through the experience of female scientists in Romania who presented their countless efforts in engaging young females in science through citizen science camps and acting as role models.[10] The second workshop took place in Brussels, in March 2020, with trainer Daniëlle Jansen, an expert in Wikimedia projects (Wikipedia, Wikidata, and Wikimedia Commons), inclusiveness, and gender, who encourages female citizen scientists to publish on Wikipedia, and Quentin Groom from Meise Botanic Garden who works on the use of information technology in the analysis and dissemination of scientific information (see Box 14.1).

Cost Action CA15212 workshops have also demonstrated that providing networking opportunities can help to overcome knowledge gaps due to gender, educational level, and geography. A key challenge is to give value to what non-scientists have to share and encourage them through training sessions and meetings with scientists to adjust their level of involvement depending on their current resources, as proposed by the DITOs Escalator Model (DITOs 2019) (see the Recommendations section).

Achieving inclusiveness and diversity in citizen science projects needs a collaborative environment that provides learning and development opportunities in order to ensure the quality of research. Evaluation criteria of gender and diversity aspects in citizen science projects are also required.

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[8] https://cs-eu.net/events/internal/workshop-wg-4-wg-6-citizen-science-and-gender

[9] https://cs-eu.net/events/internal/wg1-workshop-inclusiveness-and-equal-opportunities-wikipedia-publishing

[10] Report WG4 & WG6 Citizen Science and Gender – Iasi (RO) 03/2019 https://cs-eu.net/sites/default/files/media/2019/05/Report_WG4_WG6Workshop_CitizenScience_and_Gender_20190320.pdf

Table 14.3 Percentage of female participants by event topic

Event topic	Percentage		n=
	Females	ITC	
Concepts and Methodological Framework for Mapping Stakeholders in Citizen Science	100.00%	57.14%	7
Citizen Science and Gender	100.00%	28.57%	7
Citizen Science & Social Innovations	81.82%	63.64%	11
Citizen Science Training School Barcelona	80.00%	40.00%	10
People-Places-Stories	77.78%	0.00%	9
Citizen Science in Social Sciences and Humanities	76.92%	30.77%	13
Co-creating the European Citizen Science Platform of the Future	73.68%	36.84%	19
Citizen Science in Social Sciences and Humanities	73.33%	33.33%	15
Citizen Science Strategies in Europe	70.00%	10.00%	10
Synergies of Citizen Science and Education	69.23%	30.77%	13
Progress and Prospects of Exploring Synergies between Citizen Science and Education	66.67%	11.11%	9
Doing Better Citizen Science 'From Data Quality to Project Design'	65.38%	30.77%	26
Exploring the Interplay between Human Learning and Machine Learning	64.29%	21.43%	14
Motivation of Participants in Citizen Science Projects	63.64%	18.18%	11
Citizen Science Strategies in Europe – MC Meeting	61.40%	50.88%	57
Citizen Science Training School Erice	58.33%	20.83%	24
City + Citizen Science	58.33%	41.67%	12
Develop Concepts for Training Workshops to Enhance Synergies between Citizen Science and Education	57.89%	21.05%	19
Vespucci Training School on Digital Transformations in Citizen Science and Social Innovation	56.00%	32.00%	25
Systematic Review on Training Requirements and Recommendations	55.56%	22.22%	9
A pan-European Comparison of the Development and Implementation of CS Strategies / Policies	55.56%	22.22%	9
Building a Community Network on Synergies between Citizen Science and Education	53.85%	23.08%	13
Fourth Citizen Science Cost Action – MC Meeting	50.00%	34.48%	58
Degrees of Public Participation in Scientific Research	50.00%	58.33%	12
Recommendations for the Development of (national) Citizen Science Strategies	50.00%	45.00%	20
Author Meeign	47.37%	13.16%	38
Citizen Science and Open Data: A Model for Invasive Alien Species in EU	47.37%	0.00%	19
Roadmap to Consolidate and Expand the Knowledge Base on Participation and Learning in Citizen Science	47.06%	0.00%	17
Third Citizen Science Cost Action – MC Meeting	45.71%	45.71%	35
Citizen Science and Environmental Monitoring	45.45%	36.36%	11
Kick – it – off – the – ground – MC Meeting	44.07%	35.59%	59
Lessons Learned from Volunteers' Interactions with Geographic Citizen Science Applications	41.67%	41.67%	12

(continued)

Table 14.3 (continued)

Event topic	Percentage		n=
	Females	ITC	
Citizen Science and Open Science	41.67%	0.00%	12
Develop and Test an Ontology for Citizen-Science Metadata	35.71%	7.14%	14
Citizen Science Social Innovation as Promoter of RRI	33.33%	55.56%	9
Identifying and Describing Major Challenges for Citizen Science in the Next Decade	33.33%	16.67%	6
On Citizen-Science Ontology, Standards and Data	30.00%	5.00%	20
Creating a Citizens' Information Pack on Ethical and Legal Issues around ICTs	35.29%	17.65%	17
Ensuring scientific quality of Citizen Science through data quality and project design	28.57%	14.29%	14
Citizen Science as a Tool for Education / Promotion of Scientific Literacy in Evolution	28.57%	14.29%	7
Quality Aspects in Citizen Science	25.00%	65.5%	8
Inclusiveness and Equal Opportunities in Wikipedia Publishing	25.00%	37.5%	8
Towards a New Ontology of Citizen Science	22.22%	33.33%	9
Coordination of Efforts with Existing Networks and Groups Working on Standardization in Citizen Science	16.67%	50.00%	6
Citizen Science Training in Coimbra	10.53%	63.16%	19
House of Apps: Create great apps for citizens	0.00%	0.00%	6

The D-NOSES Inclusive Engagement Model

D-NOSES[11] is an ambitious citizen science project, funded by Horizon 2020, which aims to include *odour pollution* in policy agendas worldwide. D-NOSES is committed to being inclusive in the *citizen engagement* process. This includes people from different sociocultural backgrounds, socio-economic status, literacy levels, religious affiliations, minority groups, gender, age, people with disabilities, etc. They share the common issue of being affected by odour problems in their communities. Odour pollution is the second largest category of environmental complaints globally (ADEME 2005) even though it is an under-regulated issue that leaves citizens and entire communities unprotected and often leads to socio-environmental conflict. D-NOSES has developed an innovative methodology to improve odour issues at the local level using citizen science and participatory mapping strategies –

[11]D-NOSES (Grant Agreement No. 789315) is a Horizon 2020 project funded under the SwafS call. For more details: https://dnoses.eu/about-d-noses/

Box 14.1: Workshop on Citizen Science and Inclusiveness in Wikipedia Publishing

With over 134,000 active contributors on the English-language Wikipedia alone, it can be argued that Wikipedia is the most diverse international citizen science project in terms of usage, participants, and languages. It has an irreplaceable role in formal and informal education and in the democratisation of information globally. Furthermore, since 2012, Wikimedia has developed Wikidata with multilingual, public domain data. The workshop helped to identify the knowledge gaps that prevent some population groups from using these tools, most notably female citizen scientists. Women are indeed under-represented on Wikimedia – for example, only 11% of women publish on the Dutch-language pages and 20% on the English-language pages. Women account for only 17% of the biographies published on the English-language Wikipedia pages. This is a major concern – the low level of female representation could be due to a lack of information, difficulty in accessing the tools, or other tangible obstacles that impair women from being involved and included in this community of practitioners. During the workshop, discussions explored various ways to encourage women to take part in the Wikimedia community. First, we need to avoid making rigid distinctions between female non-scientists and female scientists, and even male non-scientists and male scientists. Non-scientists and women are inhibited from publishing and think that it is not for them. This is observable in Europe and the USA. Daniëlle Jansen stressed, however, that it is very different in the Caribbean, where women networks are traditionally in charge of education and knowledge transfer. Thus, there is a lot to learn from practices in different geographical areas and cultures, notably including women and their networks that can leverage support. We need to disinhibit women and offer them training and promote the use of their local and national languages to publish their articles on Wikipedia. Recognising such inputs as being equally important as the articles published on the English-language pages will encourage under-represented communities to participate.

this is being validated in ten different pilot sites in Europe, Chile, and Uganda. The main tool for data collection to collaboratively build odour maps is the citizen science *open app* OdourCollect (odourcollect.eu). With the community maps platform Odours Affecting Communities, communities affected by odour issues can map them collaboratively so they can be viewed by all. All D-NOSES tools and resources are being placed in the project's Odour Observatory (odourobservatory.eu), the first of its kind. The project enhances digital inclusiveness and science education regarding the use of new technologies, particularly for women and girls. The project has also created other tools for ensuring inclusiveness in specific social environments, for example, the Smell Diaries[12] for the elderly or people with difficulties in accessing digital technologies. The D-NOSES methodology aims to empower citizens and key stakeholders to generate, access, and use data related to odour pollution. The collected data is then used to inform and co-design possible solutions to better manage and mitigate odour problems. Thus, stakeholder engagement – particularly citizen engagement – is fundamental to its model.

The project aims to engage the *quadruple helix* of stakeholders (*citizens and CSOs, public authorities, industry and SMEs, and academia*) while ensuring inclusiveness and diversity in engagement. Odour pollution may have similar effects in neighbourhoods with completely different socio-economic profiles. One of the key challenges is how to orchestrate the engagement of different stakeholders – citizens, CSOs and NGOs, industries, local and regional authorities, odour experts, etc. – as they can be affected in different ways by the problem and have conflicting interests and goals. The D-NOSES *engagement model* is based on engagement models from project partners Ideas for Change (the Bristol Approach, Rogers et al. 2017) and Mapping for Change (Haklay and Francis 2018). D-NOSES will combine best practices from both models and expand them with new methods and tools specific to the domain of odour pollution, the quadruple helix approach, and inclusiveness. The aim is to involve people from different social backgrounds in all the project phases – from *problem definition* to *pilot design* to *data collection*, including contributing to *action*, following the *extreme citizen science* approach (see phases in Fig. 14.1).

The phases of the D-NOSES inclusive engagement model are outlined in Fig. 14.1. Partners leading pilot case studies are encouraged at an early stage to understand the social realities of the areas affected by odour issues being focused on. In each of the phases, the project aims to identify the communities affected by odour pollution (engaging not only the 'usual suspects', i.e. people already interested in science, but all community members) and co-create methods and tools to engage them in the project and improve their quality of life. The model starts with desk research and then leads to fieldwork and ethnographic research. It includes key stakeholders to conduct preliminary conversations, to better understand the existing different realities. Co-creation workshops are a key method used to make people feel the project is theirs, contributing to their involvement as active actors who construct actions within the phases proposed, and eventually contribute to local decision-making. The pilot studies are shaped by the co-creation of the actors concerned. One of the main challenges of citizen science projects is to involve and engage participants who can contribute to data collection for a sustained period of time. Moreover, it is difficult to have a diverse group of people who may not be familiar with one another nor exposed to public participation in their locales. At the end of the chapter, recommendations and conclusions are made regarding how to meet the need for inclusiveness by following the D-NOSES engagement model.

[12] https://odourobservatory.org/wp-content/uploads/sites/2/2019/09/Smell-diary-template.pdf

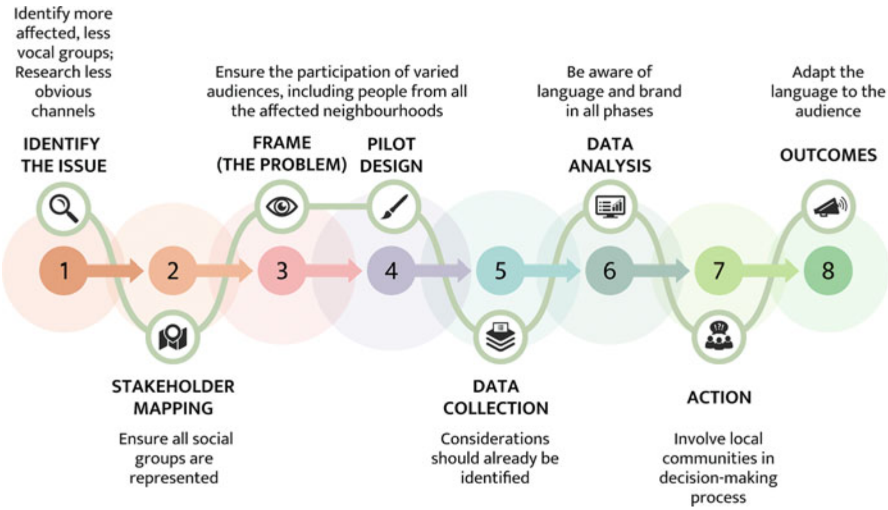

Fig. 14.1 The D-NOSES inclusive engagement model
The D-NOSES phases for the pilot case studies, plus the recommendations and tools to meet inclusiveness in stakeholder engagement in citizen science initiatives, have been co-created in the D-NOSES Consortium (particularly through partners Mapping for Change, Ideas for Change, and Ibercivis). Partners Mapping for Change and Ibercivis have benefitted from additional funding from two Short Term Scientific Missions under the COST Action CA15212 to work on the development of the D-NOSES engagement model, amongst other topics of interest

DITOs: Addressing Gender and Inclusiveness

With more than 3.8 million people online, the Doing It Together Science (DITOs) project reached an enormous number of participants. Events were organised in 18 countries – 15 EU member states, Switzerland, the USA, and Israel. Belgium hosted the largest number of events followed by the UK, Slovenia, and the Netherlands.

Including workshops, science cafes, gaming competitions, and the travelling DITOs bus, more than half of the DITOs events (441/829) used interactive formats involving 165,372 citizens. DITOs events reached people of all ages. Those under the age of 20 and those aged 50–80 participated the most. In total, 48.5% of all DITOs event participants were female. The BioBlitzes and conferences had particularly strong female participation with 56.7% and 54.5%, respectively, while there was a higher percentage of male participation in game-related events (see Fig. 14.2).

For DITOs, it is interesting to note that gender participation did not depend on the event facilitator's gender, nor did it vary much between event types. However, female participation varied significantly between different countries. DITOs results

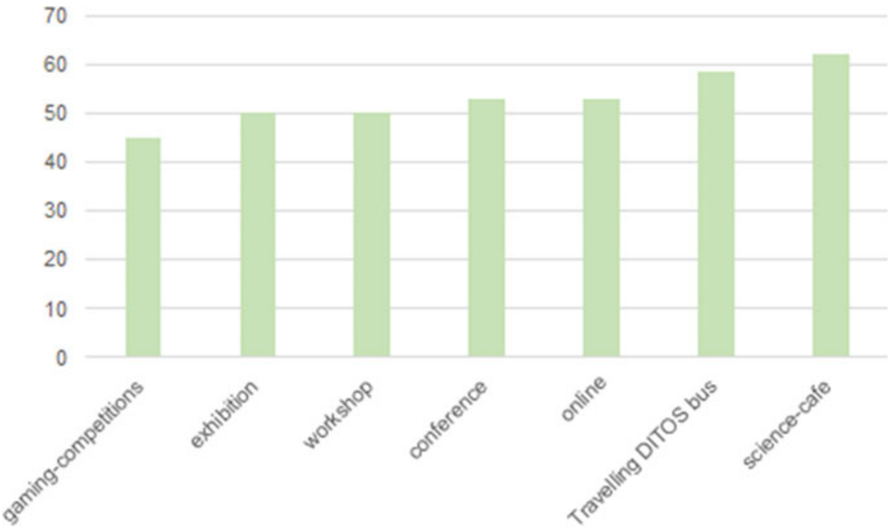

Fig. 14.2 Female participation according to DITOs event type

seem to be in line with other studies reporting difficulties in attracting women to science studies, for example, in German-speaking countries (Kröll 2010).

All DITOs events went through an evaluation process to collect information on the participants' profiles, including gender. In general, gender distribution was based on estimates from the event facilitators or organisers, but for some events gender information was based on participant questionnaire data. Note that Fig. 14.3 shows a relatively equal distribution between just under 40% and just over 60% females. The age axis has been scaled to emphasise any differences in gender participation.

Interestingly, higher percentages of female event participation come from Switzerland, Germany, and Luxembourg – where traditionally female STEM (science, technology, engineering, and mathematics) student rates are lower than the European average. This may be due to the fact that some of the activities in DITOs were about communicating scientific processes rather than producing science, thus encouraging citizens to engage in science. Such an approach may have been appealing to an audience that is not interested in STEM activities.

Recommendations

As the definition of citizen science is contested (Haklay et al., this volume, Chap. 2), we recommend that citizen science is explained to *target audiences* before they start a project or activity. Indeed, from the evaluation of the practices described, for

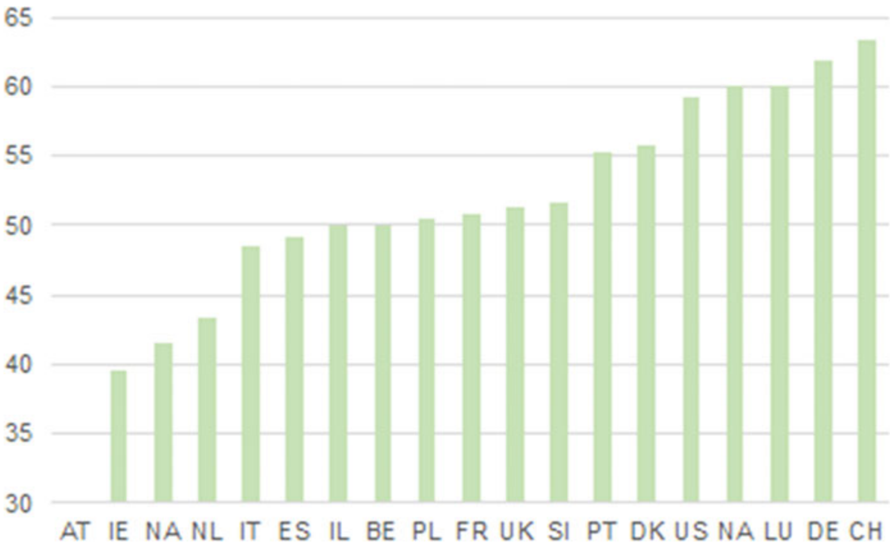

Fig. 14.3 Percentage of female participation in events per country. No relevant data for Austrian policy round table in the reporting period. Note the scaling between 30% and 65%

example, in the DITOs project, the partners highlighted that 'creating inclusion begins within the organisation/team/facilitator making sense of the terms they are promoting and then designing events around that' and that 'inclusion means starting with the needs/interests of participants but that to be inclusive you need to be also exclusive' (DITOs 2019). Inclusion is also about understanding and learning from the target audience. Citizen science and participatory science are often unfamiliar concepts for participants; project leaders may need several iterations of defining terms and objectives so that they are understandable and expectations can be made clear.

The term science in itself is sometimes a barrier, and all project terminology must be chosen carefully to make sure that practitioners and volunteers talk the same language and have the same understanding of the objective. Time commitment is also key to create trust and facilitate fruitful collaboration (Senabre et al., this volume, Chap. 11).

In the DITOs project, through the implementation of the *escalator model*, the organisers approached activities and events viewing participants not only as data collectors or passive consumers of science activities, but with the aim of achieving creative scientific skills, analytic work, and science-based citizen engagement. It is important to understand the escalator as a number of forms of interaction, which are suitable for different types of audiences and their interests and varying capabilities of organisations and facilitators. Not all participants want to move up the escalator, and not all organisations are interested in 'educating' participants to become autonomous researchers.

Offering multiple project entry points as well as multiple ways to participate at different levels of commitment are key to engaging new and diverse participants. This requires acknowledging that people have very different interests and motivations for engaging in citizen science. Real inclusion within citizen science is more likely to occur if issues are framed around participants' values, focusing on local and tangible concerns, and if individuals believe their actions have impact (Whitmarsh et al. 2010). Framing research problems as local issues can help to engage individual citizens if they feel a sense of place attachment (Devine-Wright 2013). This requires reconsidering the role of different axes of inequality (e.g. gender). By providing an inclusive and integrative framework, different groups are supported to engage with specific topics. The citizen science inclusiveness and gender balance has not been considered so far as a research topic. In order to increase inclusiveness also in the area of gender equality, gender balance should be striven for in all phases of a citizen science project.

Another recommendation is addressed to funding organisations supporting more engagement from citizens in science: to consider more inclusive citizen science approaches to ensure that organisations, projects, and activities take advantage of the broadened connection inclusiveness brings to stakeholders and a more diversified audience for project research.

Looking at the inclusive engagement model proposed by the D-NOSES project and reflecting upon its implementation in a number of ongoing citizen science initiatives resulted in a number of recommendations to meet inclusiveness. First, it should be acknowledged that engagement, involvement, and active participation is extremely costly in terms of human resources and time commitment. Engagement needs to be maintained continuously over time. The more project leaders or facilitators participate in actions and are present in the communities affected, the better and the wider community engagement is. This needs to be considered if aiming to achieve greater engagement in a citizen science project, particularly regarding inclusiveness.

Moreover, it is important to plan engagement actions in each project phase to ensure inclusiveness from the outset. Deepening the knowledge on the social realities of the affected communities and undertaking ethnographic fieldwork prior to engagement have been crucial to ensuring inclusiveness. Acknowledging the participation of citizens from the beginning of a project is important to better understand the different realities and shapes research questions, methods, and tools for engagement (e.g. adapting D-NOSES to the contexts and needs of citizens affected by odour issues). Participants need to feel part of the project, and the usual gap between 'us and them' should be avoided. Questions that need to be answered include: Have less vocal groups been identified? Has it been ensured that all groups are represented when choosing the stakeholders to involve? How can we ensure participation within the different social realities represented? Are we involving communities when constructing the engagement methods and tools? When and where is it better to conduct rapid appraisals or co-creation workshops to ensure a wide variety of participants? Are data collection strategies adapted to the capabilities of the different communities involved? Are the voices of citizens and communities really being heard? Are they able to participate in local decision-making with quadruple helix stakeholders, allowing for a positive change?

As an example, in the Barcelona pilot case study in the D-NOSES project, varied socio-economic and sociocultural realities have historically been affected by the same odour issues in the east of the city, by the coastline, where several odour-emitting industries cohabit with a variety of communities – from a socially disadvantaged area to a newly refurbished neighbourhood by the sea. Getting a deeper understanding of these realities has been crucial to involve people in the project and apply different engagement methods, data collection strategies, and tools accordingly. Participation in community events has also been significant for engagement and inclusiveness. In these events, we have been able to co-create engagement strategies to be more inclusive and achieve broader participation with the support of the already participating citizens. Getting to know the community channels of participation – in this case, CSOs and neighbourhood associations – has been relevant to organise encounters and workshops. Adapting the language to local terms within D-NOSES actions has also been valuable. In this way, people feel the project is theirs – increasing the impact of its actions and achieving inclusiveness.

Challenges and Future Trends

Thanks to digitalisation, citizen science is experiencing a revival. In recent years, hundreds of projects have been initiated, encouraging people from different backgrounds to participate in the collection, labelling, categorisation, and counting of different types of data. Digital platforms and tools have been developed to organise these different processes of participation (Skarlatidou et al. 2019) in innovative forms. Digital infrastructures can present both obstacles and opportunities for more diverse ways of undertaking citizen science through multiple ways of participation. Social groups that have been historically excluded from the hegemonic processes of production of knowledge remain excluded, and new inequalities emerge. Improved access channels are needed to link the potential brought by digitalisation potential with those from diverse, nontraditional, and excluded backgrounds to foster inclusion, empowerment, and emancipation.

As we live in the information revolution era, where technology plays a key role, citizen science approaches should consider training on the use of technologies and mobile applications to prevent knowledge gaps and achieve diverse participation. In order to overcome the language barrier for non-English speakers, software and interactive websites should enable participants to publish in and use their own language to share local or national concerns and knowledge.

Providing incentives and career opportunities for young citizen science researchers will help to attract new volunteers. Within this framework, developing close, cooperative relationships between universities and non-governmental organisations on citizen science will have significant advantages. The professional infrastructure of universities (access to technology, well-equipped libraries, specialised staff) and their scientific expertise (in fields such as statistics, information technology, legal and ethical knowledge, quality assessment, and communication) can provide open access to the public in citizen science and support sponsors in carrying out research projects in citizen science.

As citizen science movements grow, we can observe that some segments of the population are more inclined to take part than others due to their level of education, their geographic location, and the network or social environment they belong to. While broadening diversity is desirable to ensure varied contributions to science in both quantity and quality, it is important, however, when undertaking projects to ensure that the uniqueness and diversity of communities is respected and represented. Identification of target participant groups allows for more effective engagement strategies to be implemented, including tailored materials, communications, and training. Running small-scale trials or focus groups within target communities is a common method of assessing the effectiveness of engagement techniques and the suitability of materials and methodology (Tweddle et al. 2012). It is important to consider how topics and audiences impact engagement. Some studies suggest that locality is an important aspect of engagement with citizen science and acts as a catalyst for sustained engagement. Designing activities and projects that are grounded in local issues creates a captive audience and can maintain engagement for longer periods (Rotman et al. 2012). Pandya (2012) proposes a general framework to design citizen science projects that align with community priorities and increase inclusion. This framework involves five actions for citizen science project development and implementation: (1) aligning research and education with community priorities, (2) planning for co-management of the project, (3) engaging the community at every step, (4) incorporating multiple kinds of knowledge, and (5) disseminating results from the work widely (outside of scientific publication). Bonney et al. (2016) focus on Community Science Projects (CSP) as a type of public participation model within science defined by the nature of the activities in which their participants engage and its potential to engage a range of audiences that typically have not previously engaged with science. Such projects meet people where they are —geographically, intellectually, and in terms of their values, interests, families, and jobs.

Conclusion

In this chapter, we have tried to present a variety of inclusive models that can be taken as best practices to increase citizen inclusion in (citizen) science and in societal challenges. Another societal challenge in which inclusion has played a major role has emerged while writing this chapter: the COVID-19 health crisis, which has highlighted inclusion through health concerns and the need for rapid reaction from several stakeholders including governance organisations, science, citizens, and industry. An efficient and responsive quadruple helix has not yet been put in place, and it is probable that more channels and direct links need to be developed to achieve a coordinated response. Efforts should be made to foster inclusiveness and equal opportunities within all fours areas of society (industry, science, citizens, policymakers) and to form the quadruple helix. If each stakeholder and community could open more doors, form collaborations, and leave aside preconceived ideas towards the other three, they would enrich solutions for local, national, and global scientific issues.

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Chapter 15
Learning in Citizen Science

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Abstract Citizen science is a promising field for educational practices and research. However, it is also highly heterogeneous, and learning happens in diverse ways, according to project tasks and participants' activities. Therefore, we adopt a socio-cultural view of learning, in which understanding learning requires a close analysis of the situation created both by the project tasks and the dynamics of engagement of the participants (volunteers, scientists, and others). To tackle the complexity of the field, this chapter maps learning in citizen science into six territories, according to *where* learning might take place: formal education (schools and universities); out-of-school education (science and nature clubs, summer camps, outdoor education, etc.); local and global communities (neighbourhood associations, activist associations, online communities, etc.); families; museums (science museums, art museums, zoos, and botanic gardens); and online citizen science. For each territory, we present key findings from the literature. The chapter also introduces our six personal journeys into the field of learning and citizen science, displaying their variety and the common lessons, challenges, and opportunities. Finally, we present four key tensions arising from citizen science projects in educational settings and look at training different stakeholders as a strategy to overcome some of these tensions.

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Introduction

We have heard these questions many times, from teachers, project leaders, politicians, activists, and volunteers, all active in the field of citizen science (Fig. 15.1). They reflect the emerging importance of educational practices and research in citizen science. Citizen science pioneers shaped the field by introducing citizen science as 'a two-way street', in which scientists depend on amateurs to collect data, but 'participants gain from the projects, too. From backyard birders to school children, amateur ornithologists become proficient in bird identification, acquire the skill of patient observation, imbibe the process of scientific investigation, and gain the satisfaction of furthering scientific knowledge' (Bonney 1996, p. 7). In this vision, passion and collaboration help people gain knowledge of the topic under study, practical and methodological skills, and some familiarity with the scientific process.

However, demonstrating the educational benefits of citizen science projects in a scientific way is not an easy task. First, citizen science appears in many forms and is a highly heterogeneous field, embracing various disciplines and topics, from astronomy to ecology, from psychology to mathematics, and beyond. Within any given field, citizen science projects may vary considerably. In this chapter, we focus on a vision of citizen science which fully embraces its social responsibilities and its educational potential by engaging citizens in meaningful scientific activity connected to real-life challenges.

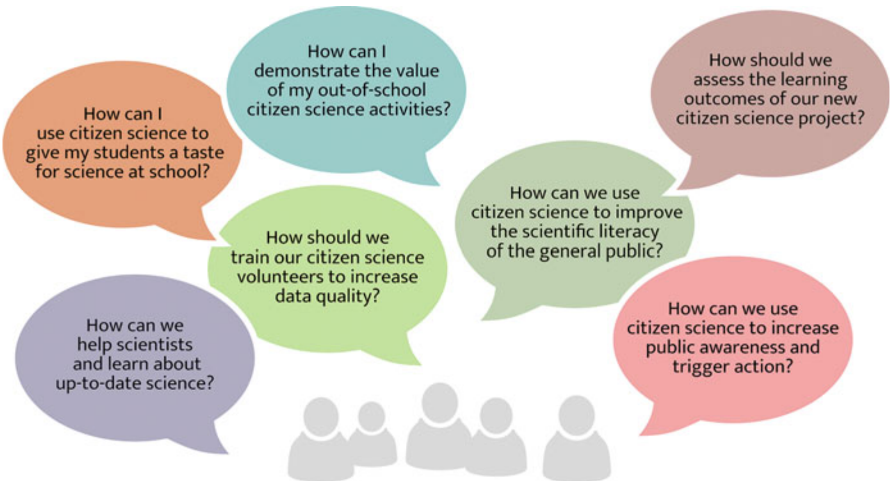

Fig. 15.1 Frequent questions regarding learning in citizen science

Second, the role of research in this field is varied. Over the last 20 years, educational research in citizen science has tackled this challenge by investigating individual learning outcomes in multiple projects, establishing typologies of learning outcomes (see Kloetzer et al. 2013; Phillips et al. 2018; Jordan et al. 2012; Ballard et al. 2017a). Researchers have also explored how these learning outcomes are produced and the dynamics of learning (see Kloetzer et al. 2013; Luczak-Roesch et al. 2014; Jordan et al. 2016). From an educational perspective, evaluation and design have also been a primary research focus (see Bela et al. 2016; National Academies of Sciences, Engineering, and Medicine 2018). In addition, researchers have investigated learning in citizen science for specific populations (e.g. school children or young people in out-of-school activities; see Perelló et al. 2017); in connection to participation, motivation, and creativity (see Jennett et al. 2016); and in connection to place (see Evans et al. 2005; Karrow and Fazio 2010; McGreavy et al. 2017). Citizen science is also connected to technological progress, with a new field emerging on collaboration and learning between humans and artificial intelligence (see Franzen et al., this volume, Chap. 10). Although educational research on citizen science is blossoming, we still lack integrated knowledge about the educational benefits and dynamics of citizen science, both in formal and informal settings.

In this exciting but challenging context, this chapter aims first to map the field for readers. We look at the interplay between learning and citizen science by organising the field into six *territories*. In each of these territories, we offer landmarks for the motivated explorer by providing selected bibliographical references. We provide an introduction to the field for educators, scientists, project leaders, and activists running citizen science projects who would like to learn more about their educational potential and how to support it.

Consistent with our view of science as a contextualised, historically constituted, and continuously developing activity, the second part of the chapter presents six personal journeys to the field of learning and citizen science. These accounts reflect varied pathways and emphasise that citizen science is not a formal discipline, but often crosses multiple established fields. As such, there is no formal path to citizen science; the steps that each of us took are as diverse as our professional backgrounds, research topics, and educational motivations. Through presenting our six stories, we hope to inspire others to join our collective efforts in understanding learning in citizen science.

Finally, we reflect on some challenges for learning in citizen science by highlighting some key outcomes of our collective work in COST Action CA15212 *Citizen Science to Promote Creativity, Scientific Literacy, and Innovation throughout Europe* over the period 2016–2020. We identify some tensions between the field of education and the field of citizen science, as well as some strategies to overcome them, including training recommendations for different stakeholders.

Mapping the Field

To tackle the complexity of the field, we have adopted a model mapping the field of learning in citizen science according to the institutional settings potentially involved. The model presents six territories according to where learning might take place. These territories indicate different sociomaterial contexts and resources, cultural and institutional values, and, sometimes, the various groups who may take part in citizen science projects. They are:

1. Formal education (schools and universities)
2. Out-of-school education (science and nature clubs, summer camps, outdoor education, etc.)
3. Local and global communities (neighbourhood associations, activist associations, online communities, etc.)
4. Families
5. Museums (science museums, art museums, zoos and botanic gardens, etc.)
6. Online citizen science (Fig. 15.2)

Fig. 15.2 Mapping the field of learning in citizen science into six territories

Formal Education

The integration of citizen science into formal education provides the unique opportunity to reach all sections of society, thereby fulfilling the promise of its transformative potential for all beyond its typical audience of well-educated, affluent individuals (Ruiz-Mallén et al. 2016). Schools are perceived as potential multipliers: teachers and educators play a key role as intermediate experts (Weinstein 2012) – they act as participants, facilitators, and motivators in citizen science projects.

However, school settings also place specific constraints on learning. Research has repeatedly highlighted challenges to learning via citizen science projects in schools. We will outline some of the main challenges below.

Students' Motivation If teachers or staff at universities participate in or initiate citizen science projects where students are automatically enrolled (Kelemen-Finan et al. 2018), student engagement is delicate. Self-determined learning, which is a key feature outside schools, is limited in this context.

Engagement of Teachers The adoption of citizen science projects by teachers is critical, but difficulties can arise. How teachers and educators view their roles in teaching, alongside a perceived scholarly authority over their students, can contradict the reality of their engagement in citizen science projects (Fazio and Karrow 2015). Their multiple tasks as participants and facilitators makes school participation in citizen science challenging, especially if teachers lack confidence in their content knowledge, scientific literacy (Jenkins et al. 2015), or identification skills for outdoor projects (Kelemen-Finan and Dedova 2014) – this may require training to overcome (Jeanpierre et al. 2005; Zoellick et al. 2012).

Connection to Curricula The relationship between learning and learning objectives is institutionally defined, through national and disciplinary curricula, programmes, exams, evaluations, etc. Teachers' and consequently students' participation in citizen science depends on school frameworks and curricula (Jenkins 1999) which need to allow for real-life learning in scientific projects. Flexible curricula facilitate teachers' engagement.

Balance Between Competing Interests Teachers and scientists need to balance educational and scientific outcomes to guarantee successful cooperation (Kelemen-Finan et al. 2018). The varying goals of students, educators, and scientists influence the learning processes in the respective interfaces between them; for example, teachers might focus on increasing the content knowledge rather than the scientific literacy of their students (Scheuch et al. 2018), while most scientists focus on data quality. Consequently, a third party, such as a university, can mediate between scientists and educators to ensure that both research goals and educational outcomes can be achieved (Zoellick et al. 2012). Additionally, citizen science projects adapted to the school context should be publicised so that teachers can easily identify them.

Key factors of success regarding citizen science projects in formal education have been identified in the literature. First is *institutional and technical support for* *teachers*. Support from school principals and colleagues is an important aspect of teacher participation in citizen science, which often requires additional (time) resources from teachers (Harlin et al. 2018). Technical support may also be required.

Second is *ready-to-use material and lesson plans connected to school curricula*. Providing teachers with well-designed materials with lesson plans, background information, learning objectives, and connections to the curriculum is essential (Jenkins 2011). These were successfully implemented in the Monarch Larva Monitoring Project (Kountoupes and Oberhauser 2008) where citizen scientists monitored the larval host plant, as well as the eggs, caterpillars, and pupae of monarch butterflies at a specific site. In the Classroom FeederWatch project (Bonney and Dhondt 1997), the tasks were linked to the curricula of the respective age groups (Bonney et al. 2009, 2016). Projects can be connected to the school curriculum through their topic but also through dealing explicitly with data analysis. For example, the two projects above have value for teachers despite their contributory nature, because they offer web tools to download data and instructions for data analysis to empower citizen scientists to perform their own analysis (Bonney and Dhondt 1997). These resources reduce the risk to teachers of failing to comply with the educational goals of school curricula (Gray et al. 2012). Smaller contributory projects often lack the resources to fulfil both scientific and educational goals, especially if students are involved in data collection without prior experience of the inquiry process (Jenkins et al. 2015). This was also shown by Brossard et al. (2005) who concluded that the understanding of the *nature of science* only increased if it was addressed explicitly throughout a project.

Inquiry-based learning within citizen science increases engagement, motivation, content learning, and understanding of the nature of science (Jenkins 2011). Furthermore, the established relationships between educators, scientists, and students contribute to students' aspirations (Paige et al. 2015). One comparative study found significant positive effects from participation in citizen science projects, compared to classroom-based science education, on content knowledge, mastery, and self-efficacy in scientific observation skills (Hiller and Kitsantas 2014). In university teaching, the nature of feedback to participants in citizen science projects had an effect on their motivation and efforts: a combination of positive and directive feedback was more effective than positive feedback alone (He et al. 2018). Participation in citizen science provides the ability to question 'the mechanisms involved in the transfer of scientific knowledge between research and other communities, about the articulation of expert and lay understandings of science, and about the ways in which the public understanding of science is understood by science teachers and others' (Jenkins 1999, p. 708).

Out-of-School Education

Citizen science projects have also conquered the after-school and out-of-school sphere. The Mad Science project engaged students from low-income communities in an after-school curriculum including participatory sensing in apprenticeships with scientists. The programme led to more favourable views of technology, enjoyment of interactions with technology, and increased aspiration for engagement in *science, technology, engineering, and mathematics* (STEM) education and/or careers (Heggen et al. 2012). An example of a scaled after-school programme without direct contact with scientists is the Science Action Club, which began in 2011 and has since engaged 62,000 youth and educators with an environmental education-focused after-school curriculum; this also involved citizen science activities, for example, Bug Safari using iNaturalist. Citizen science summer programmes, which were part of Ballard et al.'s (2017a) study, represent another format for out-of-school initiatives. Through observations and interviews, youth development of Environmental Science Agency was investigated. The study found three key citizen science practices which could open up pathways to Environmental Science Agency development: 'ensuring rigorous data collection, disseminating scientific findings to authentic external audiences, and investigating complex social-ecological systems' (Ballard et al. 2017a, p. 65).

Local and Global Communities

Evaluation of the learning taking place within communities is often more complex than that of student learning in formal and informal environments. This is due to the unstructured nature of this experience and the diversity of participant backgrounds, prior knowledge, and experiences. When involving adults in citizen science, learning is free choice and self-directed (Falk and Dierking 2012); learning outcomes are generally aligned with the participants' experiences (Phillips et al. 2018). Engagement and learning can also be affected by the personal goals and agendas of the participants. For example, in the Science in the City Air Quality Monitoring project undertaken by Mapping for Change – led by Extreme Citizen Science (ExCiteS) research group from University College London – citizens from various local communities across London volunteered and played an active role in designing the research plan in their area, collecting data, mapping them, and interpreting and reporting the results. The initial citizen inquiry, driven by local concerns over high pollution levels in the city of London, leads to the implementation of a protocol which monitored nitrogen dioxide (NO_2) and particulates. This triggered rich, diverse, and sometimes unexpected learning among participants, depending on the activities concretely endorsed by the participants in the project. The learning included (1) on-topic knowledge (understanding of the distribution of pollution in time, space, and height, as well as its main effects and influencing factors); (2) increased awareness of the issues of air quality and political engagement; (3) increased community identity and empowerment; and (4) increased skills in social media, communication, campaign coordination, management of the monitoring tool, online mapping, and writing based on scientific data (Kloetzer et al. 2018).

Social learning is key in a local community context. It emphasises learning as a process in which knowledge is socially constructed and distributed within the community (Bela et al. 2016). In addition to the individual learning of knowledge or skills, participants become members of a *community of practice* who learn to collaborate, reflect on their activities, and make joint decisions and judgements (Peltola and Arpin 2018). Since members in a community of practice often have diverse expertise, engaging in such communities usually requires its members to move out of their comfort zones and adopt new practices, perceptions, and communication strategies (Sagy et al. 2019). Learning in such a context goes beyond the acquisition of new knowledge and skills and may include establishing shared perspectives, clarification of arguments, enhanced dialogue between stakeholders, and the development of trust and new partnerships (Peltola and Arpin 2018).

Citizen science projects within local communities often revolve around controversial topics such as pollution, contamination, and other environmental hazards. Participants tend to be citizens who are concerned about their local environments and wish to take an active role in environmental protection. The main goal of participating in such projects is to advance knowledge of societal relevance, raise public awareness, and promote problem-solving and actionable data (Golumbic et al. 2019; Nascimento et al. 2018). Citizen science carried out by local communities often blurs traditional categories, combining them for social change: for example, mixing do-it-yourself (DIY) science, online collaboration, environmental activism, and political education. A good example of an innovative citizen science community is Public Lab, which defines itself as a 'DIY environmental science community'. It was initially established in 2010 as a result of the Deepwater Horizon oil spill, but it is now a global network of local initiatives and communities sharing tools and online communication. It defines itself through four mottos: *see for yourself*; *build a shared knowledge base*; *strengthen your community*; and *be the change*. As reported in a semi-structured interview with one staff member, 'it's not just about knowledge, although that's a key part, it's very much about what is the enemy' (Kloetzer 2017). Indeed, many citizen science projects conducted in local communities report learning outcomes associated with the above goals (e.g. Haywood 2016; Overdevest et al. 2004), articulating the unique learning process taking place within a community of practice.

Families

Some citizen science programmes are well suited for families, as they require a low commitment to voluntary work and limited time investment, are open to all, are accessible in the everyday environment, and often look at wildlife attractive to children. A reduction in nature experiences available to children has been repeatedly documented over the last 40 years, due to urban life and the central role of cars in cities, which limits children's freedom of movement (Tonucci and Bobbio 1996), and the lack of authentic outdoor experiences (Louv 2008). Citizen science is a way to encourage nature observation, reconnect families to nature, and foster intergenerational exchange.

Citizen science projects are now commonly included in recommendations for families on science and nature-related activities for school holidays. For example, an August 2019 *Guardian* article (Batten 2019) suggested participating in Puffarazzi (an RSPB puffin survey) and the Big Seaweed Search, while the YMCA's Summer Buzz provides information on how kids can become citizen scientists.[1] This shows that, in addition to organised programmes (e.g. after school or out of school), citizen science activities are promoted to families, youth groups, and individuals as opportunities to connect with nature, spend time outdoors, and contribute to science.

However, Gottschalk Druschke and Seltzer (2012), researching the learning benefits of citizen science projects involving families, reported limited benefits. Only half of the families initially engaged in the project studied continued to submit at least one (out of four) bee collections during the 4-month project. Comparing pre- and post-project surveys, they concluded that 'even those people still reported minimal content knowledge gains, modest shifts in attitudes, and potentially negative shifts in their perceptions of the involvement of non-scientists in scientific research' (p. 183). The researchers suggest that they did 'not spend enough time formulating and implementing a plan by which our citizen scientists would actually achieve these goals' (p. 183). Evans et al. (2005), engaging families in local birdwatching, conclude that interactions with scientists play an important role in increasing knowledge and attachment to an ecological place. They also suggest that 'ideally, a citizen ecological/conservation science effort should be infused into multiple aspects of the community and include not only homeowners but also school and civic groups working toward a common goal' (p. 593). We would therefore suggest that citizen science projects dedicated to families should include an explicit reflection on their educational goals, tasks, and local connections, if they aim to improve knowledge, awareness, and engagement with ecological issues in the general public.

Museums

Museums, especially natural history museums, have a long tradition of working with amateur experts and capacity building within and outside formal education systems (Star and Griesemer 1989; Sforzi et al. 2018). As centres which work simultaneously with the public and scientists, museums, zoos, and botanical gardens are ideally situated at the intersection between science, education, and engagement. In continuing this tradition, many nowadays aim to increase 'their public value and impact across society and over large geographic areas' and to engage their audience with key issues on a local and global level, such as biodiversity loss and the climate crisis

[1] https://www.ymca.net/summer-buzz/ways-for-kids-and-teens-to-become-citizen-scientists

(Sforzi et al. 2018, p. 431). Citizen science as a format aligns with these aims and incorporates the scientific and educational mission of museums.

Museums run a variety of different types of citizen science programmes catering to a broad audience. Ballard et al. (2017b) identified four main types in natural history museums: (1) BioBlitzes and other citizen science events; (2) ongoing monitoring programmes; (3) bounded field research and inventory projects; and (4) data processing of digitised collections. The same study reports educational outcomes, in addition to conservation outcomes. Evidence from participant surveys represented the learning outcomes as an 'increase in knowledge about the natural history of the site or the science process, interest or self-efficacy toward environmental science and science in general' (Ballard et al. 2017b, p. 93). Trouille et al. (2017) report that museums increasingly use crowdsourcing citizen science projects 'to engage their visitors, create metadata for digitized materials in their collections, and assist in their research efforts'. This is also apparent on Zooniverse where 15% of active projects involve museum collections or museum researchers (G. Miller, personal communication, 28 November 2019). A popular task is transcribing labels, records, and other archive materials, for example, the AnnoTate and the Notes from Nature projects which are helping to digitise collections. Other tasks are tailored to specific research needs, such as marking areas on bird skins for Project Plumage or identifying different types of blood cells for Monkey Health Explorer.

In addition to running, initiating, conducting, and coordinating citizen science projects, museums also use exhibitions and events – for example, Ecsite's Sparks exhibition,[2] Berlin Citizen Science Day[3] at the Museum für Naturkunde, and the Star-Spotting Experiment at the Natural History Museum, London – to tell stories about citizen science, encourage participation, and raise awareness of citizen science and its impact on policy and education.

Besides museums, other institutions in the informal learning sector have also been active players in the citizen science field. FrogWatch is one example of a monitoring project run by the Association of Zoos and Aquariums (AZA) since 1998. Citizen science programmes run by botanical gardens are similar to the ones run by natural history museums in that they target under-recorded species (e.g. Kew Gardens' The Lost and Found Fungi Project and the RHS Cellar Slug Hunt) or ask citizens for help with the digitisation of their collections (e.g. 'Die Herbonauten' or 'Armchair archivists 19th century letters'). From an educational perspective, the Budburst project run by the Chicago Botanic Garden is especially interesting: they provide extensive material that educators can use and have established the Citizen Science Academy,[4] providing professional development courses for educators to support the use of citizen science in the classroom and other educational settings.

[2]https://www.ecsite.eu/activities-and-services/news-and-publications/beyond-lab-beyond-sparks

[3]https://www.museumfuernaturkunde.berlin/en/press/press-releases/first-berlin-citizen-science-day

[4]https://www.chicagobotanic.org/education/citizen_science_academy

Online Citizen Science

Research into learning through online citizen science projects has grown over the last 10 years, in parallel to the extension of these projects, linked to the increased accessibility of high-speed Internet on personal computers and mobile devices. Online citizen science has developed flagship platforms in the volunteer computing movement, for example, the BOINC community and Foldit, in which volunteers co-created several scientific papers. As in other citizen science projects, the tasks delegated to volunteers can vary widely, triggering different learning opportunities. While intuitively one might imagine that projects requiring some kind of thinking from the volunteers (e.g. through classification of images, transcription, or solving games) should have more educational potential than projects requiring them to give some of their computer power to the community, in practice, thinking and learning might happen in unexpected places, for example, through overcoming the technical difficulties or uncertainties in a project (Kloetzer et al. 2016).

Learning is linked to sustained participation, which is a challenge for most online citizen science projects, in which the majority of volunteers do not return after an initial engagement or, at least, do not return regularly. The feeling of learning something due to participation in a project and opportunities for engagement in social activities around it all contribute to sustained participation (Kloetzer et al. 2016). Price and Lee (2013) investigated how volunteers' attitudes towards science changed after 6 months of participation in the *citizen cyberscience* project Citizen Sky. Their results revealed that improvements in scientific literacy were related to participation in the social components of the programme, but not to the amount of data contributed. This highlights the important role of wider communities in learning, a finding also seen in the context of informal learning through participation in digital gaming practices.

Researchers from the Citizen Cyberlab research project proposed a typology of learning dynamics and outcomes in five and six main categories, respectively, (Jennett et al. 2016), outlined in Fig. 15.3.

However, sound evaluation of the learning outcomes of these different dimensions still requires some effort. In some online citizen science projects on Zooniverse, participants self-report learning outcomes such as contributions to their scientific literacy (Masters et al. 2016) – however, Dickinson and Crain's (2019) large-scale study showed participation in a classification project on Zooniverse did not lead to increased content knowledge. Comparative or experimental methods can contribute to a more precise evaluation of the educational potential of these projects. Mixed methods, including close analysis of the task and activity offered to the participants (requiring time-consuming observations in both digital and non-digital worlds) as well as open interviews, are required. A recent systematic review (Aristeidou and Herodotou 2020) points to a lack of experimental and longitudinal studies in the field.

Fig. 15.3 Thematic map of volunteers' learning (from Jennett et al. 2016)

In principle, online citizen science projects are interesting because they are open to a wide audience (all connected people can participate if they wish) and usually have a low entry cost (you can participate online from your home for a few minutes per day). Therefore, they can engage people who live in isolated places or have limited time to participate in citizen science projects. They can also play a role in lifelong learning and development for people with scientific interests which they cannot easily fulfil in their everyday, physical lives. From a theoretical perspective, learning in these kinds of citizen science projects relies heavily on self-initiated and self-directed learning, as well as on social learning in communities of practice. However, most research has demonstrated that participants in online citizen science projects are, in the majority, well-educated Western males with a pre-existing interest in science and technology. Therefore, online citizen science has still to prove that it can attract a larger and more diverse audience.

Personal Journeys in Citizen Science and Learning

Recently, people interested in the interface of learning and citizen science have started to form a community of practice. There is no direct, formal pathway to engagement in citizen science and education, so in this section we share and reflect on our personal journeys into the world of citizen science and learning. We hope our stories illustrate that diverse backgrounds are valued in the field and that there are multiple opportunities to use one's expertise to contribute to this field. These journeys are also a way to reflect on learning from the perspective of scientists, particularly key learning processes and barriers to learning. This narrative section will then be elaborated into an extended map of volunteers' and scientists' learning.

Personal Journeys into the Field (Boxes 15.1, 15.2, 15.3, 15.4, 15.5, and 15.6)

Box 15.1: Yaela's Journey

As a young science researcher, I felt my work was novel and exciting and had great global importance. But conveying this excitement to my fellows and friends was not an easy task. This experience ignited my interest in science education and science communication and led to a PhD in science communication. As part of my research, I worked with the CITI-SENSE project, an EU citizen observatory for air quality monitoring. This was my first introduction to citizen science, and I fell in love. Citizen science brings the two branches of

(continued)

Box 15.1 (continued)
my professional development together – doing science and teaching/communicating science. By connecting the two, the public can be truly involved and empowered by science; they can help science, understand science, and use science in their day-to-day lives. My involvement in CITI-SENSE led to the development of a local citizen science project, Sensing the Air, which I have led for the past 5 years, and later to the design of a citizen science project, the Radon Home Survey, in collaboration with the Taking Citizen Science to School (TCSS)[5] research centre. My journey into citizen science has taught me that scientists are not the only experts and that lay expertise is not only valuable but crucial for scientific development. I have learned to consider many perspectives, embrace the diversity of ideas, and find innovative ways to progress science for the mutual benefit of many audiences.

Box 15.2: Silvia's Journey
My first contact with citizen science was in 2006, working as research assistant for a project for an Austrian biodiversity monitoring programme. In this study, Prof. Wolfgang Holzner promoted citizen science indicators for biodiversity (*Laienmonitoring*). Besides acquiring reliable data on attractive and well-known species like swallows and orchids, one major aim was to engage the public and schools in nature observations, thereby contributing to nature education awareness-raising. During my PhD, I aimed to initiate participatory research with farmers in Austria by encouraging farmer-led research experiments on grasslands to regulate the toxic plant autumn crocus (*Colchicum autumnale*). I was the coordinator of an interdisciplinary research team exploring biodiversity in gardens and schoolyards with 16 schools in Austria, funded by the Austrian Sparkling Science research programme. One major aim was to investigate the possible impact of citizen science on different learning outcomes of students and teachers. This project was the starting point for a spin-off citizen science project called 'Hedgehogs on their way – punks in our gardens'. The resulting contact with different stakeholders from science education led to the initiation of a training course in citizen science for teachers, consultants, and others interested in implementing local citizen science projects. I then became co-chair of COST Action Working Group 2[6] which enabled me to learn from social science researchers, especially in regard to exploring motivations of citizen scientists. It was also a unique opportunity to gain insights into the theories and methods of educational researchers.

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[5] https://www.tcss.center/english

[6] https://www.cs-eu.net/news/workshop-report-wg-2-synergies-citizen-science-and-education

Box 15.3: Joseph's Journey

I first encountered citizen science when I was finishing my PhD in astrophysics in Ireland. A colleague was looking for more efficient ways to analyse images of sunspots and realised that the Zooniverse platform would work perfectly. With help from our research group, we created Sunspotter – an online tool for classifying sunspots. Funded by Science Foundation Ireland, I facilitated workshops in schools across the country – helping students participate in the Sunspotter project while also learning about astrophysics. When I took up my academic post as a junior professor in science education in 2014, I continued my citizen science journey by sharing stories about *Sunspotter in the Classroom* (Roche 2015) and helping to coordinate national citizen science initiatives (Roche 2017). Being part of COST Action Working Group 2 (Synergies of Citizen Science and Education) has been one of the highlights of my citizen science journey. Membership of the working group helped me to undertake a 'Short Term Scientific Mission'[7] to compare citizen science education research in the UK and Ireland. I spent time at University College London exploring future possibilities for combining citizen science and science capital.[8] This built on work that I started during a Working Group 2 workshop called 'Synergies of citizen science and education'. I am now working with my colleagues at University College London to help understand how we can better serve the learning needs of the citizen science community through the establishment of a European platform called EU-Citizen.Science.

Box 15.4: Aiki's Journey

I seem to have discovered citizen science when I did not even have a clue about what it entailed. While studying biology at the University of Tartu, my wish was to become a scientist. Life changed my plans and I ended up being a biology, chemistry, and science teacher. As soon as possible, I started taking part in science projects with my students. For the Hello Spring project, we gathered data about the arrival of migratory birds; for the Air Pollution Project, we measured the pH of precipitation. In 2000, we joined GLOBE. Our students collected atmospheric and hydrospheric data. Only later did I learn about the concept of citizen science. Recently we took part in the Herbarium project, mapping *Primula veris* and collecting yeasts from the plants. My

(continued)

[7]https://www.cs-eu.net/news/stsm-role-citizen-science-education-comparing-research-agendas-uk-and-ireland-joseph-roche

[8]https://www.informalscience.org/sites/default/files/Citizen_Science_and_Science_Capital_A_Tool_for_Practitioners.pdf

Box 15.4 (continued)
students and I have learned how to gather and analyse data, and we are proud to be involved in real scientific research. The biggest challenge is to understand how to interpret the data and use it for learning experiences in the mixed-ability classroom or for conducting student research. It is not easy to motivate students to be patient and focused and use their own initiative, which is essential for this kind of work.

Box 15.5: Julia's Journey
My journey into the citizen science and learning sphere was not straightforward. I was en route to becoming a science teacher, when I became interested in informal learning. I decided to get a PhD, studying science learning at the interface of schools and an outreach lab, and then branched out to investigate learning outcomes in a science museum and science centre context. It was not until I started my MSc in science communication at Imperial College that I learned about citizen science as a participatory approach to science, citizen science typologies, and citizen science projects. With my educational background, citizen science seemed ideal as a setting for authentic science learning, and from my science communication perspective, participation seemed to go even further than the dialogue model in public engagement. Participating in the COST Action opened the door to the citizen science community for me, connected me to people with similar interests, and led me to my job as an educational researcher studying youth learning in citizen science programmes for LEARN CitSci. One of the key insights I gained about citizen science and learning is that the typologies are incredibly helpful to compare, characterise, and communicate about citizen science programmes on a meta or organisational level, but that, in addition, the character of participation in citizen science projects seems to be established during individual interactions. I am interested in future research that investigates the power relationship in these negotiations for participation and insights into how educators can support and shape participants' experiences.

Box 15.6: Laure's Journey
I am a psychologist, researcher, and teacher at the University of Neuchâtel. As a researcher, I am interested in participatory and transformative methods. My engagement in citizen science developed through my collaboration in the research project Citizen Cyberlab, designed to foster and study creative

(continued)

Box 15.6 (continued)
learning in online citizen science. The ethnographic element of the project was successful. We studied existing projects and carried out interviews with lots of volunteers and some scientists on the dynamics of participation and learning in the project. We discovered that citizen science projects offer *opportunities for learning*, which depend both on the design of the projects and the way volunteers decide to engage in these projects. We also discovered that the meta-aspects of the projects (social aspects, feedback on individual and collective performance, communication between scientists and volunteers, etc.) were critical to long-term engagement. The co-construction element of the project was not so successful. Firstly, project leaders found it extremely difficult to express the learning goals of their projects in a form which was acceptable for educational research. Secondly, the projects increasingly grew in number and complexity, and we felt unable to manage this. We then founded the ECSA Working Group on Learning and Citizen Science. What I find most interesting in this group is the mixed and interdisciplinary nature of our community, bringing together people from very diverse occupations and backgrounds: schoolteachers, scientists, science educators, and educational researchers, among others.

Our Emerging Community of Practice: Opportunities and Challenges

Our journeys and learning may be individual and personal, but together, they highlight shared opportunities and challenges in the field of learning and citizen science. Using citizen science in educational contexts and emphasising its educational goals offer opportunities to engage citizens in authentic scientific research, to break down barriers to the scientific community, to connect people's everyday lives to science, and to bring science and society together. This also provides opportunities for inspiring interdisciplinary collaborations between educators from the formal and the informal learning sector and scientists and researchers from psychology, education, and the social sciences. However, this multitude of perspectives and fields is also a challenge. Therefore, we need to develop and establish structures and formats to enable and maintain such collaborations. Only if we find ways to build relationships that go beyond individual citizen science projects can we start to fully understand our shared practices, make use of the synergies, address the challenges, and share our insights to inform the broader citizen science field.

Based on our own experience, which the journeys above partly reflect, and some exploratory research (interviews with scientists involved in Citizen Cyberlab citizen science projects), we can draft an extended map of volunteers' and scientists' learning in citizen science projects (Fig. 15.4).

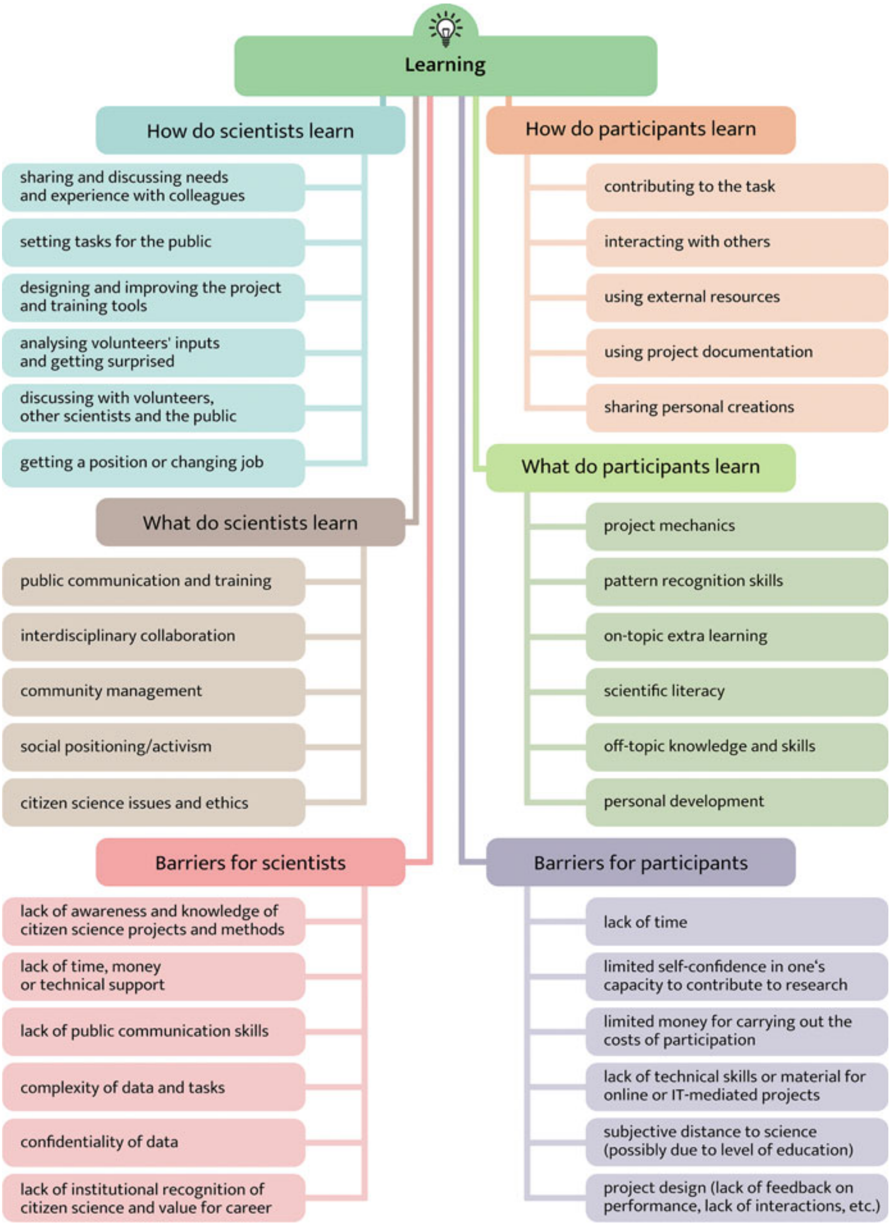

Fig. 15.4 Extended thematic map of volunteers' learning

The right half of the thematic map has been simplified to accommodate all types of citizen science, not only online citizen science. We have also added barriers to participation and learning for volunteers. The left half of the thematic map extends the learning outcomes, dynamics, and barriers to scientists who lead citizen science projects. This shows that scientists progress from undertaking citizen science because of a scientific need (such as a need for widespread computer power or data they cannot afford to access through conventional means) to discovering both the opportunities and challenges of citizen science, including interdisciplinary collaboration and new professional opportunities, alongside the lack of institutional recognition.

The development of the first community of practice (Lave and Wenger 1991) in the field of learning and citizen science was facilitated by the Cost Action workshops. In the following section, we share insights from those workshops.

Challenges for Education and Citizen Science

To conclude this chapter, we would like to highlight some challenges for education and citizen science which have consequences for the design of educational citizen science projects. We will present, first, four tensions linked to the integration of citizen science into mainstream education and, second, training needs for both volunteers and scientists.

Tensions Arising from Citizen Science Projects in Educational Settings

Four tensions have been identified if Citizen Science projects are integrated into mainstream education (Roche et al. in review). These tensions are competing scientific and educational goals; differing underlying ontologies and epistemologies; diverging communication strategies; and clashing values between advocacy and activism.

The differing onto-epistemological perspectives between citizen science and education is one of the most nuanced tensions to navigate. A synergy can be achieved if the educational, learning, and scientific outcomes are considered at the design stage of each project and individualised learning outcomes measured during participation.

There has long been tension around communication between scientists and wider society with one-way communication often being favoured over dialogue and participatory approaches. Opportunities for solutions arise from collaborations between scientists and communication experts. As open science becomes more firmly embedded as a cross-cutting aspect of research that scientists need to address in order to be awarded European research funding at the highest level, citizen science has the chance to be firmly embedded throughout institutions of higher education.

The tensions recognised between advocacy and activism also have potential for synergies to be developed. Transformative approaches to education, where students are empowered to be active partners in their own learning, adhere to the visions of both social activism and citizen science.

While these tensions and synergies are often only broadly discussed, it is important to recognise and address such tensions within individual projects. This would ensure maximum benefit, both in terms of learning and educational goals and in terms of the project's scientific and social goals.

Training Requirements for Citizen Science Projects

Implementing citizen science projects successfully while adhering to the needs of the diverse stakeholders involved is a complex task which requires thoughtful design and construction. Different audiences have varying perspectives on challenges linked to citizen science projects demanding unique solutions for each audience. One of the synergies identified to alleviate gaps of knowledge and experience is to develop training sessions that support citizen science conduct while ensuring that desired outcomes are satisfactorily accomplished. Providing such training can help obtain the required scientific outcomes while improving participants' scientific competence and increasing awareness of the issue at hand. How to best design these training sessions, the training requirements for diverse projects, and the topics that need to be addressed were some of the issues discussed in one of our workshops. The full conclusions of our discussions are documented in a report (Lorke et al. 2019).

In this workshop, we identified three key audiences of citizen science project training and systematically structured the needs and challenges of these groups, followed by recommendations for what facilitators need in order to train the participants accordingly. The three groups are:

Participants: people who take part in citizen science projects and contribute to the project with different levels of engagement (data collection, classification, defining research questions, and so on). Can include the general public, students, etc.

Facilitators: people who train or educate participants in a citizen science project, or lead groups of participants. Can include scientists, teachers, nature guides, museum educators, etc.

Project designers: people who initiate and design citizen science projects. Can include scientists, engagement professionals, project coordinators from NGOs, interested citizens, etc.

A summary of the needs of participants, facilitators, and project designers is provided in Fig. 15.5, divided into three categories: core needs, operational needs, and engagement needs.

Understanding the needs and challenges of the different audiences identified allows us to form recommendations for designing training which specifically addresses the needs of each group. These recommendations also account for the diversity of participants in each group and their varied skills, knowledge levels, and

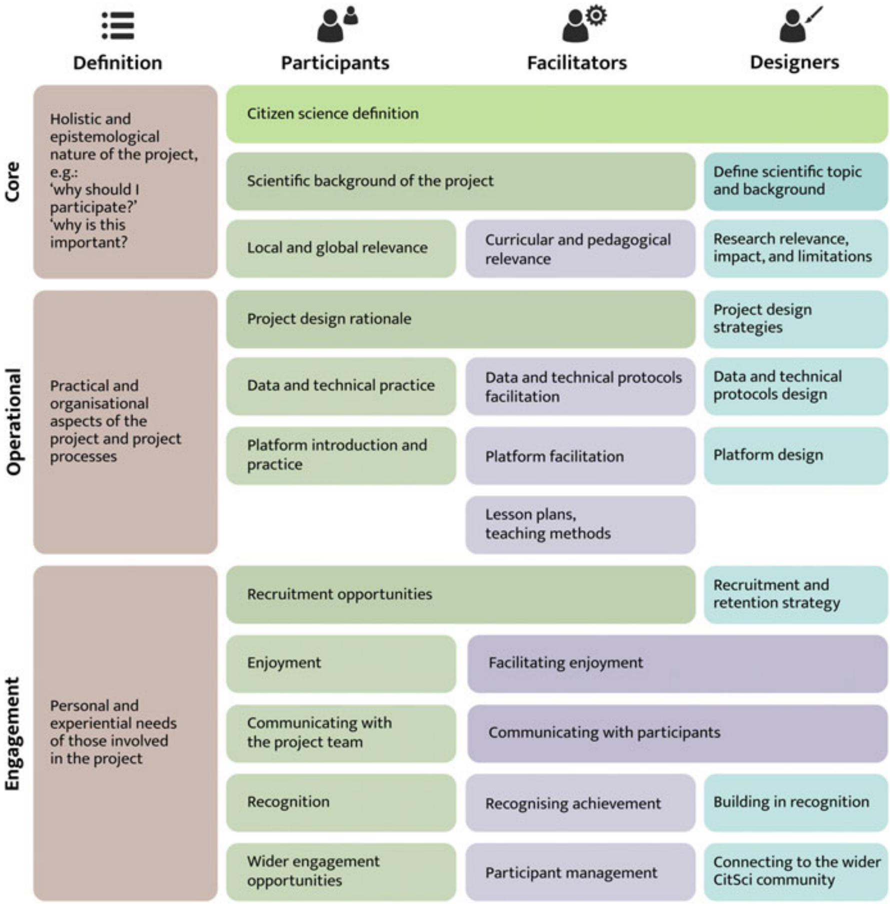

Fig. 15.5 Summary of training needs in citizen science. (Lorke et al. 2019)

experiences. This approach (from need to recommendation) served as a useful working model and provides grounds for designing further training that supports citizen science participants, facilitators, and designers. It also ensures that desired outcomes are addressed throughout the design and implementation of the training, providing good experiences and meeting the diverse needs and goals of citizen science.

Conclusion

One key lesson from our journey so far is the complexity of the field of learning and citizen science. Citizen science projects are diverse; they happen in different settings and offer variable educational opportunities which are embraced by different audiences in contrasting ways. Our map consisting of six institutional territories organises our emerging knowledge and presents key scientific findings. However, what remains to be explored outweighs our current knowledge. Understanding the educational potential and benefits of citizen science and how to assess and grow them – in order to answer the numerous questions of teachers, project leaders, politicians, activists, and volunteers in citizen science – requires mixed methods, combining quantitative analysis of large cohorts of participants and fine-grained, dynamic understanding of specific cases. Finally, we propose analysing citizen science projects as *potential educational situations*, created both by the tasks offered in the citizen science project and by the personal and collective dynamics of engagement of all participants (volunteers, scientists, and others).

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Chapter 16
Citizen Science Case Studies and Their Impacts on Social Innovation

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Abstract Social innovation brings social change and aims to address societal challenges and social needs in a novel way. We therefore consider citizen science as both (1) social innovation in research and (2) an innovative way to develop and foster social innovation. In this chapter, we discuss how citizen science contributes to society's goals and the development of social innovation, and we conceptualise citizen science as a process that creates social innovation. We argue that both citizen science and social innovation can be analysed using three dimensions – content, process, and empowerment (impact). Using these three dimensions as a framework for our analysis, we present five citizen science cases to demonstrate how citizen science leads to social innovation. As a result of our case study analysis, we identify the major challenges for citizen science in stimulating social innovation.

Keywords Social change · Empowerment · Societal challenge · Digital innovation · Active citizenship · Environmental issues · Air pollution · Nature conservation

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Introduction

Social innovation is a key topic in both policy and academic discourses. Over the last few decades, there has been a special focus on innovation in the European Union (EU) Framework Programmes (FP5, FP6, FP7, and Horizon 2020) as well as in the smart specialisation strategies of each EU country (e.g. social innovation in Lithuania and sustainable innovation in Italy, Hungary, Greece, and the UK). The EU has funded many projects that explicitly or implicitly reference social innovation. Examples include the FP6 project KATARSIS (Growing Inequality and Social Innovation: Alternative Knowledge and Practice in Overcoming Social Exclusion in Europe); the FP7 project SI-DRIVE (Social Innovation: Driving Force of Social Change); and the H2020 projects SIC (Social Innovation Community) and DSI4EU (Digital Social Innovation for Europe). There is also increasing interest in the topic of *citizen science*. This is mainly reflected in the EU programme 'Science with and for Society' (SwafS) that aims to build capacity and develop innovative ways of connecting science to society (Horizon 2020 n.d.). The EU has already funded many projects related to citizen science; recent examples include Doing It Together Science (DITOs) and the EU-Citizen.Science platform.

A similar discourse around the importance of social innovation also exists in academic research. Social innovation is understood as a new practice or initiative that makes it possible to address *societal challenges* in various contexts, such as the environment, education, employment, culture, health, and economic development, but also in terms of achieving *social goals* (Viñals and Rodriguez 2013) and bringing about *social change* (Dias and Partidário 2019). The literature provides a myriad of approaches towards social innovation, including linking social innovation to sustainable development (Eichler and Schwarz 2019), capacity building (Howaldt et al. 2018), digitisation (Bria et al. 2015), and urban development (Gerometta et al. 2005). Concurrently, citizen science projects are tackling a range of related issues, including the environment and biodiversity (Ries and Oberhauser 2015), sustainable development (Irwin 1995), and health (Wang et al. 2019). These synergies between citizen science and social innovation show their interconnectedness. The connection between these two concepts is twofold: (1) citizen science leading to social innovation and (2) citizen science as social innovation. This chapter explores the latter perspective.

The chapter is composed of four sections. The first section presents the concept of social innovation and its historical development as well as perspectives of social innovation analysis. The second section introduces the conceptualisation of linkage between social innovation and citizen science. These two sections are linked by the argument that both citizen science and social innovation can be analysed using three dimensions – *content*, *process*, and *empowerment* (*impact*). The third section illustrates how citizen science projects result in the development of social innovations, revealing their content, process, and empowerment (impact) dimensions. The fourth section concentrates on understanding the challenges that hinder the potential of citizen science to create social innovations and providing recommendations and future trends for research.

Conceptualising Social Innovation: History and Current Developments

Social innovation is a broad, multifaced concept. Although interest in social innovation is increasing (Eichler and Schwarz 2019), the concept itself is still difficult to define because the meaning of the term ‘social innovation’ varies across research contexts and disciplines (Rüede and Lurtz 2012). As stated by Phills et al. (2008), it can be ‘a product, production process, or technology (much like innovation in general) . . . it can also be a principle, an idea, a piece of legislation, a social movement, an intervention, or some combination of them’ (p. 39). Although ‘social innovation as a phenomenon has been constantly present in the evolution of human societies’, the concept of social innovations ‘appeared in social science discourses only during the last decades scattered throughout various disciplines as public administration, history, social movements, management, social psychology, economics, and social entrepreneurship’ (Cajaiba-Santana 2014, p. 44).

There is a mutual conditionality between social innovation and social change. The potential of social innovations to create social change has been emphasised by many who view social innovation as a driver or a vehicle of social change (Cajaiba-Santana 2014; Phills et al. 2008). On the other hand, social innovations are shaped by sociocultural, economic, and political environments (Phills et al. 2008). Thus, social innovation is both an object and a driver of social change.

Social innovations should not be understood as antithetical to technological innovations. Many social innovations directly or indirectly use technologies and/or initiate technological innovations. The concept of *digital social innovation* shows that these two types of innovations co-evolve. Digital social innovations ‘inspir[e] digital solutions to social challenges’ (Bria et al. 2015, p. 4) and are defined as ‘a type of social and collaborative innovation in which innovators, users and communities collaborate using digital technologies to co-create knowledge and solutions for a wide range of social needs and at a scale and speed that was unimaginable before the rise of the Internet’ (Bria et al. 2015, p. 9).

There are many ways to analyse social innovations, from generic to specific frameworks. It is common to use a generic framework in innovation analysis, for example, the one suggested by Carayannis et al. (2003) which focuses on four main aspects: (1) the *content of innovation*; (2) the *process of innovation*; (3) the *context of innovation*; and (4) the *impact of innovation*. While Moulaert et al. (2005) stress three dimensions of social innovations: (1) the *content/product dimension* (‘satisfaction of human needs that are not currently satisfied, either because “not yet” or because “no longer” perceived as important by either the market or the state’ (p. 1976)); (2) the *process dimension* (‘changes in social relations, especially with regard to governance, that enable the above satisfaction, but also increase the level of participation of all but especially deprived groups in society’ (p. 1976)); and (3) the *empowerment dimension* (‘increasing the socio-political capability and access to resources needed to enhance rights to satisfaction of human needs and participation’ (p. 1976)).

To sum up, the conceptualisation of social innovation shows that public interest, participation, and engagement are crucial for successful social innovation. All these require social capital, public trust, cooperation among citizens, and knowledge co-creation.

Linking Social Innovation and Citizen Science

The number of social innovation definitions outlined results in a broad variety of terms associated with social innovation in various disciplines. As Putnam (2000) and Grimm et al. (2013) state, in organisational studies, social innovation is framed as social capital, participatory process, and citizen engagement; in territorial studies as community formation and participation; in environmental studies as sustainability; in entrepreneurship studies as social entrepreneurship and co-creation; and in social policy as public engagement. They have one common denominator: *inclusivity*. Meanwhile, citizen science is also identified with a myriad of terms, such as *participatory action research*, *public participation in scientific research*, *community-based participatory research*, and *collaborative civic science* (Christopherson et al. 2018; Eitzel et al. 2017); however, citizen science also appears as an umbrella term for such research (see also Haklay et al., this volume, Chap. 2).

Social innovation and citizen science serve similar purposes and are therefore interconnected. Social innovation is aligned with several purposes, such as to encourage diverse change (e.g. social, political, systemic, behavioural); to prompt creativity; to act for the societal good (e.g. solve social problems, improve the general quality of life); and to pave the way for new opportunities (Farmer et al. 2018; Grimm et al. 2013; Lagares Izidio et al. 2018; Nicolopoulou et al. 2017; Tsai-Hsun 2016). Meanwhile, citizen science aims to solve certain societal issues through co-creation and other participatory approaches as well as to contribute to scientific value (see for more detail Haklay et al., this volume, Chap. 2). Hence, citizen science could be seen from two perspectives. First, citizen science as social innovation, that is, citizen science is an innovative way of carrying out scientific research (e.g. the Zooniverse platform as digital social innovation). Second, social innovation indirectly develops and is an outcome of (some) citizen science projects and complements other significant citizen science impacts. The latter will be comprehensively explored in the next section by presenting five citizen science case studies.

Given the conceptual affinity of social innovation and citizen science, the kernel of both social innovation and citizen science is co-creation. To be more specific, citizen science is a *goal-oriented social innovation* which aims to build a sustainable and inclusive society (Grimm et al. 2013); this can be via inclusion in scientific discovery (mostly evident in scientist-led citizen science practices) or by fostering sustainability and the societal good (mostly evident in community-led citizen science practices; see Göbel et al., this volume, Chap. 17). Citizen science is also a *process-oriented social innovation* which induces social interaction and self-actualisation (Grimm et al. 2013). Moreover, citizen science fulfils three dimensions – content, process, and empowerment (impact) – inherent to social innovation (Hillier et al. 2004; Moulaert et al. 2005). These dimensions fit well with the purposes of citizen science projects; they usually focus on lay people and their contribution to the maintenance of moral values in science as well as to science-produced welfare development (Münkler 2001 as cited in Gerometta et al. 2005). Hence, these appeal to the togetherness of participants, particularly in *Extreme Citizen Science* which is characterised by a high capacity for social change and involvement in scientific practice in general (da Cunha 2015) (see also Case Study A).

Furthermore, letting the knowledge of citizens penetrate and modify scientific practice creates a more favourable environment for social innovations (Novak et al. 2018; Schäfer and Kieslinger 2016) as well as more transparent solutions (Novak et al. 2018). Given this reasoning, it seems reasonable to marry these two concepts and explore more closely the social innovation impacts of citizen science. Social innovation affects social practices (Schäfer and Kieslinger 2016), and by doing so it transforms into citizen science in various ways: by affecting social structures, academic settings, academic culture, behavioural patterns of scientists, and other processes of scientific practice.

Citizen Science Case Studies and Social Innovation

In this section, we provide case studies from citizen science projects showing how citizen science relates to the concept of social innovation from different perspectives (see Table 16.1). The first case study describes how Extreme Citizen Science projects and technologies for social innovation provide the methods and tools to support communities all over the world – regardless of local people's background, literacy levels, and cultural and environmental contexts – to collect, analyse, and act on information to address community needs (as identified by them), promote equality, and help achieve environmental sustainability at both local and global scales. The second case study, looking at *Dejchej! Brno* (Breathe Brno) and *Můžu dýchat* ('Can I breathe?'), illustrates innovative ways to build inter-sectoral social ties and social capital in the community as well as expand opportunities for the public to use open data in the Czech Republic. The third case study, Fortepan, is an example of how communities can use open data for historical memory in Hungary via different ways of knowing, doing, organising, and framing their activities. The fourth case study, INVOLEN, presents an Italian experience of science and environmental education and shows how citizen science projects can help to build inter-sectoral social ties and social capital. The fifth case study, Improve My City, describes how citizens and government can communicate and collaborate to improve their neighbourhood by reporting local problems and suggesting new ideas through their mobile phones. All the case studies include examples of how citizen science can lead to social innovation.

Table 16.1 Descriptions of case studies

Case study	Duration	Geographical location	Stakeholders
A. Extreme Citizen Science projects and technologies for social innovation (https://www.geog.ucl.ac.uk/research/research-centres/excites)	5+ years	Worldwide	Local communities, NGOs, scientific experts, others (depending on the project)
B. Breathe Brno and 'can I breathe?' – citizen projects promoting air quality	6+ years	Brno, Czech Republic	NGOs, scientific experts, public institutions, local governance
C. Fortepan – online crowdsourced photo collection documenting the twentieth century	10+ years	Hungary	Academic researchers, amateur researchers, photo enthusiasts
D. INVOLEN – intergenerational learning for nature conservation volunteers	32 months	Italy	Schoolteachers, NGOs, scientific experts, researchers, students, older people
E. Improve My City – direct citizen–government communication and collaboration platform	Initially 3 years, now ongoing	Thessaloniki, Greece (also in various cities globally)	Citizens, local authorities, policymakers

Case Study A: Extreme Citizen Science Projects and Technologies for Social Innovation

Context Extreme Citizen Science is defined as a philosophy of 'situated, bottom up practices which take into account local needs, practices and cultures and which work with broad networks of people in order to design and build new devices as well as knowledge creation processes which can truly transform the world'.[1] Extreme Citizen Science research group (ExCiteS) projects and their associated technologies, developed with the aim of supporting individuals and communities in the collection of *traditional ecological knowledge* (TEK) and other environmental knowledge to provide the evidence needed to resolve local issues, are an essential requirement for taking further action which can have real impacts.

The two main tools which have been developed for this purpose are Sapelli and Tap&Map. Sapelli is an open-source data collection app for Android devices, which supports offline and autonomous data synchronisation via SMS and the Internet. Its interface is icon based, and information is organised using hierarchical decision trees, which are codeveloped with local communities during the *free*, *prior*, *and informed consent* (FPIC) and *community protocol* (CP) processes which are implemented by all ExCiteS projects (for further information on the FPIC and CP

[1]As defined on ExCiteS home page: https://www.geog.ucl.ac.uk/research/research-centres/excites

processes, the reader may refer to Tauginienė et al., this volume, Chap. 20). Although Sapelli was developed to support users with limited or no literacy skills, interaction problems with complex hierarchical structures and difficulties in registering input from touching screen interfaces (when users suffer from rough skin and calluses) led to the design and development of Tap&Map. Tap&Map is a smartphone app accompanied by a set of cards equipped with *near-field communication* (NFC) technology. Each card has an icon printed on one side which represents a data item for which information is collected. The user scrolls through the card objects to identify the correct card and taps it on the phone to register the new information.

Box 16.1 provides an overview of the most recent ExCiteS projects, which are currently being implemented around the world.

Box 16.1: ExCiteS Projects

Kenya: Collecting Data for Indigenous Plants with Maasai Warriors. Maasai warrior communities in Narok county, Kenya, have led an Extreme Citizen Science project since early 2019. One of the greatest threats their community faces is the loss of TEK and increased deforestation in Maasai Mara National Reserve. Sapelli is used to assist communities in collecting and recording TEK related to Indigenous plants; it is the aim of these communities to preserve this knowledge and pass it on to future generations. After the project launched, within a few hours, individuals had gathered over a hundred data items, and since then they have collected thousands of data points with information about the medicinal and other properties of local Indigenous flora.

Namibia: Natural Resource Management and Fighting Illegal Cattle Invasions with Ju/'hoansi. The Nyae Nyae Conservancy in Namibia, officially registered in 1998, has been threatened since local communities have come into contact with agricultural economies, especially due to extensive cattle farming in traditional hunting and gathering grounds. As primary custodians of the conservancy, the Ju/'hoansi use Sapelli and Tap&Map to collect data to fight illegal cattle invasion in their territory and, more recently, to manage their local community forest resources (Laws 2015).

Brazil: Natural Resource Management for New Conservation Legislation with Indigenous Communities. Mainly situated in Brazil, the Pantanal is the largest wetland in the world with local fishers being totally dependent on it for their daily livelihood. Current legislation for resource management and consumption in the area, which does not consider people's traditional practices, led to the fishers' physical and economic displacement. Sapelli has been used with local communities since 2014, who collect data about the use of natural resources and their management strategies. The data collected provided evidence that Indigenous practices are sustainable and, as a result, local people have been officially recognised as a traditional community giving them the

(continued)

Box 16.1 (continued)
right to protect their livelihoods using their traditional practices (Chiaravalloti 2019).

Cameroon: Supporting Baka Communities Tackle Illegal Wildlife Crime and Animal Monitoring. The Baka hunter-gatherers and Mbulu farmers of Cameroon live in the forest in Dja Biosphere Reserve, which hosts a large variety of plants and animals to support their livelihood but is currently being depleted by illegal wildlife trade and extractive industries. Current conservation legislation excludes Indigenous communities and their knowledge and turns them into conservation refugees. Sapelli has been used, since 2015, to collect data about illegal wildlife crime and animal monitoring, which at the moment is the only viable solution to obtain reliable data to inform effective forest management in the future (Hoyte 2017).

Link to Social Innovation An increasing number of people, driven by a sense of responsibility and environmental awareness, are interested in citizen science activities to protect the wider planet's ecosystem and its natural resources. At the same time, Western beliefs that techno-scientific innovations, complex legislation, international agreements, and Eurocentric conservation models are the solutions to create a sustainable future have slowly started to crumble. Increasing attention is being focused on TEK for its potential to significantly contribute to the sustainability debate; as has been recognised within Indigenous communities for millennia, it is this kind of knowledge that has enabled people to rely on their local environments and survive for thousands of years. TEK is mostly undocumented, and researching it requires zooming into remote local environments to understand how Indigenous peoples interact with them, one of the aims of the ExCites projects. By listening to community problems and providing the appropriate tools and methods to collect data in the most remote areas of our planet, Extreme Citizen Science has a direct impact on conservation, natural resource management, and environmental governance – above all in terms of promoting equality, just forest management, and empowering local communities to take ownership of and address their issues of local (or global) concern. ExCiteS projects engage with extremely marginalised communities, often ignored by the global sustainability debate, and by doing so, they improve people's awareness of local environments and knowledge and our responsibility to protect them. They further build community capacity and individuals' skills in the use of technology, project management, and scientific literacy, utilising local but also global perspectives in identifying solutions to fit the local cultural, social, and environmental contexts.

Case Study B: Breathe Brno and 'Can I Breathe?' – Citizen Projects Promoting Air Quality

Context The quality of the air influences the health and well-being of all living beings, and it is a particular concern for those living in urban environments. European countries are required to follow national and EU air quality directives (2008/50/EC Directive on Ambient Air Quality and Cleaner Air for Europe). Unfortunately, many European cities are either not able to manage air quality satisfactorily or the citizens themselves are not willing to reduce their personal emissions (or they may not be aware of how to do so). Brno is one of the many European cities which exceed the air pollution limits of particulate matter (PM) and nitrogen oxides (NOx) (CHMI 2019). Within this framework we provide a case study of projects using citizen science to address this issue.

Two citizen science projects, that are dealing with air quality, work in collaboration with the city of Brno. First is Breathe Brno, which started as a bottom-up informal civil initiative to highlight the environmental and health consequences of air quality (focusing on PM) in Brno. Breathe Brno was initiated in 2013 by several young mothers with small children with the aim of drawing municipality attention to the problematic air conditions and the breaching of air pollution limits in Brno. They focused on making this problem visible to the public and stimulating the municipality to address it. Another related project is 'Can I breathe?', coordinated by the NGO Nesehnutí, with a similar aim, although more oriented towards air quality in general.

Link to Social Innovation The content of the projects is linked to social innovation in several aspects. The mothers were attempting to resolve a very complex issue with limited resources, but they decided to cooperate with other NGOs and scientists to raise public awareness and put pressure on local governmental actors to take action. Their aim was to address the problem of the limited official information provided by the authorities. They created web pages with simple graphics pointing out the actual daily levels of PM in several parts of Brno, based on open data from the Czech Hydrometeorological Institute (CHMI), derived from 12 meteorological stations. The availability of this information itself has an important impact as citizens can now better evaluate whether the pollution levels are acceptable but also which public spaces of Brno are more 'pollution-safe' for taking a short walk (e.g., with a baby in a pram), carrying out exercise, or any other type of outdoors activity. The citizens who participated in the project connected their web page to Nesehnutí's, which manages a more complex map of air pollution in Brno ('Can I breathe?') based on other open data sources. This map is further enhanced by a *do-it-yourself* software application simulating daily predictions of air pollution hour by hour. These applications go beyond the standard provision of an air quality index. Both projects also provide additional information about the issue, ask the public to submit their own experiences, and signpost other ways of potential public participation.

From the process's point of view, at first the mothers' activity was not taken seriously by the municipality of Brno, despite their efforts to gather evidence of air quality measurements at several official spots. The turning point was when they started to cooperate with NGOs such as Nesehnutí and the Centre for the Environment and Health and when they invited the internationally respected air pollution expert Kaare Press-Kristensen to verify their concerns. Based on the recommendation of several volunteers, experts made additional measurements in other locations of the city, and this provided further scientific evidence about the serious state of the issue and initiated wider public discussion. Since then, several additional measurements of air pollution (PM, NOx) have been realised with the help of volunteers (the latest in 2019, covering 34 new places).

Several attributes of ongoing social empowerment (impact) were identified. First, the public's understanding of air pollution and its health and climate change consequences has been increasing. Women, especially those leading the project, were appreciated as relevant stakeholders for negotiating and dealing with this urban health issue. As a result, civic initiatives are now promoting a set of practical measures – such as the use of public transport, cycling and effective cycle routes, and the establishment of low emission zones by limiting the entry of cars to the city centre – to be implemented in the Brno local plan. It seems that citizens' interest in this issue has increased. For example, people now question in which parts of Brno they would buy a house due to the air pollution or where they can buy cheap metres to evaluate the local environmental conditions themselves. The issue is now frequently discussed in local media. Moreover, Nesehnutí recently initiated a new citizen-driven participative web page called *HejbejBrno* (Move Brno), focusing on a wider spectrum of urban issues, transport issues, and public spaces. The pressure that these projects put on the municipality, together with the obligation to abide by EU air quality directives, has stimulated several measures, although their actual impact is yet unclear. Currently, every measure undertaken by the municipality, for example, the preparation of various strategic documents and plans dealing with air quality, is carefully monitored by civic initiatives. Recently, around 30 civic initiatives joined forces via the Brno Climatic Coalition Association with the shared goal of improving the air quality in Brno. It proves that the environmental movement in Brno has become a respectable partner in democratic society, as continually assessed by researchers dealing with environmental and civic initiatives and their impacts in CEE countries (i.e. Fraňková et al. 2015).

Case Study C: Fortepan – Online Crowdsourced Photo Collection Documenting the Twentieth Century

Context Citizen science practices in Central and Eastern European (CEE) countries are relatively new but already manifest a range of social innovation dynamics and agency. Some are linked to international projects or umbrella organisations that coordinate knowledge exchange focused on global environmental issues. Others connect to regional platforms, for example, the European Citizen Science Association or EU-funded H2020 projects that enable transnational networking, primarily for predefined societal challenges. National-level organisations also embark on citizen science journeys to collect data, raise awareness, and monitor specific issues. Finally, local grassroots movements and community-based activities, often in multi-actor settings, also engage in public participation in research, although these are not always explicitly considered citizen science. In this qualitative case study approach, the theory of *transformative social innovation* (TSI) (Avelino et al. 2015; Haxeltine et al. 2016) is used to understand the emergent field in Hungary and the social configurations that create transformations in global challenges. According to TSI theory, the practice of social innovation comprises heterogeneous social–material collectives. It has human and non-human elements and can be perceived with cognitive, material, social, and normative dimensions (Haxeltine et al. 2016). Social innovation processes are transformative as they include new ways of knowing, doing, framing, and organising that challenge established, dominant institutions.

The case study, Fortepan, is an open-source curated online photo archive launched in 2010 in Hungary. Started as a private collection by two high school friends, today Fortepan is the largest photo archive with nearly a hundred thousand freely downloadable annotated images. It features pre-1990 private photo collections (before the mass proliferation of digital photography) curated by the founder, Miklós Tamási, and maintained by volunteers. Fortepan solicits private donations; no public money is involved. The project collects citizens' good-quality amateur, private photos and makes them publicly available under the Creative Commons 3.0 licence in an easily searchable web interface. The primary mission is not scientific research or the contextualisation or interpretation of the photos but conservation.

Nevertheless, anyone can interpret the photos, and Fortepan is, therefore, recognised as an excellent research opportunity for professionals who can uncover unexpected photos with a simple thematic search. In essence, Fortepan provides a common digital heritage that anyone can use in any way, even for commercial purposes. Fortepan photos are often used by academics to illustrate a point and for book covers. Literary works have also been inspired by the rare and often enchanting old photos. In addition, Fortepan has created photo books and calendars on specific themes (coffee houses, urban environments, women) that build on the open access archive of pictures of everyday life.

Link to Social Innovation Fortepan has a number of socially innovative elements; we will explore their transformative aspects. By experimenting with volunteerism and community management approaches, Fortepan generates new knowledge on the history of everyday life. By collecting and making old private photos publicly available and building a collective memory, while being careful not to undermine professional photographers or museum professionals, Fortepan is experimenting with new ways of doing. By positioning private photos as part of our collective memory, emphasising sharing as a pathway to the future, and developing a scientifically sound and free resource base, Fortepan is framing photo archiving in a novel way. New ways of organising are also visible: volunteerism, engaging amateurs to provide photos, building on informality, grassroots, and non-market-based cooperation with public collections and news media.

In conclusion, Fortepan created a publicly accessible digitised visual collection that can help us to represent our collective memory. It provides enhanced public participation; it is a prefiguration of a citizen science project but has the potential to turn into one.

Fortepan is mobilising the recent interest in the history of everyday. Fortepan volunteers spend several hours a day deciphering the photos from private family collections using an Internet forum to crowdsource and interpret the data necessary to identify details. The collection is unique as public collections and museums do not provide open access, high-quality, and royalty-free photos in Hungary. Moreover, such archival collections are mostly comprised of propaganda photos and press photos, which are created for a particular institutional purpose and do not reflect the viewpoint of everyday people.

Case Study D: INVOLEN – Intergenerational Learning for Nature Conservation Volunteers

Context Sustainable development and the reduction of human pressure on the environment are strategic challenges that require a dramatic change in our behaviour to avoid depleting the world's resources available for future generations. An important role can be played by schools through science and environmental education formats that foster active citizenship. Citizen science projects can provide a method that is particularly effective with younger students (Locritani et al. 2019). Moreover, education that includes activities focusing on local territory (place-based education) stimulates proactive behaviour and responsibility (Schild 2016), while integrating ICT in these activities increases students' interest and involvement. Within the framework of INVOLEN (Intergenerational Learning for Nature Conservation Volunteers), funded by the Lifelong Learning Programme of the European Union (2012–2015), a *learning model* was developed and tested in Italy, Greece, France, Hungary, and Slovenia. The model brings together students and elders and promotes both mutual respect and social cohesion between different generations in voluntary activity for nature protection and conservation (Ugolini et al. 2016). A focus group (of students and elders, guided by a facilitator, working with experts like environmental guides, teachers, and researchers) is convened to learn more about a local protected area and promote and protect the site by following a methodology structured in six units (for details see Papageorgiou et al. 2015). We will explore the multiscale benefits reported by a focus group in Livorno, Italy, comprised of elders and students, aged 12–13, also referencing pre- and post-project questionnaires completed by all participants (Ugolini et al. 2016).

Link to Social Innovation From the content point of view, a focus group, composed of students, elders, and environmental and ICT experts, selects and works on a local area of interest (e.g. a nature area or green urban area). Then the focus group applies the INVOLEN methodology (for details see Papageorgiou et al. 2015) that consists of indoor and outdoor meetings led by a facilitator. In the first stage, elders and experts share their knowledge about historical, social, economic, and ecological features of the area. Then the whole group participates in field trips to undertake practical actions for the conservation of the area (e.g. waste cleaning and marking trails), and students document the experience with photos, videos, and storytelling. The collected material and the resulting stories constitute the basis for the creation of a *location-based game* (LGB) aiming to promote the area (Papageorgiou et al. 2015).

INVOLEN successfully involved students in taking care of their local areas by increasing awareness of nature and curiosity for experiential knowledge, fundamentals of citizen science. Therefore, even though this project is not a typical citizen science project, it contributes to it by transferring the knowledge of the local territory to the local community and the general public through the action of stakeholders of different ages and cultural backgrounds.[2] INVOLEN also involves elders in voluntary activities. Moreover it targets improvement of communication skills and mutual respect by fostering intergenerational experiences. Therefore it promotes a sense of community both at the territorial and intergenerational levels, using a known environment to trigger a sense of belonging and reinforcing understanding between generations regarding their skills.

The main subject of the process dimension is the focus group that works in formal and informal settings, changing the roles and leadership of participants according to the topic. Elders led the meetings in which they shared their knowledge connected to stories about the traditional uses of nature but also personal experiences and hobbies. The science and environmental experts brought their experience of the natural environment and its threats. Students were the main beneficiaries because they gained knowledge of the environmental, cultural, and social value of the area. However, during LGB creation and development, students became leaders and supported elders in the technological part of the project, thanks to their confidence in the use of ICT tools and apps. The group, especially the students, found a space for expressing their creativity and learnt to manage competences needed for working in groups (e.g. codesign and communication).

From the social empowerment (impact) dimension, elders improved their self-confidence and communication with the students. They also became more familiar with ICT and aware of the potential of digital devices. Students were encouraged to be more involved in active nature protection and showed interest in learning more about conservation issues and solutions for their local area. Moreover, elders benefited from social inclusion by building new relationships, reducing isolation, and feeling useful. In addition, the capacity of NGOs, schools, and adult education institutions to provide innovative education improved, as did the qualifications of

[2]See http://www.involen.eu/en/learning-tools-resources

their staff. Therefore, there is great potential in terms of social innovation because the model improves awareness of local, environmental, and social issues, thus promoting active citizenship, and fosters the application of science thinking and ICT tools to propose solutions to tackle these issues. The model had a strong impact in other communities (30 groups from 5 countries) that applied it during the project. Later on, the model was also successfully applied in several national and international projects such as an ongoing ERASMUS+ project (Daylighting Rivers) where LGB was integrated into an *inquiry-based learning model* (Pedaste et al. 2015) to study environmental issues related to rivers in urban areas (Ugolini et al. 2019). See also Kloetzer et al. (this volume, Chap. 15) and Hidalgo et al. (this volume, Chap. 11) for additional experiences that relate to social innovation and education and learning.

Case E: Improve My City – Direct Citizen–Government Communication and Collaboration

Context The inclusion of new innovative solutions for more direct, structured, and transparent communication between citizens and government has been pursued by an increasing number of cities in recent years. Among these cities, Thessaloniki chose Improve My City (IMC) as its official application for reporting non-emergency issues with the goal to engage citizens by inviting them to support their common collective effort for better everyday living. This case study explains how IMC is actively being used in the municipality of Thessaloniki as a citizen science application (Tsampoulatidis et al. forthcoming) and how it promotes the development of social innovation and describes its societal impact by analysing the collected citizens' data from the last 4 years (as of late 2019).

IMC is a free and open-source software platform that facilitates citizens to directly report local issues about their neighbourhood such as potholes, trash, graffiti, illegal advertising, etc. but also to promote new ideas, for example, new parking spots, suggesting the renovation of abandoned buildings and calling for charity actions, just to name a few. IMC is also available for smartphones to further empower citizens to report issues while on the move.

Link to Social Innovation By using IMC, citizens are becoming the eyes of the city, in the sense that they can act as living sensors of their neighbourhood, and from the content perspective, they can directly inform the local authorities about their problems and ideas, allowing city officials to perceive citizens' concerns from a different point of view. The reported issues are automatically forwarded to the appropriate departments in the municipality to monitor, manage, and schedule their settlement. Through IMC, the municipality interacts with the citizens publicly in a highly transparent manner since all responses and actions taken in addressing the issues are recorded and become available online for everyone to see, comment on, and support (by voting on them). This, according to Tsampoulatidis et al. (2013,

p. 839), adds a social dimension to the collected content and stimulates public participation. As of late 2019, almost 60,000 issues have been submitted by approximately 13,000 registered users, resulting in more than 200,000 recorded actions (e.g. status change) and about half a million exchanged emails. Importantly, after the analysis of the collected data, some unforeseen collaborative actions have also emerged. Citizens have teamed up by creating action groups focusing on specific areas of the city such as the historic centre or targeting specific issues such as blocked pathways for wheelchair users. These examples clearly denote that IMC encourages collaboration and facilitates ‘togetherness’ of community members in developing social innovation.

An interesting fact that highlights the process dimension of social innovation in IMC is that transparency and interactivity between citizens and government result in high levels of appreciation, especially from users who get feedback on their actions (e.g. comments or positive votes). Examination of the app’s analytics also shows that users who receive feedback keep submitting new issues and spend more time using the app. Moreover, there are recorded cases where citizens have helped the authorities in the process of resolving an issue by giving suggestions and ideas or even offering volunteer work (e.g. gardening).

As for the empowerment (impact) dimension, IMC’s direct impact is twofold: (1) local authorities are informed about actual issues in real time, even for remote areas and neighbourhoods, which otherwise, following the traditional approach, would take longer to be spotted; and (2) the collected data is processed and analysed (via IMC analytics that provide smart interactive visualisations and maps) and made available to policymakers, local administrations, NGOs, and various communities and groups to support evidence-based decision-making. Equally important is the indirect societal impact. Collaboration reinforces the sense of community service, increases local authorities’ responsiveness, and strengthens trust in the government. Moreover, IMC promotes transparency, cultivates a participatory culture, creates communities, enhances and encourages citizen–government communication and collaboration, and produces open data that can be used by all. Furthermore, economic impact is achieved by reducing functional costs via effective monitoring and scheduling, while environmental impact is attained by heavily reducing paperwork and unnecessary travel.

Challenges, Recommendations, and Future Trends

In this section, we briefly present some of the most critical challenges from the implementation of the case studies presented in this chapter and make recommendations to maximise social innovation impacts in similar contexts.

Narrow disciplinary attitudes and the presumptions which surround domain specificities often limit the effective assessment of societal problems and subsequently the solutions developed to address them using citizen science. For most citizen science practices to succeed and to maximise their social innovation impacts, *interdisciplinary implementation approaches* can be beneficial, as they have the potential to expand understanding of societal and scientific problems in specific contexts and therefore support the design of novel solutions which can be used to address them.

Community-led or bottom-up projects in citizen science are now commonly used to address specific problems that communities are facing using scientific approaches and tools (e.g. projects for collecting data and monitoring noise or air pollution). It is not uncommon for these problems to be entangled in local politics, which can be difficult to expose, or for previous collaborations to have resulted in distrust. We, therefore, suggest that starting by *building trust with local communities* is of utmost importance for the success of any citizen science project and for maximising its social innovation impact. For example, in Case Study A, to build trust, researchers spent significant time in the field developing community protocols and lived with local communities to understand people's needs, cultural contexts, and ways of living. Similarly, in Case Study E, in order to promote transparency and trust, the local authorities in Thessaloniki recently decided to record offline issues through the workflow of IMC by dedicating employees to input the data, which is a good practice to ensure inclusion.

While citizen science activities may attract people of all ages, backgrounds, and interests, the focus so far has been on the limited demographic profile of *Western*, *educated*, *industrialised*, *rich*, *and democratic* (WEIRD) societies (Dourish 2015). For everyone to benefit from citizen science and create social innovation impacts globally, it is important that there is an increase in the number of citizen science projects which engage marginalised, underrepresented, and hard-to-reach communities and groups. For example, although they are less popular, citizen science projects which target communities in developing countries, similar to those presented in Case Study A, can result in capturing local Indigenous knowledge which has an important role to play in the global environmental sustainability agenda. Similarly, Case Study B describes the engagement of a social group that is usually underrepresented – women with small children.

Support at the policy level is also a major factor in the success of citizen science projects in order to achieve social innovation. Projects primarily require that officials accept the fact that all actions taken (or not taken) can be openly and transparently discussed by citizens (Case Study B). There is evidence that the types of data collected may influence the way legislation is shaped to benefit local communities (Case Study A), but this is a challenging process with extremely long timescales, personal and political hurdles, and other barriers. To address these issues, we need to strengthen the promotion of citizen science and its recognition at policy level.

Last but not least, with the increasing use of digital tools to support and enable citizen science activities, it is frequently overlooked that technological intervention design should not only reflect the scientific needs but should also suit local contexts of use and be intuitive and easy to use if they are to succeed in their desired goals and impacts. With many examples of projects failing on that front, it becomes evident that the assumption that usability is 'a built-in property' of any technology which is used to support citizen science is false. We, therefore, suggest that *designing 'user-*

friendly' technologies to support participants in citizen science activities becomes an integral element for consideration and evaluation in citizen science practice.

This chapter provides some insights and illustrations on how citizen science can lead to social innovation. We emphasised that, in using citizen science, it is important to create innovative milieu through learning, networking, cooperating, and addressing communities' challenges (Crevoisier 2004).

We have to consider further how to expand the understanding of applying citizen science and its technologies so that all communities are involved and empowered through participating in citizen science projects and fully benefit from their anticipated social innovation impacts. *Responsible research and innovation* (RRI), mostly relevant to the EU, can be seen as one of the preconditions for enabling social innovation in citizen science. The European Commission lately defined RRI as 'an approach that anticipates and assesses potential implications and societal expectations with regard to research and innovation, with the aim to foster the design of inclusive and sustainable research and innovation' in a co-creative spirit (Responsible Reasearch & Innovation, n.d.). Particular efforts should be directed towards gender inclusiveness and establishing citizen science as an umbrella for public engagement and science education (e.g. all societal actors should be targeted, including national and local policymakers, citizens, and so forth, and communication should be informed by evidence). This is also a way to demonstrate the social responsibility of scientists and scientific organisations towards citizens alongside carrying out research not only in an innovative way but also with integrity, transparency, and openness.

Thus, schools and other educational and scientific establishments are suitable spaces 'to start fostering citizens' autonomy and responsibility for change through lifelong learning' (Schäfer and Kieslinger 2016, p. Y02-9) and to develop skills to contribute to social innovation through science education and sensitising local and global issues, for example, in health, environment, and culture. This can be achieved by replicating and partially translating social innovation, which will allow social innovation to be both recognised and scaled up (Mulgan 2006). This will help consider ethical and democratic values as well as to develop citizens' commitment to social responsibility (Lagares Izidio et al. 2018). Therefore, the focus on schools and education and science organisations as hubs for citizen science and social innovation should be considered more intensively in the future.

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Chapter 17
Science as a Lever: The Roles and Power of Civil Society Organisations in Citizen Science

Claudia Göbel, Lucile Ottolini, and Annett Schulze

Abstract Citizen science has become an umbrella term that encompasses a growing range of activities, actors, and issues. This chapter examines the potential of citizen science to generate transformative knowledge and argues that civil society organisations (CSOs) are key actors in this regard. However, the roles of CSOs are neglected in the literature on citizen science. We turn to the traditions of community-based research and participatory action research to learn more. With two case studies on health and safety, we show how transformative knowledge enables concerned communities to claim their rights and enriches scientific knowledge generation. Through a socio-historical analysis, we find three main roles grassroots CSOs take on in participatory research: (1) a technical role in the production of data and knowledge; (2) a governance role in the deliberation on research activities and risk assessment; and (3) an advocacy role by campaigning for transformative knowledge. These roles determine the ability of grassroots CSOs to generate legitimacy and rely on CSO members belonging to different spheres of society, scientific skills, and access to marginalised communities. Finally, we discuss the conceptual and practical challenges of accounting for CSOs' roles in order to build a more just and transformative future through citizen science.

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CSOs as Key Agents of Transformative Research

This chapter contributes a reflective social science perspective on the organisational context of *transformative knowledge production* in citizen science. It focuses on *civil society organisations* (CSOs) that belong to neither the state nor the market but the so-called third sector of civil society, for example, associations of amateur naturalists or climate justice movements. It builds on a recent article by Strasser et al. (2019) that traces the rise of the citizen science concept in relation to historical and political contexts. The authors argue that the current popularity of citizen science is linked to changes in science policy, in which the understanding and promotion of participation have shifted from a focus on deliberation to one on knowledge production. They show how the rise of citizen science is grounded in experiences from *community-based research* and *participatory action research* carried out in the context of social movements in the fields of health, environmental activism, and development studies since the 1960s. However, proponents of citizen science today who refer more often to amateur naturalists do not commonly evoke this legacy. From this perspective, several promises of citizen science, such as the democratisation of science, scientific literacy, and enhanced knowledge generation, can be critically interrogated.

In this chapter, we are particularly interested in the promise of producing 'better science', which is a leading argument to explain the value of citizen science. Strasser et al. (2019) highlight that fundamental transformations of scientific knowledge have been achieved in the past through work by and with 'concerned' persons and communities who directly, often physically, experience harmful or precarious conditions. It is by drawing on these experiences that they can substantiate knowledge claims on the phenomena in question and make available to research alternative perspectives on these issues:

> It is no historical accident that many of the successful challenges from lay people to scientific orthodoxy emerged from knowledge grounded in their own body or its immediate environment. The credibility of the knowledge claims made by women health activists in the 1970s, by AIDS patients in the 1980s, or by residents of toxic neighborhoods in the 1990s was based on their intimate experience of their own bodies and physical environments. ... Seen in this light, the contribution of participatory research could be far more significant than simply adding an army of unpaid volunteers to help in solving current scientific problems at a lower price. It could result in a different kind of science and a different kind of knowledge. If participatory research can transform how knowledge is being produced, at a deep epistemological level, then it could hold important potential for transforming who can produce legitimate knowledge and what we know about the natural world. (Strasser et al. 2019, p. 65)

Strasser et al. thus locate the promise of innovation and improvement of science through citizen science – which is fuelling the growth of citizen science agendas today – in the epistemic authority hard-won by concerned individuals and groups over the last century. Against this background, they call for more emphasis on community-based research and participatory action research, approaches focused on work with concerned groups, as well as the historical and sociological studies of the latter.

This chapter builds on these suggestions. We begin by examining the organisational settings and dynamics of participatory research processes. In particular, we consider how citizen science needs to be organised to generate transformative research. We argue that CSOs are key actors in this regard. They bring together those who are typically excluded from research processes, advocate for their perspectives, do research, and establish links to institutions. Prominent examples are the cases of AIDS treatment activists and movement organisations (Epstein 1995), patients' associations (Callon and Rabeharisoa 2008), and environmental justice movement organisations (Ottinger 2010).

Thus, CSOs can act as catalysts to enrich scientific data and knowledge by brokering knowledge between institutionalised research and social movements.[1] The idea of knowledge brokerage relies heavily on knowledge transformation: 'knowledge brokers can be understood as persons or organisations that facilitate the creation, sharing, and use of knowledge' (Meyer 2010, p. 119, following Sverrisson 2001). In this chapter, we focus on the generation of transformative knowledge through participatory research with an emphasis on the active roles of CSOs.

Definitions of CSOs are as numerous as definitions of civil society (cf. Evers 2020). On a general level, CSOs are understood as social networks with (in)formal social relations between different actors (individuals, groups, organisations, etc.) as well as the patterns, which are formed by these relations. In the context of the United Nations, for instance, CSOs are defined as 'non-State, not-for-profit, voluntary entities formed by people in the social sphere that are separate from the State and the market. CSOs represent a wide range of interests and ties. They can include community-based organisations as well as non-governmental organisations (NGOs)' (HRRAFI 2019). In the context of the European Union, a similar definition can be found, referring to CSOs as 'any legal entity that is non-governmental, not-for-profit, not representing commercial interests, and pursuing a common purpose in the public interest' (Gall et al. 2009, p. 33). The latter shows that there is an important normative dimension: what belongs to 'the public interest' is wide-ranging and often contested. From a sociological perspective, CSOs are constituted by informal networks and individuals, bound together by shared values and solidarity mechanisms, and mobilised on conflictual issues. These varying perspectives need to be taken into account in order to properly characterise CSOs. Other important aspects for the analysis of CSOs include organisational history; forms of organisation, such

[1]Moreover, these processes can be characterised as an exchange of perspectives and perceptions that lead to 'alignment, co-creation, and entanglement' (Sedlačko 2016, p. 6) as well as revealing contradictory data and scientific uncertainty. Gaining knowledge and knowing need to be understood as social interactions that are embedded in hierarchies.

as legal status; and forms of action, such as protest, evidence collection, and advocacy. On this basis, it is possible to distinguish NGOs, community-based organisations, and registered associations on different societal levels with their respective objectives and structures. In this chapter, we will focus on small grass-roots CSOs that are part of new social movements.

In order to mobilise the analytical potential of social science research for our study, we adopt the differentiation by Strasser et al. (2019) between the concepts of *citizen science* and *participatory research*. Participatory research is broadly understood to refer 'to the many ways in which members of the public have engaged and continue to engage in the production of scientific knowledge, and how they make sense of this engagement' (Strasser et al. 2019, p. 67). There are many varieties of participatory research performed by and advocated for by different communities of practice. Their common trait is that the generation of scientific knowledge happens in a participatory way, with an emphasis on including people and communities who are not usually part of these processes. In this space of participatory research, citizen science is 'a recent and increasingly fashionable label' (Strasser et al. 2019, p. 55). We aim to disentangle this interpretation along with the conceptions of particular forms of participation and doing research. This distinction makes it possible for us to analyse and put into perspective the discursive level at which citizen science is established in current debates among practitioners as well as in research policy.

Against this background, we argue that to learn more about transformative participatory research, it is necessary to examine the characteristics and roles of CSOs in citizen science and participatory research. For this purpose, we will first review literature on citizen science regarding how CSOs are addressed. Since, as we will show, citizen science literature has a lacuna with respect to CSOs, we then proceed to mobilise additional sources. We will analyse two historical case studies situated within the traditions of participatory research and ask what we can learn in order to undertake innovative citizen science today in terms of generating transformative knowledge. Our first case study concerns the Nord-Cotentin Radioecology Group as a *pluralist* expert group on environmental health and nuclear risk in France in the late 1990s. The second case explores the association Arbeit & Gesundheit e.V. that has worked between academia, new social movements, and the state to improve occupational health and safety in Germany since the 1980s. Based on the points raised by these cases and by synthesising findings from grey literature on stakeholder workshops, we then discuss conceptual and practical challenges for the participatory generation and the application of transformative scientific knowledge. Finally, it is our hope that this will provide a basis to strengthen citizen science by leveraging the power of CSOs.

CSOs in Citizen Science

This section explores literature published explicitly on citizen science, the variant of participatory research that currently receives considerable attention from the media and decision-makers across Europe (see Vohland et al., this volume, Chaps. 1 and 3).

It asks how citizen science is organised and how CSOs are involved. Painting with a broad brush, one can observe that, beyond case studies of single citizen science activities, the literature on citizen science approaches these questions in three ways: *participation typologies*, *managerial logics of knowledge production*, and *good practice repositories*. The first key strand of scholarly work on the organisation of citizen science systematises the diversity of participatory research activities with the help of participation typologies. Such classifications of project types are based on models of governance, a key feature of project organisation, for example, if and how deeply volunteers or collaborators outside academia are involved in research and project management tasks (for an overview, see Ceccaroni et al. 2016). A second strand looks at the managerial logics of knowledge production in citizen science from a procedural perspective and examines the challenges. For instance, Franzoni and Sauermann (2014) identify the matching of projects and people, division of labour, integration of contributions, project leadership, and motivational aspects, as organisational challenges. A third strand of literature on the organisation of citizen science comprises guidelines for undertaking citizen science activities (see Sanz et al., this volume, Chap. 21). They are written either by practitioners or for them. Such good practice repositories often stem from capacity building activities and are both a product and the basis of the ongoing standardisation of citizen science.

Beyond these three stands, scarce systematic and comparative research has been carried out on the organisation of citizen science to date. A stakeholder analysis of 16 citizen science projects from various disciplines found 6 groups of stakeholders (Gobel et al. 2017): (1) CSOs, informal groups, and community members; (2) academic and research organisations; (3) government agencies and departments; (4) participants of citizen science initiatives; (5) formal learning institutions such as schools; and (6) business or industry. These provide diverse contributions to citizen science projects and are involved to varying degrees across different governance models. Along those lines, a review of projects on the German and Austrian citizen science platforms (Pettibone et al. 2017) found that project initiation and coordination lie with a heterogeneous group of actors. Most projects in their sample are initiated by scientific organisations, while actors from civil society represent the second largest group of project initiators, and government and media organisations are responsible for a smaller fraction of projects. Pettibone et al. point out that little is known about the concrete roles of these actors and their rationale for engaging in citizen science. They find a diverse range of third sector organisations involved in citizen science: ‘These groups include non-profit organizations (i.e. NGOs) focused on political or social issue engagement (such as environmental groups), some of which have professional research components (such as BUND or NABU) or are structured as research organizations (such as UfU). In addition, we consider independent groups interested in scientific research outside the academic context (*Fachgesellschaften* in German), which we group with engaged individuals and small groups of individuals’ (Pettibone et al. 2017, p. 6).

European and national meta-organisations concerned with the establishment of citizen science networks for practitioners, professional organisations, and science-policy mediators are another type of CSO in the field of citizen science (Göbel et al.

2016). Roles of CSOs in citizen science thus emerge as significant but understudied in the literature on citizen science. The first two strands of literature on participation typologies and managerial logics do not scrutinise CSOs, while the third stream on good practice mentions CSOs as potential partners but remains practice oriented and unsystematic. Arguments from capacity building work on improving CSO involvement will be covered in the section on challenges.

This general lack of scrutiny of CSOs is related to common implicit assumptions in citizen science literature. First, much of the scholarly work seems based on a model that portrays citizen science as a relationship between two parties – *researchers* and *volunteers* (cf. Eitzel et al. 2017). This neglects the diverse range of other actors involved, including CSOs as representatives of organised civil society. Second, the prototypical format of citizen science activity usually discussed is that of temporally limited research and engagement projects. Organisations running these projects and marketing them to the public and the networks which support them are largely absent from the research landscape. For instance, Tancoigne (2019) shows that CSOs are invisible in citizen science communication on Twitter and that, generally, there is a lack of attention to the brokers of citizen science. A third aspect that is neglected in the literature on citizen science – without a direct link to the scrutiny of CSOs, but important for studying them – is that the governance of citizen science activities, such as the distribution of decision-making power and tasks, changes over time. While such considerations are sometimes mentioned (e.g. Franzoni and Sauermann 2014), deeper empirical research on such linkages and project dynamics is currently missing.

In this light, we hypothesise that the lacuna regarding the involvement and roles of CSOs is a systematic one. Dominant framings of how participatory research is undertaken in the citizen science discourse mostly paint pictures of stable two-party relationships between researchers and lay individuals in temporally limited projects. This narrow model, however, only partially corresponds to empirical findings that show diverse CSO engagement in participatory research activities labelled as citizen science. Participatory research by and with CSOs is thus not only a neglected aspect of the past, as Strasser et al. (2019) have shown, but continues to be overlooked today. In order to learn more about the organisation of transformative participatory research and to enrich discussions on citizen science, we now turn to mobilising additional sources.

The Roles and Power of CSOs in Participatory Research: Two Case Studies

This section draws on two paradigmatic case studies to explore how the generation of transformative knowledge has been organised, especially how CSOs have been involved in participatory research in new social movements since the 1960s. It focuses on the creation of legitimacy – a central challenge for collaborations that cross the boundaries of scientific institutions (Tratschin 2016).[2] Both cases are bottom-up initiatives in which grassroots and non-formal organisations have affected changes in work and living conditions.

Mindful of the shortcomings identified in the citizen science literature above, we present two case studies on multiple and evolving forms of collaboration with various partners. In addition, the case studies have been chosen to broaden the knowledge base of citizen science in three ways. First, the case studies provide a historical perspective that helps to consider contemporary citizen science initiatives as rooted in the heritage of earlier forms, rather than as innovations. Second, the case studies provide examples from the fields of social sciences and health that figure marginally in the citizen science discourse compared to experimental and environmental sciences. Third, our focus is on scientific knowledge generated in or close to contexts of application – public expertise in risk governance involving state agencies and occupational health knowledge relevant to workers, industry, and workers' unions.

Environmental Health and Nuclear Risk: Pluralist Expert Groups

This first case study examines the involvement of CSOs in the field of risk evaluation by describing a key moment in the recent history of regulatory agencies in France: the opening up of public expertise to CSOs by setting up a *pluralist* expert group – the Nord-Cotentin Radioecology Group (GRNC).[3]

Regulatory agencies are part of the state apparatus (Jasanoff 1990; Joly 2009) – they provide knowledge for the government and public administration that serves as an input for drafting public policies, acting on crisis issues, monitoring compliance, and controlling risks (Demortain 2017).[4] To perform risk evaluation, a central task of regulatory agencies is to convene expert committees to elaborate so-called public expertise to resolve controversial issues. Public expertise consists of a report or study elaborated on the contemporary state of scientific knowledge in order to answer to a pragmatic issue or question (Roqueplo 1997). Over the last10 years, several French regulatory agencies have established a policy of *openness to society*, which aims to better include civil society in public expertise.

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[2]From a communication science perspective, (dis)empowerment can be understood as the ability of individuals and CSOs to consolidate protest by gaining legitimacy from the political as well as the societal sphere.

[3]The case study is based on published literature, current research, as well as unpublished interviews.

[4]As scientific bodies, the scientific work of regulatory agencies is meant to be independent from the political work of the administrations that they are linked to. At the same time, their scientific work happens in close relationship with administrative work and consequently follows different standards to research undertaken at universities or other research institutes. These particular conditions are expressed in the concept of *regulatory science*.

One of the first experiences that led to openness policies was in the late 1990s on the issue of sanitary effects of nuclear contaminations. In 1997, an epidemiological study attested the nuclear waste reprocessing plant of La Hague, Nord-Cotentin, which caused environmental contamination that was responsible for an increased rate in child leukaemia. The mothers of the region's sick children mobilised to close the plant, calling themselves Angry Mothers. Environmental activists, CSOs, and independent radiologists, who were already mobilised in the local anti-nuclear movement, joined them in their protests. The accused company and several epidemiologists working on the subject disputed that the results of the study provided evidence of environmental or health contamination. The controversy became public and a subject of intense media interest.

In order to respond to the controversy and to determine the credibility of the study, the Institute of Protection and Nuclear Safety (IPSN)[5] convened a first group of experts. After an initial expert report, based only on data gathered by the accused company, did not convince protesters, the environmental minister asked for a second expert report on the controversy. The new scientific director, Annie Sugier, played a key role here as she was highly regarded by all of the parties involved in the controversy due to her professional record in three different fields (the nuclear industry, CSOs, and public expertise). She proposed replicating the controversial original study by conducting a pluralist expert study which actively involved local CSOs in the expertise process (Miserey and Pellegrini 2006).

Two parallel working groups were created. The first group was to replicate the epidemiology study to investigate the rates of child leukaemia in the area; this group was composed of scientists from different public institutes. A second group was to lead a radioecological study to investigate possible radioactive contamination around the plant; this group included some of the protesting associations as well as plant representatives and scientific experts from different public institutes. Once the pluralist group was composed, every party was involved in every stage of the expert work: identification of questions and problems, corpus building, data analysis and interpretations, synthesis reduction, as well as public communication (Miserey and Pellegrini 2006; Topçu 2013).

The final report indicated an increased rate of child leukaemia in the area but did not manage to establish any environmental contamination causality. However, several other possible causes were identified in the conclusions, leading to the formation of a second pluralist radioecological group. The uncertainty maintained in the scientific results is an important characteristic of the GRNC's work. It underlines the potential of such an organisation to be used as pluralist expertise to calm down a controversy even in the absence of a scientific consensus (Barbier 2019). These findings also highlight how such a scientific device also changes the knowledge produced. GRNC opened the doors of the technical and administrative spaces of technology assessment to CSOs. By being 'invited' to take place in the

[5]Until 2001, the IPSN was a department of the public administration of the Commissariat for Atomic Energy.

pluralist group, CSOs moved from positions of outside witnesses and protesters to inside contributors to the scientific work. It was the first experience of an institutional turn in the way IPSN cooperates with CSOs. Multiple institutional, social, and technical changes followed (Ottolini forthcoming).

For the work of the pluralist expert group on radioecology, legitimacy has been a central issue. For instance, the inclusion of CSOs, in general, as well as which ones were included, in particular, was justified by *technical legitimacy*. Therefore, not all the protesting groups were invited; only the ones that produced data and were able to take part in technical deliberation could get involved. Legitimacy was also an output of the process. The associations involved were recognised for their technical legitimacy. Not all NGOs involved in the protests and collecting data joined the group; some refused to become part of a state-led technology assessment process, fearing participation would decrease their ability to be critical. This could have also affected the NGOs legitimacy in the eyes of their supporters. The fact that CSOs held different positions in the GRNC matters to be remembered. In addition, it should be highlighted that the legitimacy of the radioecology group and its work was questioned regarding its entire membership, not just the NGO representatives. Company representatives and scientific experts also had to prove their legitimacy to the other parties involved. For instance, scientific experts had to demonstrate their independence from the nuclear industry. At the time, such pressure on experts' legitimacy was unusual (Callon et al. 2009). Finally, at the centre of the argument for more openness of the French risk evaluation institutes was the hypothesis that improving relationships with NGOs would counter a perceived lack of legitimacy. The GRNC experience has been a crucial episode in establishing this question as a matter of concern for regulatory agencies in France.

Occupational Health and Safety: Between Academia and New Social Movements

This second case study examines processes in the field of occupational health and safety in Germany regarding how (scientific) knowledge is gained by including a variety of perspectives on workers' experience, academic perceptions, and political considerations. The case study describes relevant moments in the history of a part of the German health shop movement located in Hamburg, fighting against authoritarian structures within the German health system that led to the foundation of a registered association called Arbeit & Gesundheit e.V. (Work & Health association).[6]

In the 1970s and 1980s, parts of Western Europe mobilised around new concepts of occupational health and safety within a broader health movement; this had ties to

[6]The case study is based on expert interviews with former activists within the health shop movement as well as people committed to Arbeit & Gesundheit. e.V.

the anti-nuclear, peace, environmental, and feminist movements. In West Germany, tensions arose between established university physicians and medical students regarding scientific approaches, data, analytical results, and recommendations to industry and politics. One salient topic was confrontation with the national socialist past. A focus was on the role of medicine in selecting productive bodies while neglecting a holistic approach that embraces human beings in their psychosocial and physical constitutions as well as the environment surrounding them. Also contested were the established power relations of the old, elite governing universities, hospitals, and occupational health institutions. Another salient topic was the critique of industrial hazards. Examples included exposure to polyvinyl chloride (PVC), used in the mechanical engineering industry, which leads to angiosarcoma of the liver, and isocyanates used to produce foams, in the automotive and timber industries, which lead to obstructive airway diseases (Schulze et al. 2018, pp. 258–259).

In European countries like the Netherlands, the United Kingdom, Denmark, and West Germany, university staff as well as students discussed how to make scientific knowledge available and comprehensible to 'lay people' (EWHN 2016). They also claimed that people not working in academia should have the option to co-decide research topics and projects. These discussions led to the establishment of *science shops*[7] at universities and of working groups, for example, on occupational health, to which trade union members, students, and academic staff were committed (EWHN 2016). These developments were accompanied by the founding of independent advice centres on healthy working and living conditions.[8] Members came from labour unions, health and technical professions, academia, and community activism (regarding the role of traditional actors and their relation to new forms of engagement, see Schulze et al. 2018; Jenkins and Marsden 2019).

In this context, the concept of so-called health shops was born, referring to community-based, self-determined approaches of health care, moving science shops from the university to the community (see also EWHN 2016). Stemming from the health shop movement and inspired by the Italian workers' movement,[9] the NGO Arbeit & Gesundheit e.V. was founded, in 1987, by some of the people involved in the working group Workers' Medicine from the health shop in Hamburg. Its aim was to enhance and institutionalise two approaches: (1) focus on workers as experts of their health and their working environment and (2) utilise workers'

[7] Science shops are scientific research spaces in which information and education are carried out for and with citizens (Wals et al. 2016, p. 35; see Senabre Hidalgo et al., this volume, Chap. 11). They started with issues and hazards at the shop floor level (EWHN 2016).

[8] Prominent examples include the London Hazards Centre, founded in 1984, in the United Kingdom, and the Committees/Coalitions on Occupational Safety and Health (COSH-groups) in the USA, where the first one was established in 1972.

[9] The Italian workers' movement declared in the mid-1960s that 'Health is not for sale!' (Calavita 1986, p. 199), founding working groups at shop floor level and establishing the principle of non-delegation. This meant that neither union representatives nor occupational physicians had to decide which claims were to be negotiated with employers. Instead the workers themselves collected data on health issues and working conditions to use for improvements in the workplace.

knowledge of occupational illnesses. These perspectives were used as the basis for research and scientific consultation, as well as setting the scene for new relationships with experts from other domains, such as occupational physicians, politicians on local and national levels, and toxicologists.

Participatory research was fundamental here: the health shop movement provided interaction between people coming from different (institutional) backgrounds. Medical students shared their knowledge about questionnaires with the workers who conducted research inside the factory; both aimed to correct hazardous conditions. Here, the participatory research initiative was bottom-up in two ways: in the mobilisation of students within the university environment with its hierarchical structures and in the mobilisation of workers within the industry vis-à-vis its occupational health physicians. Both groups become actors leading research processes. The founding principle of Workers' Medicine was 'non-delegata', referring to gaining control over working conditions, especially in improving health and safety issues at work (Calavita 1986, p. 201). This is especially important in the context of participatory research because it relates to at least two aspects that enable knowledge production that widens the scope of the scientific discourse and medical practice. These are monitoring of the workplace by workers and having an internal exchange of information and experience, for example, of symptoms, through questionnaires and group discussions. This helped to 'identify previously unknown occupational risk factors, indicate the presence of known factors, and provide indications for solutions' (Reich and Goldman 1984, p. 1034, with regard to Berrino and Morosini 1977).

However, this way of producing knowledge was controversial: due to the subjectivity of the individual experiences, the collection of data was considered biased, and the lack of expertise to take into account hazards not experienced first-hand, like 'non-odorous toxic gases', was also considered problematic (Reich and Goldman 1984, p. 1033). In this context, legitimacy was achieved in three main ways. The first was cooperating with academia in the construction of questionnaires, gathering data collectively, and analysing data comparatively.[10] Bargaining with employers in a science-based way was the second way to achieve legitimacy. This involved using the collected data and its analysis, as well as mobilising expertise outside the factory. It became an important part of the strategy of the workers group to co-determine work processes and to co-regulate and by doing so to gain power in protecting their health. As one of the interviewees put it: the data became 'a rational basis for a constant debate about health issues at work' (member of the working group and of Arbeit & Gesundheit e.V. 11 July 2017). The third way to gain legitimacy was

[10]The reports of workers were compared regarding the symptoms, looking for similarities and differences. That was done by forming homogenous groups by bringing together workers who were assumed to experience the same exposure (Calavita 1986, p. 202). Here, the predecessor of Arbeit & Gesundheit e.V., the working group Workers' Medicine, played a central role: as members of this working group were also members of work councils and medical students specialising in occupational medicine, bringing people together to plan research activities as well as facilitate negotiations with the employer and within the work council.

through legal recognition by becoming a registered association and receiving public funding from the Senate of Hamburg. Through this, the institutionalisation process of the demands in the health shop movement began. The financial support represented stability and seriousness. This made Arbeit & Gesundheit e.V. an actor relevant to trade unions and politicians. By creating credibility in the scientific expertise of the actors (work councils representing workers' interests and activists from the health shops), these zones of plausibility opened the path to negotiations on legislation and regulations like the Technical Rules for Hazardous Substances, for example, on carcinogenic hazardous materials.

Evolving Roles and Relations

In this section we examine the two case studies in relation to each other. For this purpose, we discuss the roles of the leading CSOs, the relations of CSOs to other actors, and the evolution of those relations. These constellations, we argue, lay the fundamentals for the transformation of the creation and use of scientific knowledge by including hitherto excluded perspectives to which both case studies testify. For both community-based organisations discussed, participatory research was used as a lever to elaborate and justify their positions. While different factors led to the emergence of collaborations in each case, it was especially the connection to science that enabled activists and engaged citizens to pave the ground for being recognised as legitimate negotiators. That differentiated them from 'mere' protesters and people being mainly committed to parliamentary activities in their pursuit of social and political change.

The presentation of the two case studies challenges the idea that successful participatory research always has its starting point in academic research. To the contrary, in these two case studies, it involved an interplay of diverse actors who worked on social and cognitive injustices and used science to gain legitimacy as well as to enrich the knowledge base. CSOs have taken on central activities and leading positions in the collaborations that can be summarised in three different roles:

1. A *technical role* in the production of knowledge, such as gathering data or choosing methodologies of data interpretation
2. A *governance role* in the organisation of research activities, such as choosing or bringing up new topics of research
3. An *advocacy role* that includes campaigning for transformative knowledge and translating or brokering knowledge between contexts of research and application.

For CSOs to fulfil these roles, three factors were important. First, the members of the CSOs belonged to multiple organisations, for example, social movements, universities, trade unions, and work councils. This enabled the actors to meet in different spaces, exchange information, and develop ideas for change. Second, for generating transformative knowledge, CSOs had access to academic skills. Third, CSOs also had access to otherwise excluded communities, for instance, in the workplace. On this basis, CSOs were able to shift their position from being objects of research or outside protestors to becoming co-developers of research. In this position they were empowered to make claims and to observe, collect, interpret, and, finally, negotiate scientific knowledge. This meant gaining legitimacy,[11] that is, representing justified authority for communities, scientific institutions, as well as politicians (see, e.g. King 2003, p. 25).

In addition to the focus on the generation of knowledge, our cases show the importance of contexts of knowledge application for this type of participatory research.[12] Both the cases are in scientific domains that rely on the embodied expertise of concerned groups to (re)claim epistemic authority – occupational medicine and social sciences (health shop) and epidemiology (pluralist expertise). We argue that the nature of such participatory research is closely tied to it taking place as applied research. Without the contexts of occupational health regulation or risk governance, the work of Arbeit & Gesundheit e.V. and the pluralist radioecology group cannot be understood.

Challenges for CSOs in Citizen Science

In this section, we link what we have learned from the case studies to broader debates on the involvement of CSOs in participatory research, particularly citizen science. We do this by focusing on five core issues that represent conceptual and practical challenges associated with understanding and analysing roles of CSOs in participatory research. For a discussion on the roles of technologies in citizen science, see Butkeviciene et al. (this volume, Chap. 16):

1. *Taking mistrust and controversies into account*. Both case studies challenge our understanding of what is nowadays called citizen science on fundamental, conceptual, and political levels. At the heart of both case studies, we find suspicion towards scientists, experts, and company authorities, who are assumed to act in favour of industrial interests. This approach taken by the CSOs actually represents a form of mistrust, which today's politicians seek to minimise by funding citizen science. However, such an approach disregards that it was mistrust that acted as a catalyst for civil society groups to engage in research themselves and become legitimate parties in the processes of scientific knowledge generation and application in contexts that directly affect their lives and bodies (cf. Wynne 2006). The role of CSOs is therefore not only to participate in research activities

[11]'An account of legitimacy involves assumptions, principles, and arguments in terms of which authority is justified' (King 2003, p. 25). See Ruokonen (2013) regarding the relation between trust, trustworthiness, and responsibility from a philosophical perspective.

[12]Although this characteristic has been prominently highlighted in the strand of science and technology studies work on technical democracy pioneered by Callon et al. (2009), it is largely absent from current discussions on citizen science.

but also to achieve transformative goals, that is, to change specific living and working conditions, which endanger their own and other people's health. Moreover, CSO action aims to claim a right to know (see EWHN 2016), thereby democratising knowledge (see Derickson 2016 for an example of workplace health hazard information access). This tension of approaches to science, participation, and (mis)trust highlights the productivity of both sociotechnical controversies and including critics in scientific processes to question technical roles and responsibilities in scientific work (cf. Callon et al. 2009). Making visible and exploring controversy and critique in our analysis of citizen science offer the opportunity not only to change our understanding of participatory research but also to enable deliberation on scientific governance (see also the concluding section).

2. *Considering values as drivers*. The role of CSOs is closely linked to values which motivate participation in and commitment to collective action. Therefore, it would be interesting to ask what values motivate involvement in science, producing one's own data and using these for demanding change, as well as which values provide the basis for legitimacy. A historical perspective reminds us that different actors can mobilise different (registers of) values at different times and thus may change our perception of the roles of values in (participatory) science.[13] Moreover, we should also gain insight into the socio-economic conditions the (non)participating individuals and communities live in, which may affect motivations and strategies to pursue goals as well as the choice of collaboration partners. Additionally, a systematic approach of researching citizen science has to analyse how these actors mobilise for change and produce collaboratively scientific results. New communication technologies and more sophisticated techniques of participation can widen the repertoire of scientific and political participation, which will bring challenges to methodological approaches.
3. *Inclusiveness*. This brings us to the question of who can take part in collaborative research (see also Paleco et al., this volume, Chap. 14). As far as the cited literature and the two case studies indicate, it is usually necessary to speak the language of science and administration as well as the language of law. This requires analysing the settings in which CSOs and their members are able to act as researchers and acknowledged as experts outside scientific institutions. Therefore, the question of who is marginalised needs to be scrutinised. One can hypothesise that those who have not obtained expert knowledge or who are not able to collect data or to interpret data will be excluded from citizen science. The two case studies show how this question of inclusion and exclusion has been crucial in the history of participatory research – a topic scholars and practitioners of citizen science should address more thoroughly. However, it is important to ensure that CSO involvement is not merely limited to providing access to volunteers. Although this can represent a valuable contribution, we have argued

[13] Understanding the roles of values in the 'moral economy' of science is a fundamental subject in the sociology and history of science (cf. Daston 1995).

that, in general, the potential of CSOs for transformative research can be best captured through drawing on their expertise and leadership to partner with them for co-creation.

4. *Ambiguity of terminology*. There is a conceptual tension in the framing of citizen science, to which we referred at the beginning of this chapter. On the one hand, the label citizen science is typically used for a subset of participatory research activities, usually involving large-scale data gathering or analysis, and closely linked to crowdsourcing (cf. Strasser et al. 2019). However, on the other hand, citizen science is also being established as an umbrella term (Rip and Voß 2013) in research and environmental policy. So, it becomes clear how citizen science claims to unite various streams of participatory research under one joint concept, including community-based research. Such umbrella terms allow scientific research agendas, societal concerns, and policy issues to be linked. We argue that more research is needed on the tension between these two usages, such as the unifying and hegemonic qualities of the concept.
5. *Funding*. Finally, on a practical level, funding conditions are a key challenge for expanding the roles of CSOs in citizen science.[14] A central argument is that the decline of public investment in academic research and universities since the early 2000s corresponded with an increase in investment in private research and innovation (Larédo 2015). Citizen science, if understood as outsourcing of research work to unpaid volunteers, might be seen as the latter (cf. Mirowski 2017). However, by taking the roles of CSOs more seriously and systematically into account, participatory research can also be understood (and further established) as a third kind of research – following a civic logic and complementing public government and private market research (cf. ALLISS 2017).

The Power of Transformative Research: Future Perspectives

This chapter started with the assumption that CSOs are key actors for generating better science, that is, knowledge that changes both understanding as well as how people live and act. We have argued that discourses on citizen science between practitioners and policymakers do not consider CSOs systematically. Through the presentation of two case studies, we demonstrated how different forms of collaboration between organised civil society and scientific institutions have a long-term history that the recent trend of promoting citizen science can draw on. The CSOs we examined took over technical, governance, and advocacy roles in the production of knowledge, closely linked to contexts of application. These cases challenge the dominant view of citizen science as a stable two-party relationship between

[14] Discussing more practical challenges of improving relations between CSOs and scientific institutions is beyond the scope of this chapter (for results of capacity building work at the European level, see Göbel et al. 2019).

academic researchers and lay individuals who collect or analyse data in temporally limited projects. Important aspects of those forms of collaborations are scientific skills and access to marginalised communities, handling power imbalances between academic institutions and CSOs and generating legitimacy. Addressing these analytically, as well as in practice, gives rise to a web of interconnected challenges that we have discussed above.

Based on these findings, how can the involvement of CSOs be taken seriously in the definition of citizen science and the shaping of this field of research and engagement practice? Here citizen science is understood as a variety of existing participatory research approaches, linked together by a joint label (not merely associated with a specific methodology for participation in research, like crowdsourcing). This is important, because through that linkage what counts as participation and what counts as research are configured. In this sense, there is a danger of generalising a citizen science model of participatory research, which neglects the contributions of CSOs and eclipses other forms of participatory research along with their associated methodologies, communities, and trusted relations. In our case studies, we have shown how CSOs have adopted multiple roles in participatory research processes, transforming the generation and use of scientific knowledge. This transformative potential is deeply rooted in the configuration of self-organised engagement with socio-techno-scientific issues, which is why CSOs play a critical role. We argue that they should be key agents in shaping the future of participatory research and need more consideration – both in research as well as in practice – in the context of citizen science.

Engaging with self-organised civil society groups and organisations also means engaging with controversial issues. These can be issues for which scientific and political consensus might not yet have been reached (as in our first case study) or maybe controversies not even yet recognised (as in the second case study). In this sense, more engagement with CSOs as part of citizen science also signifies increased politicisation of both the field and the practice. This could mean, for instance, that more citizen science projects and practitioner organisations would take positions on controversial issues and get involved in the messiness of shaping them. Another expression of taking this ambition seriously would be to ask – not only why CSOs are important for citizen science, as we did in this chapter, but notably – what role citizen science can play for CSOs.

Finally, to facilitate more work in such a direction, we need to focus on the values binding together our own heterogeneous communities of practice. It is key to examine to what degree the structures and processes we use to act together support these values, so we can improve them to ensure that they address mutual respect, equity, and inclusiveness in adequate ways. It might then be possible to nurture communities of mutual support and care, which are key to unlocking the transformational potential of making and using scientific knowledge.

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Chapter 18
Citizen Science and Policy

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Abstract Citizen science has manifold relationships to policy, which is understood as sets of ideas or plans for action followed by a government, business, political party, or group of people. In this chapter, we focus on the relationship between citizen science, government policies, and the related notions of politics and polity. We discuss two core areas of interaction between citizen science and policy. Firstly, government policies can support citizen science to flourish, for example, through legitimisation or funding. Secondly, citizen science can contribute to policymaking at various stages of the policy cycle, including policy preparation, formulation, implementation, monitoring, and evaluation. Since both of these perspectives are intertwined, the policy landscape related to citizen science is complex, and it is continuously evolving. This chapter disentangles some of the complexities, with a particular focus on the European landscape, its geographic diversity, and key players (stakeholders and beneficiaries). It presents a brief history and the current context and also includes recommendations for the future with respect to governance, policy

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impact, sustainability of citizen science initiatives, and the role of digital transformations. We showcase the pathways of leading examples but also highlight currently unanswered questions.

Keywords Policymaking · Policy cycle · Public participation · Policy impact · Research policy

Introduction

The relationships between citizen science and policy are rich and manifold. We will introduce the context of these relationships and unfold their inherent complexities throughout this chapter. Here, we will particularly focus on governmental policies, which are understood as sets of ideas or a plan for action followed by a government. On the one hand, we will introduce the characteristics of (governmental) policy that might either enable or hinder citizen science. On the other hand, we will also investigate key features that make citizen science valuable for policy and also those that might make policy uptake more challenging.

Following the overall context of this volume, we will focus on the COST context, which is primarily concerned with Europe, with a few links to the global setting and comparison with countries in other regions. This will illustrate several common European interests but also the diversity of national contexts, as well as differences in local needs.

As recently elaborated by Göbel et al. (2019), citizen science can play different roles in governance, which is understood as the intention to control and direct the public business of a country, city, group of people, etc. According to the authors, there are four roles for citizen science in policy: as a source of information for policymaking, as an object of research policy, as a policy instrument, or as a form of sociotechnical governance (i.e. a form of direct governance via non-policy actors).

The relationships between citizen science and policy can, for example, be explained by applying the framework of the Sustainable Development Goals (SDGs). A recent article by Fritz et al. (2019) detailed the possible benefits of citizen science data for the monitoring of the SDGs, that is, as *a source of information for policymaking*. Additional contributions to the global policy on sustainable development can be made by citizen science contributions to the quality assurance and analysis of data, the co-development of indicators, and much more. SDG 17, 'Partnerships for the goals: Strengthen the means of implementation and revitalize the global partnership for sustainable development', provides a policy frame that supports public engagement in scientific research, which could include citizen science, both as *an object of (research) policy* and as *a policy instrument*. Citizen science activities supporting sustainable living (e.g. numerous citizen observatories in areas such as transport, agricultural production, and noise pollution; see also WeObserve 2019) contribute *sociotechnical* change to the sustainability transition. This type of engagement substantiates one of the most famous phrases related to the SDG framework: *think global, act local*.

In this chapter, we will address the topic of sociotechnical governance only as far as government policies might affect this topic (both positively and negatively). We will distinguish between policy for citizen science (the contributions government policy might make to citizen science) and citizen science for policy (the contributions that citizen science can make to government policy) – and the interplay between these two sides of the same coin. We focus on matters related to citizen science, which overlap with, yet are different from, other concepts, such as citizen initiatives that engage citizens directly in policymaking. Elaborations on citizen initiatives and governments are, for example, provided by Mees et al. (2019) – here in the context of climate change adaptation.

The remainder of the chapter will present a detailed background of the relationships between various interpretations of citizen science and different areas of policy, followed by an elaboration of the current situation. On this basis, we will distil some of the most pressing challenges that we see at the interface between citizen science and policy today. We will conclude by outlining emerging trends and recommending possible actions to foster and build on existing relationships.

Background

Awareness of the potential value of citizen science for science, as well as its scientific and sociopolitical implications, was first formulated – publicly and explicitly – in the field of European environmental policies in 2008 (Haklay 2015). Today, citizen science increasingly influences science and science policy.

Underlying Structures

Public authorities may play different roles in governmental policy – including its proposal, negotiation and agreement, implementation, compliance assurance, and more. Hence, we will not restrict our discussion by simplifying policy and policymakers to a single role. There is no such thing as a single type of policymaker. We can distinguish multiple ways in which citizen science is carried out, or facilitated, by governmental institutions, including initiating supporting policies, managing research projects, practicing citizen science and engagement, researching citizen science governance and methods, and providing internal guidance and training. Figueiredo Nascimento and others already specified these roles and mapped them to different services of the European Commission in *Citizen Engagement in Science and Policy-Making* (Figueiredo Nascimento et al. 2016). Notably, this is complemented by opportunities with other public authorities, such as the use of citizen science in courts (see, for example, Brett 2017). Focusing on the area of policymaking, possible contributions of citizen science can be understood along the well-established policy cycle. Accordingly, citizen science can provide valuable contributions to policy anticipation (agenda setting), formulation, implementation, monitoring, and evaluation (Bio Innovation Service 2018; Turbé et al. 2019).

We should also recognise the dimension of politics. Politics (a concept related to agents, processes, and resources for general interest) and policies (related to objectives, targets, and instruments) are clearly two different but closely entangled concepts (Lange et al. 2013). In this chapter, we will primarily address the relationship between citizen science and policy – without losing sight of the close relationship of these two notions with the notion of politics. For example, citizen science, paired with scientific evidence, can be a tool to create political pressure, as examples in biodiversity (especially insects; see Schmitt 2017) and air quality have clearly shown (Van Brussel and Huyse 2019). The philosophical notion of 'the political', that is, what is related to general interest, as research is, should be also kept in mind. Citizen science is a practice that promotes the development and exercise of different capacities and responsibilities regarding research by all members of society.

Last, but not least, all of these evolving relationships between policy and citizen science depend strongly on what is considered, perceived, or advocated as citizen science. Haklay et al. (this volume, Chap. 2) have already introduced the challenges and approaches of defining citizen science as a generic concept. However, we need to briefly revisit and emphasise the possible interpretations of citizen science before introducing its relationships to policy. Notably, requirements for definitions (quality), criteria, and terms of reference for citizen science will depend on the purpose – in our case mostly on the policy angle under consideration. For example, the selection of proposals in response to a citizen science call will depend on the funder's criteria of what qualifies as a citizen science project. The inclusion of an activity as part of a citizen science inventory or platform will depend on the owners of this platform – and might be in conflict with the criteria or interests of supporting funders. In both cases, *terms of reference* need to be provided, and review processes need to be put in place.

Clarifying Concepts: Policy-Politics-Polity

The term *policy* refers to the set of objectives, together with plans or programmes for action, regarding a specific aspect of collective interest, for example, the policy of a company or a specific association. In particular, when we refer to objectives, plans, or programmes at government level (local, regional, national, etc.), then we talk about *public policy*. In representative democracies, the political agents – the politicians, usually integrated in parties – will be in the main responsible for defining the different public policies (educational, scientific, fiscal, environmental, etc.) at different administrative levels. Political agents also include every non-governmental entity and every citizen who seeks to influence and/or participate in the governance of diverse public matters or those of general interest.

The discussion and theorisation about the different modes of government and citizenship – put into practice by the political agents through the policies – is the

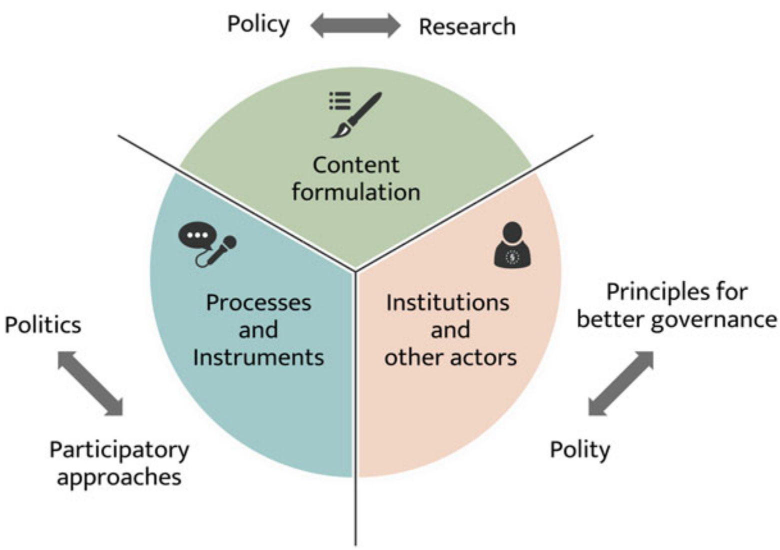

Fig. 18.1 The interdependent facets of citizen science (right) and policymaking (left) – mutual impacts

Table 18.1 Overview of the main concepts with examples and references

Concept	Key features	Examples of citizen science impacts	Literature
Policy	Content, objectives, targets	Implementation of the EC Open Science Agenda	OSPP (2018)
Polity	Formal institutions (including NGOs), principles, norms, convictions	Promotion of open and responsible research and innovation	von Schomberg and Hankins (2019)
Politics	Processes, instruments, elections, lobbying	Focused activities for more pollution regulation, influencing also election behaviour	Van Brussel and Huyse (2019)

object of *polity*. Polity is the matter of study in many social sciences, such as political sciences, political philosophy, and the philosophy of law, which ask which models and actions of government are better than others and why.

In this chapter, we are particularly interested in practical action, in *policy*, while acknowledging its interconnectedness with ‘polity’ and ‘politics’. The links between policy, polity, and politics have been extensively studied (Lange et al. 2013) and are summarised here in Fig. 18.1 and Table 18.1. Furthermore, we note, with Irure (2002), that developing and implementing a policy are a multistage process in which the role of active citizenship can be truly relevant. First, a need is identified. After deliberation and the analysis of resources, the issue is introduced into the government agenda. Then, the objectives are defined, and the strategies to achieve them are designed, together with the indicators needed to measure the results. At the same time, competent agents are sought who will develop the implementation and fulfilment of that policy. It seems necessary, thus, to understand the relations between citizen science and policies and to understand the need to take into account the knowledge of all experts – inside and outside academic and political institutions – both when identifying problems and when making decisions, as well as when carrying out programmes and monitoring them.

We understand that the development of citizen science – usually in bottom-up projects but not limited to them – is indissoluble of its influence, greater or lesser, in the development of various policies. This is also what we intend to show in this chapter.

The Development of Citizen Science and Policies

The development of citizen science, together with its presence in European policies, can be framed in a broader context, related to the so-called participatory turn (Jasanoff 2003) that developed mainly in the 1980s and 1990s. Such a context is reflected in a democratisation of very different areas of society, which involves increased awareness and acceptance of responsibility (von Schomberg 2011) and the necessity of common deliberation on common issues (MacIntyre 2016). While such participation has been developed in practical contexts, its different forms and meanings, as well as its diverse social and political implications, have been comprehensively analysed, including warnings and/or complaints about the instrumentalist interests behind the promotion of citizen participation (De Marchi et al. 2001; Mirowski 2018).

In this section, we briefly present the evolution of policies in Europe related to citizen science. We address European policy support for the funding of citizen science activities, before shifting our focus to the political agenda and the development of participatory aspects with regard to citizen science (both outlining the policy for citizen science perspective). Finally, we highlight the contributory aspects of citizen science in policy-related actions (citizen science for policy perspective).

Citizen Science and European Research Funding

The already mentioned participatory turn is indeed soundly reflected in European policies, which have incorporated notions related to citizen science from diverse sources, including (1) political and economic sciences, *co-production* (Ostrom and Ostrom 1977); (2) the sociology of science, *co-production of knowledge* (Jasanoff 2003); (3) scientific governance, the *lay-expert* relationship (Irwin and Wynne 1996); and, recently, (4) the philosophy of science, the notion of *responsible research and innovation* (RRI) (von Schomberg 2011). RRI was first introduced in the Seventh Framework Programme (FP7) for funding European Union research and development, and integrated as a cross-cutting agenda in its successor, Horizon 2020, forming a primary focus of the 'Science with and for Society' (SwafS) stream of the programme.

Interestingly, within and beyond the original RRI/SwafS agenda, a great number of European projects using a citizen science methodology, with a multidisciplinary and transdisciplinary approach, have been or are being funded following FP7. Many RRI-related projects have involved the dissemination of the concept of participation, often including the promotion of citizen science and, more recently, do it yourself (DiY) activities as a further step in public participation, beyond activities that encourage greater dialogue between all concerned, such as science shops.

The idea of co-production or *co-creation* has been present over the last few decades and now appears – under the notion of *codesign* – in the preliminary documentation of Horizon Europe (EC 2018a). In fact, these notions not only are a trend in the research and innovation area but also underpin an increasingly general vision for improving European governance (EC 2018b) – a vision already established in the white paper *Europe 2000*, through notions such as co-regulatory mechanisms, cooperation, coordination, and co-decision, all in order 'to connect Europe with its citizens, as the starting condition for more effective and relevant policies' (EC 2001a). Vohland et al. (this volume, Chap. 3) provide additional information about European research funding.

Citizen Science Beyond Research Funding

In citizen science, terms such as co-production and co-creation have often been used, not just in relation to implications in decision-making and consultation with citizens but alongside them, to achieve active involvement in all the steps of the research cycle. Cooper and Lewenstein (2016) have explained how the two different visions of citizen science – Irwin's, closer to activism and social-political demands (Irwin 1995), and Bonney's, more linked to the contribution of scientific data by citizens (Bonney 1996) – need not be two distant visions.

In this section, we also offer some more remote precedents of this participatory turn, which has led to citizen science development alongside different policies, not only in environmental areas but also in many other such as health and more recently in the digital realm, all in the context of the evolution of democracy in European countries.

Firstly, the *right to science* (Wyndham and WeigersVitullo 2018) was established in the framework of human rights, as the 'right to share in scientific advancement and its benefits' (Art. 27 in UN 1948) and, then more specifically, in the framework of social and cultural rights (Art. 15 in UN 1966). Until the last two decades, this had been mainly understood as the right to access information and knowledge, as well as the benefits of different scientific and technological developments. By the end of the twentieth century, this understanding had already evolved 'from the right to access information and knowledge to the right to participate' (De Marchi et al. 2001), mainly through decision-making regarding risk in environmental and health issues. However, it is true that a citizenry interested in sharing in scientific progress was also being formed, a citizenry capable not only of accessing but also of generating scientific knowledge.

In addition, and also on a global scale, demands for more sustainable development have fostered citizen participation in the field of environmental conservation, significantly since the United Nations Conference on Environment and Development, known at the 'Earth Summit' or 'Rio 92'. It should be remembered that the origins of *sustainable development* as a concept go back further due to a confluence of different factors, among others, the impact of Rachel Carson's dissemination work that led to the formulation of environmental policies around the world and the notion of a *principle of responsibility* towards future generations (Jonas 1984), which was also key in the emergence of the (controversial, but currently applied) *precautionary principle*.

In this context, the well-known texts by Irwin (1995) and Irwin and Wynne (1996) are useful. These authors, among many others, claim the recognition of supposedly non-expert knowledge – providing empirical examples – mainly with respect to decision-making in the area of environmental and health-related risks, which are linked to scientific-technological development. The right to participate in environmental decision-making was granted in 1998 by the United Nations Economic Commission for Europe when it adopted the Aarhus Convention. But a major step was taken when, as Muki Haklay (2015, p. 17) points out, the 'National and multinational environmental policy demonstrated, an awareness of citizen science, in particular in a speech in 2008 by Professor Jacqueline McGlade, then Executive Director of the European Environment Agency (EEA)', who announced the creation of a Global Citizens' Observatory for Environmental Change, starting with the integration of citizens' observations with official water quality data. She noted that many times people closest to the problems can give the best information and their own vision to complement the official information, highlighting the importance of taking advantage of this local knowledge.

The Bigger Picture

It is worth now remembering Irwin's rationale for focusing on environmental and health risks (1995). Among other reasons, he indicates that these issues represent other areas of social and technical debate. In fact, a few years after publication, the documents related to the creation of the European Research Area (ERA) in 2000 clearly mention 'openness, participation, accountability, effectiveness and coherence' (EC 2001a, p. 8) and the 'participation of civil society' in science and technology policies (EC 2001b, p. 14), even though they do not explicitly use the term 'citizen science'. Gradually, participation is increasingly understood in a more active and all-embracing way, including participation in all stages of the scientific process.

In fact, specific reports on citizen science and environmental policies have been published by the European Commission. *The Science for Environment Policy In-depth Report: Environmental Citizen Science* offers a comprehensive picture of environmental citizen science in Europe (EC 2013). The report explores research into citizen science and provides a wide range of citizen science projects showing the variety of approaches and topics covered. By emphasising the so-called contributory projects (designed by scientists but replying on volunteers to collect data), mostly in the environmental field, it reveals the potential added value of such projects and their benefits to society, science, and policy decision-making that still need to be evaluated. Benefits include large data sets for science, an increase in public engagement and interest in research and policy, and the improvement of policy decision-making by including various sources of knowledge and by providing evidence to support regulatory compliance and inform policymaking.

Building on the 2013 In-Depth Report (EC 2013), the report *Citizen Science for Environmental Policy: Development of an EU-wide Inventory and Analysis of Selected Practices* (Bio Innovation Service 2018) undertook a wider survey of studies and provides further insights into the relevance and usefulness of citizen science for environmental policy. The two main aims were to create an inventory of environmental citizen science projects relevant for environmental policy and assess how these projects contribute to the Sustainable Development Goals (SDGs) set by the United Nations (UN) General Assembly (UN 2015).

While the inventory affirms the predominance of contributory projects in environmental citizen science, it also points out that citizen science is covering all engagement types including collaborative (i.e. designed by scientists with volunteers contributing) and co-created (i.e. scientists and volunteers collaborate throughout all stages of the scientific process) projects in all fields of environmental sciences (Bio Innovation Service 2018). The report found that environment-related SDGs are currently unevenly represented by citizen science projects. For example, citizen science projects in the inventory contribute less to goals with a strong socio-economic focus, while marine and terrestrial nature conservation are the goals that received the best direct contribution from citizen science projects – given a predominance of monitoring citizen science projects. For the uptake of citizen science project outcomes (including data), the report identifies the importance of governments to be involved in projects from inception. Among other key results, it also shows the crucial role of NGOs in the governance of citizen science projects, while scientific excellence also increases the extent of policy use of citizen science data. The report closes with recommendations regarding the operability of citizen science projects and data management, as well as capacity building in the field of citizen science, including stakeholders from science, society, and policy. It laid the grounds for the recently published European Commission Staff Working Document on best practices in citizen science for environmental reporting (EC 2020a).

Together with these more visible examples, there are many other reports in specific fields – such as agriculture, invasive species, land use, fisheries, etc. – in which the term citizen science is not directly introduced, but the concept is present through other terms such as *participatory action research* or *community-based research* or *co-management* among many others (e.g. Nielsen and Vedsmand

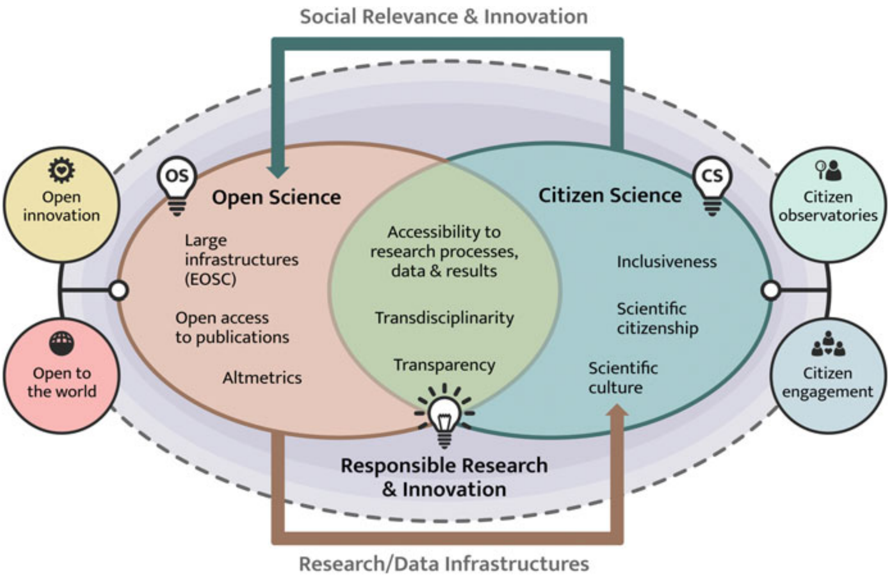

Fig. 18.2 The relationship between citizen science and open science. (Based on Vohland and Göbel (2017), modified)

(1999) show co-management as the tool for explaining the successful results in some Danish fisheries). In this sense, we could cite as examples the LIFE projects, in which citizen participation is increasingly present (LIFE Programme 2019).

Following the original Science and Society Action Plan (EC 2001b), the funding opportunities of the last three framework programmes (FPs) – 'Science and Society' (SaS), FP6 (2002–2006); 'Science in Society' (SiS), FP7 (2007–2013); and 'Science with and for Society' (SwafS), FP8 (2014–2020) – reflect some of this evolution, which is being widely studied both in academic papers and in policy reports (Owen et al. 2012; Rodríguez et al. 2019; EC 2016). Since 2010, citizen science has been explicitly placed in different European science policy frameworks, both aligned with the objectives of the Europe 2020 Strategy and related to more specific areas such as the Digital Agenda, Science 2.0, RRI and Open Science, and SDGs. Interestingly, the genesis of Fig. 18.2 traces back to 2010 (RIN/NESTA 2010), passing through different documents related to Science 2.0, Digital Science, and, ultimately, Open Science. It seems clear that European science policy still considers the Digital Agenda as a key route for citizen science and that European science policy is focusing on Open Science as the framework under which citizen science is justified (EC 2018a).

Today, irrespective of the different understandings and consequent definitions assigned to citizen science initiatives, the use and application of citizen science practices is increasing – at European as well as at national and local levels. This is due to a number of emerging factors, including a better understanding of the benefits stemming from the use of citizen-generated data and the increasingly economic value attributed to them, citizen science's support of the growing phenomenon of social innovation, and the impact of digital technology on citizen science practices.

Finally, it should not be forgotten that there are many more citizen science practices not yet catalogued or even known about and that there may be thousands of people researching outside institutions, sometimes well aware of their capacities, duties, and rights: farmers, hunters, fishers, makers, hackers, and many others contribute to the growth and dissemination of knowledge, as well as to the direct or indirect formulation of policies. As some authors have explained in different ways (see, for example, Lafuente and Estalella 2015), the history of science, research, and innovation has gone through a 200-year hiatus, in which the participation of ordinary people had been excluded – but things are already changing.

Challenges

It is clear that citizen science has the potential to transform the policy landscape by generating new sources of information and by radically altering the role citizens can play in the policy process. This presents unprecedented opportunities to increase information flows, governance transparency, collaboration, and democratisation. However, many aspects of the processes that are required to generate such citizen science initiatives often do not fit within current institutional practices. Realising the potential of citizen science for policy thus requires *disruptive innovation* that challenges and changes institutional practices and leads to a dramatic shift in power relationships amongst players within the science-society-policy interface. In particular, realising a landscape in which citizen science thrives and its benefits to policy can be fully utilised requires changes within science, society, and governance.

Changes are already underway, and there are increasing signs that key actors are willing to facilitate the required disruptive innovations. However, several key challenges remain. The first two challenges address the citizen science for policy viewpoint, whereas the following two highlight issues related to policy for citizen science. The last two challenges cut across both perspectives.

Recognition of Citizen Science as a Legitimate Scientific Approach

Some sections of the scientific community remain reluctant to recognise citizen science as a legitimate scientific approach, fuelled by a lack of knowledge about citizen science opportunities, a distrust in citizen science data quality, and a preference for data collected by fellow scientists (Burgess et al. 2017). Moreover, many academic institutional practices frustrate further growth and acceptance of citizen science. Academic career paths still largely rely on having a strong publication record in high-ranking academic journals and securing large scientific grants. Additional efforts that are needed to realize citizen science projects, including time investment in relationship building and co-creation processes with participants and policymakers, are undervalued. However, high-ranking publications and large funding grant opportunities in citizen science research are emerging. The EU investment in citizen science through the H2020 Responsible Research and Innovation Agenda has been a hugely welcomed opportunity to both advance the science of citizen science and provide career opportunities for academics specialising in citizen science approaches. Further opportunities for funding and recognition of citizen science research are needed to move citizen science further into the mainstream.

Recognition of the Value of Citizen Science to Policy

The citizen science community has long identified the benefits citizen science can bring to policy and has highlighted them to policymakers at local, national (Thornhill et al. 2016), international, and global (Fritz et al. 2019) levels. In recent years, policymakers have increasingly picked up on these benefits. The EU, in particular, has carried citizen science forward as part of its Open Science Agenda, Horizon 2020 funding programme, and numerous supportive environmental policies (see above for details).

Several EU member states have produced, or are currently developing, citizen science strategies (e.g. Germany, Austria, Italy) (Manzoni et al. 2020) or identified citizen science as a key instrument for (future) policy creation and monitoring (Schade et al. 2017). While this increasing interest is promising, funding programmes for policy-oriented citizen science remain largely limited to a few areas that have never been occupied by ‘professional science’ (e.g. biodiversity monitoring). However, significant progress has been made by some governance bodies to establish local citizen science initiatives, feeding directly into local policy implementation and resource management (Owen and Parker 2018). Outside of these areas, the benefits of citizen science remain largely theoretical for most policymakers. More real-life examples are needed to build trust among policymakers in the societal ‘return on investment’ and to fully understand the practical opportunities and constraints. Moreover, policymakers may be reluctant to invest in citizen science as long as it is not yet well known and appreciated by academia and the wider public. It can be expected that greater knowledge and appreciation of citizen science among academia and the public will facilitate greater uptake of citizen science among policymakers.

Building Trust Among Diverse Publics

The success and high uptake of various existing citizen science programmes (e.g. Van Brussel and Huyse 2019) demonstrates that there is a public appetite for citizen science approaches and that there is further opportunity for growth and involvement across a range of demographic groups. Making a difference to science or the (local) environment and its acknowledgement by policymakers are key motivations of participants in environmental citizen science projects. It can therefore be expected that the uptake of policy-relevant citizen science projects will depend on the public's confidence in whether the outcomes will lead to actual change. This puts a clear responsibility on citizen science practitioners to manage participants' expectations and not overpromise the impact an initiative will have. Where policymakers are directly involved in the organisation of a project, they have a responsibility to set clear expectations from the outset and to live up to them, even if the evidence that emerges from the project does not suit their (political) aspirations. If public trust is broken in one (high-profile) example, it has the potential to have lasting negative repercussions on projects elsewhere. This is mirrored in the criticism citizen science has received as being an instrumentalist practice, for example, aimed at cutting and outsourcing costs (Mirowski 2018). Especially if policymakers want to reap the wider benefits of citizen science (beyond access to new data sources), including transparency and democratisation of the policy process, then they need to take citizens seriously and work together to realise common goals.

Setting up such direct collaboration between citizens and policymakers will require a pre-existing level of trust. Where levels of trust between citizens and governmental institutions are not yet sufficient, independent third parties, for example, NGOs, may play a key role in bringing partners together, holding them to account, and building trust between them (Manzoni et al. 2019).

Interestingly, citizen science can arise from distrust in decision-makers and can in itself trigger a meaningful dialogue based on independent data sets, increasing trust over time.

Citizen Science Policy Instruments

Bio Innovation Service (2018) demonstrated that policy use of citizen science data is greatest where policymakers have been directly involved in the citizen science initiative from conception through to dissemination. However, existing policy instruments for research and public engagement are often separate and are not adapted for the specific processes required to lead to successful citizen science initiatives. New instruments are needed to enable prolonged and deep engagement between all parties involved, in order to build trust and recognition between actors and create shared, fit-for-purpose data collection protocols. As part of the COST Action CA15212 *Citizen Science to Promote Creativity, Scientific Literacy, and Innovation Throughout Europe*,[1] under the its Working Group 3 – Improve Society-Science-Policy Interface[2] – a pan-European survey on citizen science strategies and

[1]https://cs-eu.net

[2]https://cs-eu.net/wgs/wg3

initiatives in Europe was carried out over the last couple of years (Manzoni et al. 2020). From the preliminary outcomes of the survey, it emerged that citizen science practices operate in specific ecosystems, that is, in complex systems with interconnected processes and actors that strongly depend on the surrounding (cultural, social, governmental, and sectorial) contexts.

For any citizen science activity to be relevant for policy and achieve successful policy uptake, it has to be highly contextualised and adapted to the actual level of intervention. As such, given the variety of citizen science ecosystems and complexity of policy formulation, the analysis of citizen science approaches, and related impact assessment frameworks, need to be broken down into dedicated components with clearly defined functionality. In this context, citizen science also has its place in the process of co-creation of policy formulation, as a possible success factor for defining and achieving intended policy outcomes. It should be assessed how dedicated and well-adapted citizen science approaches can contribute to different policy instruments and policymaking processes (see, for example, Kieslinger et al. 2017).

Specific challenges have been identified around the timelines required for co-created citizen science, due to the potential for differences between participants (wanting change now) and policymakers (working to longer-term policy goals). Collaborations within an ever-changing context may lead to outcomes that are no longer relevant by the time projects produce them because the policy agenda has evolved in the meantime. Similarly, differences in capacities between professional and volunteer participants, for example, when they are available for meetings (during working hours or outside them), need to be addressed to produce successful collaborations (Göbel et al. 2019).

Pilot initiatives that can act as examples and enable learning among all parties are urgently needed before a given approach is ready to be scaled up. Consequently, growing too quickly can jeopardise public trust as it may lead to overhyped expectations that projects cannot yet realise.

Geographic Scales

Although the challenges identified above are relevant at all geographic scales, addressing them may differ in local, national, and international contexts. Building trust may be easier at the local level, where policymakers and members of the public can get to know each other personally. Indeed, successful examples so far seem to have been achieved particularly at the local level (e.g. Owen and Parker 2018, Van Brussel and Huyse 2019). In addition, examples such as the citizens' observatories (WeObserve 2019) can be used as pilot cases which will eventually also encourage uptake at higher geographical scales.

Societal Imbalance

In many Western societies, we can observe that societies are becoming increasingly split. That does not (only) refer to income gaps but also the *cultural hegemony* of the well-educated academically skilled proportion of the population. Currently, we observe a strong bias in participation in citizen science projects towards persons with an academic background (see, for example, Haklay 2015). If we assign citizen science political power with regard to agenda setting, data collection, and policy pressure towards specific policy agendas, participation should be much broader than currently.

The Way Ahead

Overall we see a positive trend in which citizen science is recognised in policies, and we also witness a certain degree of mainstreaming. At the European level, the forthcoming EU Research & Development programme, Horizon Europe (2021–2027), amongst other developments, calls for higher interdisciplinary, more inclusiveness, and full openness of research, and it is implementing in full its recently adopted open data strategy. In this context, citizen science approaches are recognised as being an important element in support of this strategy and for the new political priorities. However, in order to move ahead and address the central challenges identified in the previous section, we see a need for the following set of dedicated and focused actions:

- *Leading by example.* As trust between the key actors (policy, science, and society as a whole) is essential, building further trust will need to be done in concert by sharing best practice and stimulating projects that can act as examples across contexts and scales. When doing so, we should remain aware that the citizen science community tends to be biased towards academics, so special attention should be taken with regard to social groups.
- *Promoting the benefits of citizen science.* The promotion and support of citizen science from European scientific policies must be motivated by reasons such as the support of evidence of the benefits; the improvement of data and scientific methodologies, as well as the ways of sharing them; the achievement of the resources' sustainability and the scientific system itself; the increase of scientific capacities and education; the strengthening of co-responsibility and trust among all stakeholders and beneficiaries; the understanding of cooperation as a way to solve certain types of problems related to knowledge generation; and risk management, among many other aspects. Some of these notions also refer to policies in other fields, such as agricultural and food systems, health systems, education systems, industry, and business. These relationships imply that citizen science, like science, is an ecosystem and constitutes a complex set of activities, institutions, and people involved, seeking solutions to complex problems. Those

directly responsible for scientific policies must be aware of the need for new and imaginative solutions and of the role that citizen science can play – perhaps small, perhaps not – in the face of current challenges.

- *Embracing the diversity of citizen science approaches.* Building trust will rely on having shared expectations of the impact of citizen science projects and the ability of projects to realise them. This means that there is an urgent need for researchers, policymakers, and publics to better understand the different types of citizen science approaches and the impacts they can achieve (refer to van Noordwijk et al., this volume, Chap. 19). This will also have direct implications for the likelihood of guaranteeing the sustainability of initiatives and communities. Different management and funding formulas have to be provided, both in science and citizen science, including the management of public-private models, as well as the alternative models developed in many maker and hacker communities (e.g. gift economies).
- *Division of responsibilities – between public services at different administrative levels (acknowledging also national diversity), NGOs, citizens, and academies.* There is a strong role for independent partners (NGOs) to facilitate trust building between policy and public and to hold policy stakeholders to account. To truly fulfil this role, policy instruments need to be in place to ensure that NGOs can fulfil this role without fear of losing funding opportunities. In doing so, it has to be recognised that citizen science cannot resolve all issues at hand. There is a tension that the state outsources some of its duties (see Vohland et al. 2019). At the same time, science – and citizen science itself – has a role in the constitution of more cohesive and collaborative communities and societies (see also Pelacho et al., this volume, Chap. 4).
- *Citizen science education of academic community.* The success of citizen science requires education of the academic community, integration of citizen science in research training curricula, and opportunities for interaction and learning. Research funders have a particular role in stimulating debate and enabling disruptive innovation. Not all 'open science' approaches – within them citizen science – have the same ethical-political base; therefore different understandings of open science ought to be comprehended in order to foster good practice from an ethical-political view. Scientific policies ought to guarantee that science is not instrumentalised in a negative way, even more so in citizen science and citizen scientists (professional or not), for example, through outsourcing costs. Policies can foster or support approaches to citizen science that favour a socially robust science while at the same time leading and promoting innovation.
- *Highlighting the citizen dimension in data-related policies.* In this chapter, we deliberately focused on (research) policy that fosters citizen science approaches, as well as the benefits and challenges that citizen science can bring to sectorial policies (especially environmental policy). We did not address another cross-cutting policy area that is related to the data that citizen science intentionally or unintentionally produces and the high economic value that it brings. The creation, management, and use of citizen-generated data is another large research and policy topic, which deserves dedicated attention (Berti Suman and Pierce 2018;

Fritz et al. 2019). We recommend that such investigations are carried out with a citizen science perspective, but also with the bigger picture in mind. In other words, we see a need to intensify already ongoing dialogues, in areas such as data privacy, data governance, and data ecosystems, with the citizen science community also. The sensible use of technology (e.g. artificial intelligence) will have to be carefully considered in this (digital governance) context.

- *Developing tools and incentives to broaden participation.* Participation in Western science societies does not necessarily lead to contributing to citizen science projects, but due to their variety with regard to disciplines, purpose, and requirements, they offer the public the opportunity to participate in knowledge societies. To realise this potential, a variety of measures should be introduced, starting by sensitising children in schools, linking science to everyday problems, or offering support in the technical aspects. Last but not least, as in Western societies loneliness seems to be a real problem (the UK has appointed a minister for loneliness; see Yeginsu 2018), citizen science may offer an opportunity for meaningful social contact.

Finally, citizen science was recently given a highly supportive political framework in Europe. The European Green Deal (EC 2020b), together with the priorities to push for European democracy (EC 2020c) and to make Europe fit for the digital age (EC 2020d), offers rich and supportive grounds for further explorations. Hence, we are looking forward to exciting times, where citizen science has a great opportunity to flourish and affect positive societal, economic, and environmental change. It is up to the entire citizen science community, and the entire community, to make the best of these opportunities and to continue to establish citizen science practices for the common good.

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Chapter 19
Creating Positive Environmental Impact Through Citizen Science

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Abstract Interest in citizen science is growing, including from governments and research funders. This interest is often driven by a desire for positive environmental impact, and the expectation that citizen science can deliver it by engaging the public and simultaneously collecting environmental data. Yet, in practice, there is often a gap between expected and realised impact. To close this gap, we need to better understand pathways to impact and what it takes to realise them. We articulate six key pathways through which citizen science can create positive environmental change: (1) environmental management; (2) evidence for policy; (3) behaviour change; (4) social network championing; (5) political advocacy; and (6) community action. We explore the project attributes likely to create impact through each of these pathways and show that there is an interplay between these project attributes and the needs and motivations of target participant groups. Exploring this interplay, we create a framework that articulates four citizen science approaches that create environmental impact in different ways: place-based community action; interest group investigation; captive learning research; and mass participation census.

Keywords Change theory · Climate and biodiversity emergency · Behaviour change · Policy influence · Environmental management · Political advocacy

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Introduction

The unprecedented environmental crises the world is facing require urgent action from society, policy, and business. Citizen science has the potential to help generate the environmental data needed to understand and address these challenges and increase public interest and engagement, which are essential for societal change. Citizen science has already established itself as a critical source of biodiversity (Chandler et al. 2017a) and water quality (Hadj-Hammou et al. 2017) data. It has been identified as a key instrument to measure progress towards the United Nation's Sustainable Development Goals (SDGs) (Fritz et al. 2019) and as an excellent tool to generate public interest and engagement on air pollution (Van Brussel and Huyse 2019).

The field of citizen science is vast, with project types, engagement approaches, and project aims ranging from educating citizens to community activism and specialist scientific investigations (see Haklay et al., this volume, Chap. 2). Environmental and biodiversity research, which are the focus of this chapter, make up a large proportion of existing citizen science activities and include tasks such as wildlife monitoring, water monitoring, image classification, and historical record transcription.

As the field of citizen science has expanded over the last decade, various authors have attempted to define and describe the different types of citizen science approaches (Ceccaroni et al. 2016). These typologies have focused on how projects are managed, the role of citizens within the project, and the research topics and tasks. However, these project attributes do not work independently, and it is the interplay between them that determines the lasting impact of a project.

Given the vast array of project types, it can be difficult to talk about the impact of citizen science in general. Different projects will achieve different outcomes and impacts based on multiple factors, for example, geographic scale, depth of participant engagement, timescale, available resource, and project partnerships. To maximise the benefit of citizen science as a tool for creating positive environmental change, it is fundamental to understand *how* citizen science leads to *positive environmental impact* – actual change on the ground – and what type of projects are best suited for different contexts.

Impacts of citizen science projects can be broad, affecting the environment, society, the economy, science, and governance (Hecker et al. 2018). In this chapter, we focus on impacts on the environment; specifically, how can citizen science projects improve the environment, in areas such as biodiversity, water quality, and pollution. Impact on other domains is only included where this leads to environmental impact further down the line. We do not consider the impact on society and governance per se, but analyse how citizen science can create *behaviour change* (society) and the evidence that feeds into *environmental policy* (governance).

In this chapter, we explore the different pathways through which citizen science projects can create positive environmental impact and then identify distinct project types that deliver such impact. A framework of four citizen science approaches is presented that articulates the interplay between various project attributes, including participant appeal, task complexity, impact pathway, and project governance. We believe that this framework will help citizen science practitioners, research funders, and government agencies to create impactful projects and hence unleash the full potential of citizen science for the benefit of our shared environment.

Background

Environmental Impact

The impact of citizen science projects is often divided into three core aspects: *scientific*, *individual*, and *socio-ecological and economic* (Shirk et al. 2012). Environmental impact is a subset of the socio-ecological and economic impact and occurs when changes are made to resource management and practices that affect the natural environment. This includes changes to institutional practice (activities of organisations, businesses, and governments); collective practice (the actions of a group of people, e.g. a local community); or individual practice (activities of individuals). Each of these practices is, in part, governed by policies and can influence other practices (e.g. changes in institutional practice can inspire individuals to change their behaviour) (Fig. 19.1). An impact framework has been developed that articulates six pathways through which citizen science projects can create environmental change (Wehn and Gharesifard 2020). This framework is based on impact frameworks commonly used in research, community organising, and education, including the citizen science toolkits developed by Cigliano et al. (2015).

Pathways to Impact

Citizen science projects can change the *environmental management* performed by institutions, in much the same way as any other (applied) research can lead to management change. This change can include a shift in conservation management plans (Chandler et al. 2017b) or the use of citizen science to detect and address pollution incidents (Brooks et al. 2019; Hadj-Hammou et al. 2017; Owen and Parker 2018).

Another way in which citizen science projects can create environmental impact is by creating *evidence for policy*, which can modify institutional, individual, and collective practice. For example, marine citizen science data, shared with policymakers, has informed the design of marine protected areas (Hyder et al. 2015). Again, this pathway to impact is similar to those for other types of applied research.

Engagement in a citizen science project can inspire *behaviour change* among participants (Cigliano et al. 2015). We define behaviour change here as a measurable

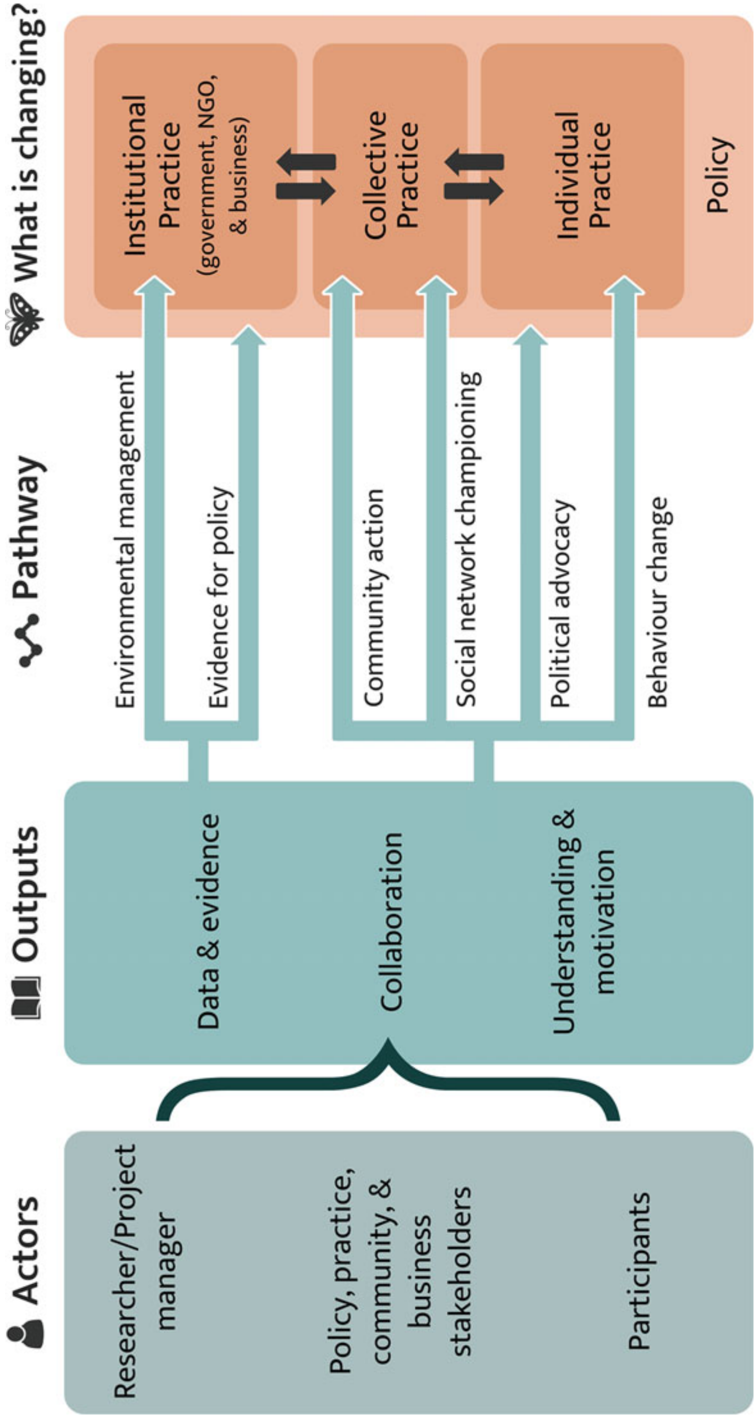

Fig. 19.1 Impact framework outlining six key pathways through which citizen science can lead to environmental change

action resulting from engagement in citizen science that is external to the protocol activities of the citizen science project (Phillips et al. 2018). Examples include increased political activism, local conservation action, and lifestyle changes. Behaviour change ranges from a one-off direct action (e.g. putting up a bird box) to incremental changes in attitude and long-term behaviour change (e.g. no longer using single-use plastic).

Another pathway that individuals can pursue to generate environmental impact is *social network championing*. Here, participants influence friends, neighbours, and colleagues to encourage them to change their behaviour. If projects can support participants to influence their wider social network, then the effect can radiate far beyond the original set of participants and, by extension, potentially change norms within a social group or in society more broadly (Johnson et al. 2014; Syberg et al. 2018).

Political advocacy sees individuals and communities involved in citizen science inspired to publicly support causes and advocate for policy change. Such pressure can push issues up the political agenda and can lead to more rapid change than through presentation of new scientific evidence alone (Van Brussel and Huyse 2019).

Finally, participation in a citizen science project can lead to *community action*. Here, participants come together to effect direct environmental change (e.g. planting trees or removing plastic waste). The citizen science project can deliver research findings that inform the action. It can also facilitate the collaboration needed for collective action and can contribute to the motivation that leads individuals to act together (Jordan et al. 2019).

Impact Framework

The positive environmental impact created through these six pathways relies not only on the scientific data and evidence produced by citizen science projects. It also relies on increased understanding and motivation among engaged individuals and collaborations between the different actors it enables. These outputs (*data*, *motivation*, and *collaboration*) can be used by all involved – including researchers, government agencies, NGO partners, participants, and industry or community stakeholders – to drive change. In researcher-led projects, data and evidence are mostly used by researchers to push for changes to policy and practices, while participants can create change through increased personal understanding and motivation. However, participation in a citizen science project can also inspire researchers to change their own behaviour and data can be directly used by participants to influence policy and practice.

The framework presented here outlines how a project *can* influence the environment. In practice, it is challenging to establish the extent to which specific environmental changes can be attributed to individual projects (Schaefer et al., this volume, Chap. 25). This framework should, therefore, be used to understand how to maximise *opportunities* to effect positive environmental change, rather than to accurately predict the changes that will occur.

Matching Impact Objectives and Participant Motivations

Across all six pathways to impact outlined, sufficient participation in a project is key to maximising its impact. Good uptake is crucial to both the amount of data collected – leading to robust scientific results that can feed into policy and practice; and the number of participants engaged – reaching more people who can be inspired to change their behaviour, influence others, advocate for change, and drive community action.

Impact, in turn, can be an important driver of uptake. Wanting to make a difference, for example, to wildlife or to science, are among the most prevalent motivations for participation in citizen science projects (Geoghegan et al. 2016). Hearing how the data will be used to make a difference and what impact the project has already achieved are among the most important motivations to sustain participation.

To maximise impact, project designers need to understand who their potential participants are, what motivates them, what barriers to participation they face, how these barriers can be overcome, and how their motivations align with the intended project impact (Land-Zandstra et al., this volume, Chap. 13).

State of the Art

Project Types

Existing citizen science typologies (Ceccaroni et al. 2016) describe two distinct participant groups: *captive learning groups* (often in schools or museums) and *place-based community groups*. Other projects are generally defined by their core aim (e.g. conservation versus investigation) or methodology (e.g. field based versus online) and primarily reach existing *interest groups*. Yet, some projects manage to buck this trend and achieve more diverse *mass participation* (e.g. Van Brussel and Huyse 2019).

Dividing participants into these four groups is a simplification of reality. Each group can be diverse and consists of individuals with complex identities. Yet, understanding the predominant motivation for engagement with a project – which differs markedly between these four participant groups – provides key insights into the types of activities that will appeal to them and the consequent opportunities for impact.

Each participant group is tied to a distinct project type which we will now explore.

Place-Based Community Projects

Place-based community projects are generally focused on improving the environment in a specific area, with participation from the local community. Participants join the project through an attachment to 'their' location or potential benefits to their personal life (e.g. health benefits from improved air quality). Another important aspect is the opportunity for social interaction. These citizen scientists may not have a pre-existing interest in the project topic or in science in general, but they may still be prepared to invest considerable time and effort for personal benefit (e.g. social contacts or health benefits).

To effect impact, community projects require the support of local stakeholders and the local population. Projects are most likely to succeed if participants feel ownership and have agency, e.g. through co-creation and opportunities to be involved throughout the research process. Projects are often community initiated. Alternatively, they can be led by scientists if scientists dedicate time to build a relationship of reciprocal trust with the local community. Working with existing community groups and community leaders is an effective way to build relationships and encourage participation from the wider community.

Projects can be long-term (e.g. ongoing monitoring and stewardship of water quality) or a single event aimed at raising awareness about a specific issue. Participation of the wider community is highest when the research tasks are simple and do not require prior subject knowledge. Given the potential diversity of the participant pool, long-term projects can benefit from having a variety of tasks and offering learning opportunities.

Captive Learning Projects

Citizen science has long been used as a learning tool in schools, informal learning groups (e.g. scouts), and museums. It is also used as part of employee learning programmes, for example, within Earthwatch's Sustainability Leadership Programme. Collectively, we refer to these as *captive learning projects*, referring to both the objective to educate participants and to the fact that participation happens through gatekeepers (e.g. teachers or employers).

Captive learners can participate in citizen science without a pre-existing interest in the research topic if they are enrolled by a gatekeeper (e.g. teacher or employer). The level of engagement largely depends on the group leader's skills and capacity to motivate. Educational projects require a citizen science leader (scientist, teacher, or engagement officer) and have a limited participant group size to allow for effective engagement. Projects can be scaled up by running multiple consecutive sessions with different participant groups or by employing train-the-trainer methods, with groups of educators trained to take the project into their respective educational settings. Captive learning projects have a high potential to engage and inspire new participant groups and can expose participants to new issues and experiences. Tasks need to be simple enough for novice participants but can increase in complexity if training is provided by the group leader.

Interest Group Projects

Many citizen science projects primarily attract participants who are already skilled or at least interested in a specific research topic. Interest group participants (e.g. birdwatchers) are more likely to stay engaged in projects and are generally prepared to commit more time to projects. Where projects offer an opportunity to meet like-minded people, this can act as an additional driver to enrol and stay engaged. Interest group projects can span a wide geographic area and often run for a long time, with individual participants making repeat observations. As participants tend to have pre-existing knowledge of the subject, they can often handle more complex and time-consuming tasks.

Interest group projects have generated reliable, high-quality data for decades, especially when projects invest in support and training for participants. The downside of this project type is that the pool of potential participants is limited and often lacks diversity. In particular, short-term projects often struggle to recruit sufficient participants, unless project leaders collaborate with existing volunteer networks.

To date, many projects have mainly white, highly educated, and affluent participants (Pandya 2012). However, some projects have reached different demographic groups, for example, where projects are initiated by specific communities and cover topics that are particularly relevant to them, but few have achieved truly diverse participation.

Mass Participation Projects

If the project task is simple, has clear societal relevance, requires limited time commitment from participants, and is widely advertised, then citizen science projects can achieve mass participation (Van Brussel and Huyse 2019). People may take part out of curiosity, because the research is relevant to their own health or local environment or because they are intrigued by the opportunity to take part in scientific research. As these projects have low barriers for participation in terms of time commitment and pre-existing knowledge, they can attract participation from a wide section of society. Whether they actually attract participation from diverse groups depends on a range of factors, including where the project is advertised; whether participation requires access to assets that are not equally distributed (e.g. travel to a national park or having a garden); and whether the organisers convey that the project is open, welcoming, and of benefit to traditionally under-represented groups.

The majority of successful outdoor mass participation projects are conducted over a short time frame, for example, performing an environmental census such as a bird count or a freshwater blitz on a specific weekend. Participants may take part because it is a fun activity or through a desire to help science or the environment. Mass participation projects can be local and place based or conducted over a large geographic area.

Large-scale projects have the potential to collect data across large geographic areas within a short time frame, generating unique datasets that cannot easily be generated otherwise. They also provide an opportunity to raise awareness of a specific issue among a mass audience. Successful recruitment of mass participation requires substantial marketing and communication, clear instructions for participants, and extensive project management.

Achieving Environmental Impact through Different Pathways

The four project types do not all lend themselves to creating impact through all six impact pathways. Below, we explore the project attributes commonly associated with each of the impact pathways and which participant groups these can attract.

Environmental Management

Many environmental citizen science projects aim to contribute data to inform management decisions, but much of this potential remains untapped (Newman et al. 2017). Chandler et al. (2017b) showed that citizen science projects are most likely to feed into management plans if they are:

- Place based and firmly rooted in the local context
- Carried out over multiple years, management impacts on average peak 6–8 years into a project's life cycle
- Deliberately designed for management purposes with scientifically robust protocols
- Co-created with stakeholders to identify their needs and decision-making timelines

In addition to such place-based projects, large-scale projects (e.g. national biodiversity recording schemes) can feed into (local) management decisions if data and metadata are made open access and have sufficiently granular spatial and temporal resolutions (Hadj-Hammou et al. 2017).

To make evidence-based management decisions, projects need to deliver high-quality data on specific metrics that are repeated over time. To collect such data, participants need to follow prescriptive and often complex sampling protocols and invest time in the project over a longer period. This is likely to be most attractive to participant groups who are already interested in or have a connection to the research topic or the research location – interest groups and place-based community groups (Owen and Parker 2018). Alternatively, such data can be collected by consecutive captive learning groups hosted at a single location (Chandler et al. 2017b).

Evidence for Policy

Evidence gathering activities can support policy change at different levels (e.g. local, national, and international government) and at different stages of the policy cycle (see also Schade et al., this volume, Chap. 18). In addition to delivering evidence that informs the formulation of new policy, citizen science can be used to evaluate policy effectiveness and inform policy implementation. In some areas, there is a long history of using citizen science data to evaluate policy, including in biodiversity monitoring and in relation to invasive species.

Bio Innovation Service (2018) conducted an in-depth evaluation of 45 citizen science projects which revealed that projects were most likely to influence policy if they:

- Received government support, not only in the form of funding, but also through active participation in the design and implementation of the project
- Had a straightforward engagement process for participants, requiring limited effort and a priori scientific skills

Scientific complexity did not appear to affect the policy uptake per se, but projects with high scientific standards and endorsed by scientists served more phases of the policy cycle.

Policymakers benefit most from large data sets that provide extensive evidence at the appropriate geographical scale. Local policy formulation can benefit from place-based community projects but can also draw information from projects operating at a larger scale. National policy formulation is best served by large data sets with extensive coverage of space and time. Such large data sets can be created through either interest group projects or mass participation projects. The latter is particularly suited for capturing a snapshot of a single moment in time across a large geographic area but requires straightforward and rapid sampling methodologies. Captive learning projects are generally less effective in informing policy due to their limited geographic coverage and clustered sampling, unless a large number of events are conducted as part of a concerted effort.

The involvement of policy stakeholders in project design helps to improve the alignment of project outputs to policy priorities. However, the potential for policy impact doesn't necessarily translate into actual policy change. The science-policy interface is complex, and many factors contribute to whether findings are adopted by policy stakeholders and lead to policy change (Rose et al. 2017). A major challenge in getting evidence-generating citizen science to create policy impact is the lack of alignment between research, community, and policymaker timelines. Policy horizons and project outputs may not coincide, and relevant results can fly under the policy radar. Researchers should be proactive in their output plans to maximise the potential for impact.

Behaviour Change

Engagement in a citizen science project and experiencing first-hand how a specific issue affects the environment can motivate and inspire participants to change their behaviour. Whether such behaviour change is realised depends on a number of factors.

People are most likely to take action or make changes to their routines as a consequence of engagement in a citizen science project if the project has a clear *call to action*. In line with general behavioural psychology principles, action is most likely to occur if the requested action is simple, fun, and complies with social norms. Literature within behavioural economics has highlighted strong biases which lead people to maintain the status quo (Rare and the Behavioural Insights Team 2019). Therefore, to maximise impact through behaviour change, it is essential to make recommended changes as convenient and accessible (physically and financially) as possible.

People are driven by different motivations and are most likely to change behaviour or take action if they care about the issue or location. Interest groups tend to have a strong connection with the research topic. They are also generally already aware of the actions they can take and may display the desired behaviours before joining the project. Captive learning groups are more likely to be exposed to new topics and information. Moreover, the guided approach of many such projects can help to take these groups on a journey, open their eyes, and inspire them to take action. Place-based community projects also have potential to inspire behaviour change, especially as the social context of the project can shift social norms. Once certain members of the community have changed their behaviour others may follow to comply with social norms. Finally, mass participation projects are likely to reach new participant groups, but as people's involvement in these projects typically remains light touch, they are likely to only lead to incremental changes rather than long-term behaviour change.

Social Network Championing

To influence non-participants via social networks and inspire them to change their behaviour, it is crucial that projects establish clear pathways for communication and dissemination across social networks (Reed et al. 2010). This can include both digital platforms – like Facebook, Twitter, and Instagram – and offline communication within communities. Influencing and awareness-raising through digital channels and traditional media can be done centrally by project leaders. However, people are more often inspired to change their behaviour if they are influenced by their own social contacts, including friends, family, colleagues, and neighbours. Projects can, therefore, increase their impact through social network championing if they inspire and facilitate participants to directly influence their wider social circles, both online and offline.

Mass participation projects are more likely to have access to the resources required to make strategic use of conventional and social media. In contrast, place-based community projects often rely on the participants themselves to use their existing networks to influence others.

Increasing public environmental awareness through social networks, also called *network environmentalism*, is most effective if projects can tap into existing networks of interested and motivated people (Johnson et al. 2014). Projects need to be engaging to a wide and diverse audience, even if only a few people are directly involved in data collection. The audience needs to be able to relate to the material being communicated; stories which are of personal relevance to the public are more likely to gain such traction (Hecker et al. 2018). Mass participation projects are often designed with a diverse audience in mind and use methods which are easy to understand. Smaller projects can also be very successful at social network championing if they invoke a strong connection to an emotive (local) issue.

For social network championing to result in environmental impact, it needs to go beyond awareness-raising and lead to behaviour change. In particular, a clear, well-defined call to action, communicated through social networks, is a powerful way to achieve environmental impact that extends beyond the bounds of the project.

Political Advocacy

Project design and framing can motivate volunteers to shape political outcomes through advocacy (Cornwall 2008). Aoki et al. (2008) identified the following criteria for citizen science to result in successful environmental activism:

- The data collected must be 'credible enough' to engage policymakers
- The project must be appealing and inspiring to a wide audience in order to mobilise action
- The project must be personally relevant to participants
- Mechanisms must be in place for advocates to be heard by the actors who can action change

For advocacy to occur, the project must be framed in a way which allows participants to fully comprehend the project topic and its relevance to current policy and practice. Participants must also find the project appealing and inspiring enough to motivate them to extend their activity beyond the bounds of the project and into advocacy. Participants need to feel that the project and related outcomes are of personal relevance to them.

Place-based community projects seem most effective at generating political advocacy – people are more likely to be motivated towards, personally relate to, and actively participate in *local* civic agendas. At local levels, it can also be easier for participants to reach policy actors and make their voices heard. Interest group projects can also inspire participants to become political advocates as participants tend to already have a keen interest in the research topic and can feel passionate about protecting species or ecosystems. Political advocacy seems to be rarer in captive learning and mass participation projects.

It is important to note that the issues that lead people to act as advocates are often extremely emotive, and a ‘policing logic’ guides the work of some citizen science groups, focusing on observing and reporting suspicious activity (Kinchy et al. 2014). Project leaders should operate ethically and not (inadvertently) mislead participants to endorse a specific agenda. To avoid such situations, projects need to operate transparently, uphold high data and project design standards, and ensure that the issue or solution they advocate for is evidence based. The data collected through the project can provide this evidence; political advocacy is, therefore, best combined with the evidence for policy pathway. At the same time, pictures and stories often elicit a much stronger public response than data alone. Data and stories should thus be used in tandem to affect evidence-based political activism.

For any citizen science project that can lead to political advocacy, it is key that the motives of participants are acknowledged, and checks are put in place to ensure data quality. For example, during the Flint, Michigan, water crisis, the desire of some participants to support lawsuits led to the falsification of some citizen science data (Bonney 2019).

Community Action

Citizen scientists take collective action to directly address environmental issues mainly in place-based community projects. These projects bring together people who are interested in improving a *specific* location, and people involved in these projects are more likely to have agency to contribute to such changes. According to Pandya (2012), community action is most likely if:

- Research and education goals are well aligned with community priorities
- Communities have a role in project management and project design
- Multiple kinds of knowledge are incorporated (e.g. Indigenous knowledge)
- Results are widely disseminated

As with behaviour change, projects are most likely to lead to community action if they have personal relevance for participants, align closely with their motivations, and have a clear call to action. In addition, community action projects need to build on or create collaborations that bring people together. A citizen science project can act as a community catalyst – offering a common goal for the community and agency to take local environmental management into their own hands. In other cases, a community may already function as a group and the citizen science project will provide an opportunity to support a local cause, which strengthens its cohesion (Chari et al. 2019).

A key strength of impact through community action is that the social network can be a strong external motivator for individuals to get involved and stay active in environmental issues.

Interactions Between Project Types and Impact Pathways

The overview provided so far has shown how certain pathways to impact are more likely to be associated with certain project types. Taking the links between impact, participant groups, and project attributes into account helps set realistic expectations and enables practitioners to design more impactful citizen science projects. Based on this, we have created a framework that articulates four common citizen science approaches aimed at creating environmental impact: *place-based community action*; *interest group investigation*; *captive learning research*; and *mass participation census*.

The impact and attributes of each of these citizen science approaches are summarised in Tables 19.1, 19.2, 19.3, and 19.4. Although this framework is based on citizen science literature, it is not the result of a quantitative data analysis or a systematic literature review; this framework is derived from our experience as citizen science practitioners and the need to better drive environmental impact through our work.

Case Study: FreshWater Watch

FreshWater Watch is a global citizen science programme, run by Earthwatch, that engages participants in the collection of water quality data in freshwater ecosystems. The programme has used all four citizen science approaches to engage different audiences and achieve environmental impact through a multitude of impact pathways.

Table 19.1 Place-based community action citizen science: impact pathways, key attributes, and example projects

Place-based community action	
Impact pathways: • Mainly local impact through: • Environmental management • Evidence for policy • Behaviour change • Political advocacy • Social network championing • Community action	**Key attributes:** • Focused on improving the environment in a specific location • Mainly attracts local participants. Can engage and motivate a diverse range of people who feel connected to the local area and personally benefit from environmental improvement, including communities who are traditionally under-represented in science and environmental movements • Can be citizen or community initiated and led and/or researcher led but most likely to succeed if participants feel ownership and agency, e.g. through co-creation • Requires local collaboration and support from or creation by community leaders who support uptake in the community • Benefits from simple tasks and a variety of opportunities to get involved, to cater to diverse interests and abilities in the community • Potential for long-term engagement and data collection, although projects can also be short-term, especially when taken up by an existing community network
Example projects: Flint, Michigan water study (Hanna-Attisha et al. 2016) Naturehood www.naturehood.uk	

Table 19.2 Interest-group investigation citizen science: impact pathways, key attributes, and example projects

Interest group investigation	
Impact pathways: • Mainly impact through: • Environmental management • Evidence for policy • Political advocacy • To a lesser extent through: • Behaviour change • Social network championing	**Key attributes:** • Focused on researching a specific topic, species, or ecosystem; e.g. long-term biodiversity monitoring • Can be local, national, or international with regular monitoring or ad hoc data collection • Mainly attracts participation from people with a pre-existing interest in and knowledge of the research topic. The potential participant pool is, therefore, more limited and often less diverse • Tasks can be more complex and time-consuming • Potential for long-term engagement and data collection, especially if opportunities for progression, sharing, and recognition are provided, and projects invest in support for their participants
Example projects: Anglers' Riverfly Monitoring Initiative (Brooks et al. 2019) Earthworm Watch www.earthwormwatch.org	

Table 19.3 Captive learning research citizen science: impact pathways, key attributes, and example projects

Captive learning research	
Impact pathways: • Mainly impact through: • Behaviour change • Social network championing	**Key attributes:** • Focused on educating participants and raising awareness of environmental issues • Requires a citizen science leader (scientist, teacher, or engagement officer) and has a limited participant group size per session • Can include schools, informal education groups, and other learning settings (e.g. businesses). Potential to engage and inspire new audiences as participants are often signed up to the activity through a gatekeeper (e.g. a teacher) • Tasks need to be simple but can require some instruction from the leader • Projects can be scaled up by using train-the-trainer approaches or providing online training for existing group leaders (e.g. teachers or scout leaders) • Potential for impact if topics are personally relevant and experiences are immersive and carried out over a longer period rather than as a one-off
Example projects: Wytham Woods climate research (Crockatt and Bebber 2015) Teatime4Science www.teatime4science.org/schools/	

Participants across the world collect the same core measurements (phosphate concentration, nitrate concentration, turbidity, and various visual indicators) and upload the data to a common online platform. Data collection started in 2012, and, to date, over 24,000 data sets have been collected globally. The method is simple and engaging for volunteers but also produces robust data (Thornhill et al. 2018).

Table 19.4 Mass participation census citizen science: impact pathways, key attributes, and example projects

Mass participation census	
Impact pathways: • Mainly impact through: • Evidence for policy • Behaviour change • Social network championing	**Key attributes:** • Focused on informing a large audience and creating a snapshot of a single moment in time across a large geographic area • Potential for mass data collection, generating a unique data set that cannot easily be generated any other way • Potential to reach new audiences and to engage them with a new topic. The audience can be more diverse if the project takes steps to actively include different groups • Requires very simple tasks with low time investment and needs to be relevant to a diverse audience • Can be repeated, e.g. annually • Requires extensive communication and intensive central project management.
Examples: *CurieuzeNeuzen* (Van Brussel and Huyse 2019) FreshWater Watch WaterBlitz www.earthwatch.org.uk/waterblitz	

FreshWater Watch was originally designed as a *captive learning research* project, targeting banking employees enrolled in a corporate sustainability programme (the HSBC Water Programme). Groups of participants in this programme were paired with university researchers focusing on a specific local research challenge. In partnership with the university researchers, Earthwatch ran training sessions covering the research purpose, sampling methodology, and opportunities for personal action in the context of the global water challenge. In this first phase of FreshWater Watch, environmental impact was primarily achieved through behaviour change. Nearly all volunteers (99%) reported a better understanding of their personal environmental impacts and 95% reported having reduced their impacts as a result (Earthwatch 2017).

A number of participants became highly engaged in the programme. They continued to collect data at regular intervals and recruited others to join them. Regular communications between Earthwatch, the local researcher, and the participants kept these ‘Citizen Science Leaders’ engaged, and many enjoyed being part of this global water community. FreshWater Watch had become a network of *interest group investigations*, and the participants’ commitment led to valuable data sets and a large number of scientific publications (Thornhill et al. 2019). Some Citizen Science Leaders also started to influence their social networks to raise awareness about water quality issues and share opportunities for behaviour change.

As FreshWater Watch became better known, Earthwatch was contacted by increasing numbers of local groups who wanted to use it to monitor and address local water quality issues. Rivers Trusts, wild swimming groups, and local communities started to use FreshWater Watch as a *place-based community action project*. Each of these groups had specific local concerns and had slightly different needs in terms of data collection. Local leaders coordinated data collection and acted on the results.

To accommodate these groups, Earthwatch incorporated co-design sessions into training programmes. They also adapted the online platform and app to allow for group accounts and to provide flexibility for groups to measure additional variables beyond the FreshWater Watch core method. These place-based community action projects create impact through a wide range of pathways. Where evidence for policy and political advocacy are identified as key impact pathways, Earthwatch works with the group leaders to establish links with the relevant stakeholders early in the project design process. Many projects are also used to inform environmental management. For example, the Lincolnshire Rivers Trust used FreshWater Watch to identify industrial pollution sources along a small river.

Many FreshWater Watch participants take measurements in locations that are not routinely monitored by statutory agencies. Because of this, FreshWater Watch has the potential to supplement ongoing regulatory water quality monitoring (Hadj-Hammou et al. 2017). With this in mind, Earthwatch recently initiated *mass participation censuses* in the form of 'WaterBlitz' events. These are time-limited campaigns where as many people as possible are asked to take measurements in a target river catchment over the course of a weekend. The WaterBlitzes are advertised through a wide range of media channels and participants receive a short online training session, where the methodology has been simplified. This approach has been particularly successful where the project tapped into existing public concern about water quality. The first Dublin WaterBlitz in 2019, for example, attracted over 1000 sign-ups in the course of a few days.

The different project types within FreshWater Watch are not stand-alone. By applying the same basic FreshWater Watch method to different project types, we have been able to integrate data from multiple different approaches into one consistent global data set. An added benefit of this adaptive approach is that it has allowed us to 'funnel' participants towards different project types that are most relevant to their developing interests and motivations. Several place-based community projects have arisen from initial participation in WaterBlitzes, which act as an entry point into the programme.

Experience has shown that each participant group and citizen science approach requires different project organisation, sampling method complexity, training, IT infrastructure, and communication channels. By adapting the programme in these ways, FreshWater Watch has been able to grow and create environmental impact through nearly all of the pathways outlined in this chapter.

Implications

Application of the Framework

The many examples highlighted in this chapter demonstrate that citizen science can create positive environmental change in numerous ways. Indeed, citizen science is often promoted for its ability to engage the public, raise awareness, and collect valuable environmental data. The framework we present here reflects our experience that impact is seldom achieved at scale through all the pathways to environmental impact simultaneously. Different approaches lend themselves to different pathways. Another layer of complexity is added by the fact that participants' motivations vary, and the same approach is unlikely to appeal to all audiences. By clearly articulating the pathways to impact and the project attributes that support them, we have highlighted four citizen science approaches that have strong potential to lead to positive environmental change. The insights provided in this chapter should help citizen science practitioners, research funders, and stakeholders to set realistic expectations and to make more informed decisions about, for example, task complexity, and target audience.

Relation to Existing Typologies

There are numerous typologies of citizen science, but our framework is the first that consistently articulates who participates in citizen science projects and links this to the pathways and scale of impact. In particular, the framework presented here is the first to articulate the difference between mass participation projects and interest group investigations. Our framework doesn't explicitly examine what role citizens play within the projects, but many of the examples in this chapter highlight that both place-based community action and interest group investigation projects can span from contributory and crowdsourcing approaches to extreme citizen science and collegial collaborations (Haklay 2013; Shirk et al. 2012). Captive learning and mass participation projects are often organised in a top-down manner and are predominantly contributory.

Overlap Between Project Types and Approaches

Our framework is not designed to be exhaustive or have mutually exclusive categories. Instead, it articulates some of the most common citizen science approaches and how their impacts and participant groups are interlinked. Some projects can fall into more than one of these project categories. For example, *CurieuzeNeuzen* (Van Brussel and Huyse 2019), to some extent, satisfies the conditions of both a place-based community action project and a mass participation census project. It has done so by being locally relevant, working with an existing community group, investing in extensive communication, and making it easy to participate. Citizen science programmes can also combine approaches to cater for different participant groups and generate a bigger movement, as is illustrated in the FreshWater Watch case study.

Key Knowledge Gaps

The framework presented here articulates how projects can influence the environment. To learn from past experiences and refine this framework, it is essential to measure the exact impact individual projects have and to analyse how this is influenced by project attributes and the specific project context. Such impact monitoring is rarely done, and, without targeted research, it remains challenging to establish exactly how large the contribution of a citizen science project has been in the context of all the other socio-economic factors that simultaneously affect environmental decision-making (Schaefer et al., this volume, Chap. 25).

In addition, there is a need to further research the mechanisms that drive some of the impact pathways, in particular, social network championing (Reed et al. 2010). There may, for example, be opportunities to focus more heavily on social network championing in the design of citizen science projects if these mechanisms were better understood. Effective knowledge exchange and collaboration between the citizen science community and other fields of science, for example, behavioural psychology, is key to unlocking this knowledge.

Next Steps

The potential for citizen science projects to achieve positive environmental impact is increasingly recognised and evidenced in this chapter. To fully understand the contribution of citizen science to environmental change, targeted tools and shared impact evaluation frameworks to measure and evaluate the outcomes and impact of citizen science projects are urgently needed. Some of these tools are already being developed, for example, within the Horizon 2020 MICS (Measuring Impact of Citizen Science: Developing metrics and instruments to evaluate citizen-science impacts on the environment and society) project.

A significant proportion of the impact of projects happens after the data collection stage, while funding rarely extends beyond this point. Therefore, dedicated funding streams will need to support thorough impact evaluation of citizen science projects. Such funding tools would also support the sharing of learning from place-based community action projects, which are currently under-represented in the scientific literature (Miller-Rushing et al. 2012). This project type is the only one that we found likely to support each of the six impact pathways we identified. Dedicated research into the functioning and impact of such projects would enable upscaling the learning from successful initiatives and unleash the empowerment value of citizen science.

To appreciate the impact of citizen science, traceability of citizen science data usage, both in science and for policy, is essential. This can be achieved by including persistent identifiers to uniquely locate citizen science data and tools to track policy development. These tools should reference both the data and participant groups involved in monitoring of environmental indicators in policies, for example, using the framework presented in this chapter. Once necessary identifiers and tools are in place, requirements to evaluate citizen science impacts can be embedded in financing agreements to facilitate impactful citizen science projects.

In the meantime, we hope that the framework presented in this chapter will lead to new opportunities to use the outlined citizen science approaches – place-based community action, interest group investigation, captive learning research, and mass participation census – to deliver urgently needed environmental change.

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Chapter 20
Ethical Challenges and Dynamic Informed Consent

Loreta Tauginienė, Philipp Hummer, Alexandra Albert, Anna Cigarini, and Katrin Vohland

Abstract This chapter uses informed consent as a point of departure for the description of multiple ethical facets in citizen science. It sets out an overview of general ethical challenges in citizen science, from conceptual issues around social imbalances and power relations, to practical issues, such as how to deal with privacy for participants as well as data protection, intellectual property rights and other emergent issues. The chapter goes on to describe the different types of informed consent, particularly focusing on dynamic informed consent as the solution to the challenges described. Finally, practice-oriented recommendations about how to tackle some of the ethical issues raised in the chapter are set out.

Keywords Research ethics · Research integrity · Informed consent · EU GDPR · Inclusiveness

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Introduction

New forms of data and participant-led research are challenging traditional oversight mechanisms and raising concerns over the ethics of collaboration and partnership between researchers and *research participants* (or *citizens* – both terms will be used interchangeably). Such developments require a critical examination of the challenges that may arise when individuals become partners in research, and a thorough discussion of the requirements that have to be met for citizen science to be considered ethical. Relationships that are complicated by imbalances of power can be observed in almost everything around us. In citizen science, these issues come to the fore, particularly because of the ways in which citizen science opens up the research process for active volunteer participation in different stages of undertaking research. Making citizens more central in the science-policy process is also inevitably constrained by pre-existing uneven power relationships between politicians and citizens, scientists and citizens, and scientists and politicians (Kythreotis et al. 2019). Also, the context in which a citizen science project or initiative is set up, and therefore who is driving the project, who has access to resources, and other specific responsibilities within a project, all contribute to the ways in which the dynamics of relationships between actors play out.

The new roles, boundaries, and relationships between researchers and research participants that citizen science entails currently lack sufficient ethical and regulatory coverage (Rasmussen and Cooper 2019a; Fiske et al. 2018; Rothstein et al. 2015). While the protection of human subjects in research has traditionally been guided by *informed consent* or Institutional Review Board (IRB) mechanisms, the widely distributed nature of citizen science challenges a one-size-fits-all set of ethical requirements for the broad variety of practices and collaborative formats that it embraces (Fiske et al. 2018). Also, many citizen science projects count on the collaboration of research participants who are not the primary subjects of research.

Citizen science poses ethical challenges since research participants become both subjects and objects of research (Resnik 2019; Wiggins and Wilbanks 2019) and may interact with researchers as equals in the research process. Yet, existing regulatory mechanisms in human subject research focus on the protection of the rights and welfare of ‘passive’ research subjects. Also, existing regulatory mechanisms in human subject research build on the paternalistic assumption that research participants may not be able to correctly assess the harms and benefits involved in the research process (Rothstein et al. 2015). Finally, the vast amounts of data collected, aggregated, and repurposed in citizen science projects imply a degree of uncertainty about the outcomes, which could evolve over time. This means that a one-to-one model of informed consent does not fit the networked structure of citizen science collaborations; new models of consent are needed. Yet, these models of consent require understanding of complex information and concomitant privacy risks, and thus a high level of information literacy which, in turn, calls for new and more inclusive consent procedures (Cheung 2018; Eleta et al. 2019) such as the model of *dynamic informed consent*. Dynamic informed consent is a strategy to involve participants, support the principle of informed consent, and solve the 'stationary' aspect of consent, via a technological construct such as a communication platform that establishes a continuous two-way communication between researchers and participants.

Before delving into more detail about dynamic informed consent, we highlight the ways in which citizen science gives rise to complex ethical issues that are not easily resolved. We explain the issues around unethical citizen science and why a high standard of ethical practice in citizen science is crucial to its success. As Rasmussen and Cooper (2019a) suggest, it is not sufficient to simply react to ethical issues; what is needed is to proactively and prospectively address problems. Furthermore, many citizen science projects exist outside of institutions where regulations apply, and there is no central authority or governing body that oversees the field of citizen science. Our key argument in this chapter is that it is not only the principle of *ethical citizen science* that is important, but that, done well and to an ethically high standard, its practice will allow for better experiences for participants and potentially more sustainable projects. Citizen science practitioners can diminish the ethical doubts of the research community by setting an example with their projects (e.g. regarding quality and integrity of data). As Eleta et al. (2019) claim, 'most importantly, to fulfil the promise of citizen science empowering people and gaining trust in science, we need to design citizen science projects with ethics at their core' (p. 7). The solution that we offer to these ethical challenges is to focus attention on developing dynamic informed consent, namely, consent that is both supported by the necessary information for participants to actively consent to participate, and consent that is dynamic, and frequently revisited, not static and negotiated only once. Hence, we see dynamic informed consent as a potent solution to shifts in the ways in which ethical research is practiced and within the current constraints related to data protection in Europe.

Ethical Challenges in Citizen Science

In this section, we consider a series of contemporary issues in undertaking state-of-the-art citizen science and the ethical issues that arise when engaging the public in research. This list constitutes a starting point for discussion – it is important to state here that it is not exhaustive and that the different dimensions are very much interrelated and intertwined. The list is the result of the collective deliberations of the authors, and, therefore, in many ways, it reflects our own perspectives and principles and values. The list starts with the more conceptual issues and goes through to the more practical issues.

Instrumentalisation

Some see citizen science not primarily as scientific approach but as a useful instrument with which to reach specific targets, for instance, in areas such as science education. There is an increasing number of school programmes being developed which support participants' learning about STEM (science, technology, engineering, and mathematics), and the scientific process itself, with sometimes limited added scientific value (see Kloetzer et al., this volume, Chap. 15).

For some, citizen scientists are perceived to be a useful resource with which to pursue a neoliberal agenda. In particular, the promise of open data and access hides disparities in remuneration (Kansa 2014). For politicians, citizen science can also be an instrument to reach policy targets, such as the mobilisation of citizens for science, in order to increase the innovative power of Europe, or to mainstream concepts such as *responsible research and innovation* (Vohland and Göbel 2017). Citizen science is also seen as an instrument to support *sustainable development*; however, sustainable development can be seen to be broadly positive and normative. As a result, the question of how to judge the *instrumentalisation* of citizen science in this area is therefore more complex than simply examining how it is undertaken.

Exploitation

In citizen science, little attention has been paid to concerns about knowledge extraction, namely, the collection and circulation of (sensitive) data without explicit individual and/or community consent, and the subsequent potential traumatisation of such extraction processes. Research participants could have varying, even conflicting, stakes in the research process, which are at odds with researchers' interests, with the latter potentially only sticking with the research for the duration of a funding cycle.

Further concerns are raised in relation to exploitation where data ownership is not properly defined, and participants' data are valued not only for the information they provide but also for the increasing commercial or research value they may entail (see Lupton 2014 and the subsection on collaboration with private partners below). This points to the need for individual input to, and community-level considerations for, research ethics reviews and consent practices (Dickert and Sugarman 2005; Box 20.1).

Box 20.1: Civil Laboratory for Environmental Action Research
Researchers at the Civic Laboratory for Environmental Action Research (CLEAR) in Canada have implemented *community peer review* processes. These combine consent, community self-determination, and peer review for

(continued)

Box 20.1 (continued)
environmental research in such a way that consent is agreed at the community level at the beginning of the research cycle. The aim of this is to mitigate unexpected and unintended harms, as well as to increase benefits to communities and their ownership over the process (Liboiron et al. 2018). This gives the research participants involved the ability to determine whether the research may cause them harm and to be part of determining how knowledge should best circulate to reduce or eliminate that harm.

Inclusiveness

There is a paucity of literature that exhaustively describes equity-driven involvement in citizen science using dynamic informed consent (Prictor et al. 2018). In some fields of scientific research, the involvement of certain citizens in research prevails. For example, in health research, Indigenous and socially, culturally, and linguistically disadvantaged people are quite often disregarded (Prictor et al. 2018), and their potential contribution, in terms of know-how, is missed or overlooked. Furthermore, the findings of research that excludes certain citizens are necessarily incomplete since they lack the ability to be extrapolated fully. Some platforms seek to reduce this constraint (Box 20.2).

Consideration of the timing and scheduling of citizen science activities is of crucial importance to ensure as wide and diverse a group of people as possible can participate in such activities. For example, being attentive to the days of the week when participation is required, as well as varying the times of day at which activities are scheduled, plays an important part in ensuring the inclusiveness of citizen science. Another way in which to increase the potential for diverse groups to participate includes reflecting on the location of activities, projects, and initiatives. Whilst some may feel comfortable attending events or citizen science activities in, for example, university or institutional buildings, or grounds, this may be off-putting and exclusive for others. Attention needs to be paid to the specific details of how citizen science activities are organised to address some of these issues (see Paleco et al., this volume, Chap. 14).

Box 20.2: Sapelli: A Tool to Translate Icons and Language in Order to Enhance Inclusiveness
The Extreme Citizen Science (ExCiteS) research group based at University College London works to develop tools specifically for undertaking more bottom-up, extreme citizen science. The particular tool they are developing is called Sapelli, an open-source project that facilitates data collection across language or literacy barriers through highly configurable icon-driven user

(continued)

Box 20.2 (continued)
interfaces. Sapelli is frequently used with communities with low levels of literacy or in some instances with nonliterate people. Whilst ExCiteS works extensively with different groups to implement the use of Sapelli in a wide variety of different contexts and countries, and to adhere to a values-based approach to implementing the use of the tool, focusing on a bottom-up practice that takes into account local needs, practices, and culture; there are unavoidable power dynamics that come into play in each instance in which the tool is used. To address potential issues surrounding imbalances of power in particular contexts, and to ensure inclusivity in the research process as much as possible, the ExCiteS group starts any project by following the steps of the free, prior, and informed consent (FPIC) process, thereby allowing for frequent discussions with all those involved in a project, to understand the local context and to subsequently address the potential issues and imbalances of power relationships that might arise.

Research Malpractice

Concern over data quality in citizen science is a long-standing issue (Guerrini et al. 2018; Balász et al., this volume, Chap. 8). Owing to the characteristics and activities of citizen science, the tasks that citizen scientists undertake are not necessarily subject to institutional or regulatory oversight (Resnik et al. 2015a). This means that whilst professional researchers are bound to methodological rigour and research integrity and are held accountable for the quality of their work, citizen scientists might not be susceptible to such formal mechanisms and pressures (Guerrini et al. 2018; Resnik et al. 2015b). This could, in turn, challenge the implications of research malpractice in citizen science projects. For instance, in archaeology, lay people may destroy places of recovery and take away valuable artefacts for science (Davydov et al. 2017). Also, conflicts of interest may stem from research participants' affiliations to private, public, or political organisations or from their individual perceptions of the harm or benefit of the research (Guerrini et al. 2018). Evidence has indeed shown that the collection of non-representative data has been used to obtain relief resources, support lawsuits, gain media attention, and support erroneous scientific conclusions (Roy and Edwards 2019). Although professional scientists themselves are not exempt from bias, conflicts of interests, and research misconduct, it is important to develop strategies that promote integrity in research collaborations among professional and non-professional scientists.

Collaboration with Private Partners

Some of the new forms of collaboration in citizen science relate to the linkage of citizen science projects with either small- or medium-sized enterprises and even larger industrial companies. The primary issue with these types of collaboration is the monetary valuation of the research results. Whilst this might be an issue that is planned for before the research takes place, it may also develop during the research process itself. A discussion at the Citizen Science Forum 2017, in Germany, demonstrated that the community is split (Ziegler et al. 2018). Other forms of collaboration, such as in the provision of services for technology and design, do not have such issues attached and can strongly benefit from the quality of citizen science tools and public dissemination.

Box 20.3: Case of the German Butterfly Monitoring Scheme
A complex case arose when a private company used and interpreted data from citizen scientists in a way that contradicted their intentions. In the case of the German Butterfly Monitoring Scheme (TMD) of the Helmholtz Centre for Environmental Research – UFZ, Monsanto wanted to use the scheme's data to demonstrate that genetically modified organism (GMO) maize does not harm butterflies. The TMD scheme delivered viable data that was useful for research (Kuehn et al. 2008), but the participants wanted to support nature conservation (Richter et al. 2018). The intended 'cooperation' between the private company and the TMD scheme did not take place, mainly because the monitoring scheme was not suited to answering the question of how harmful GMOs are for butterflies. However, the case also opened up questions of data ownership, different ways of interpreting data, and the issues surrounding properly funding independent environmental monitoring schemes.

Furthermore, when choosing the recruitment strategy for a citizen science project, diverse channels can be used to involve citizens in research. However, advertisements using the logos of business enterprises are not always recommended by the IRB, usually responsible for the ethical review of a research project. In Southern Alberta, researchers of citizen scientist radon testing survey were recommended to remove the university logo from the industry partner's website and to restrict recruitment channels and to solely use the university's website (Oberle et al. 2019). This was required to avoid a potential conflict of interest around the financial independence of researchers from the industry partner. On the other hand, citizen scientists may complain if companies which follow different interests use their data (Box 20.3).

Payment and Free Labour

Recruitment of citizens is another issue that needs to be more comprehensively discussed (Resnik et al. 2015a; Riesch and Potter 2014; Rothstein et al. 2015; Tauginienė 2019). Most often, citizens are volunteers, with the assumption that they should not be paid for their contribution. However, payment in this context needs to be understood properly; it relates to the reimbursement of citizens' costs (such as travel to an instruction meeting with researchers), not to a profit that citizens might gain from taking part in citizen science. In this sense, there can be an imbalance between researcher and citizen, where a researcher is paid for his/her time on a research project, but not necessarily for undertaking citizen science, whereas a citizen is not paid at all (Riesch and Potter 2014). In some European projects (e.g. LandSense), and also in some German projects (following a call from the German Ministry), scientists are paid to run citizen science projects. Participant recruitment strategies should be carefully chosen to avoid issues of inequity, exploitation, voice buying (in political terms, getting the agreement of lay people by paying for their contribution), and voice manipulation (Oberle et al. 2019; Resnik et al. 2015b; Rothstein et al. 2015).

The question of payment, however, also refers to another dimension of society, namely, the increasing economisation of our lives, the internalised judgement, and the framing of daily activities around their economic benefit (Brown 2015). This is especially visible in the area of environmental sciences (Lave 2017), which focuses on smaller scales, contributing activities which support institutional researchers and administrations, rather than groundbreaking exploratory research. Citizen science is therefore in an ambivalent situation (Vohland et al. 2019). On the one hand, as described above, a feeling of injustice may arise if citizens are not paid for undertaking the activities that researchers are paid for. On the other hand, citizen science can provide a space free of economic considerations where key motivations are learning, contributing subtly to sustainable development, and having fun.

Ownership and Acknowledgement

Authorship credit and/or data citation constitute practices aimed at formally recognising citizen scientists' contributions to a project (ECSA 2015; Resnik et al. 2015a). However, citizen science participants are rarely included as authors of peer-reviewed publications (Dickinson et al. 2012). The reasons are varied: there are no consistent credit assignment practices for collaborative work from one field to the next, and those that do exist mainly rely on standards around what one must contribute to be considered an author (Cozzarelli 2004; ICMJE 2019). The data produced in citizen science projects may be generated by large online communities, with participant numbers that are constantly changing and expanding, which makes it difficult to acknowledge potentially thousands of named contributions (Theobald et al. 2015). Formal acknowledgement of citizen scientists' contributions may also raise issues of data quality (Burgess et al. 2017). In addition, it might be that the results of citizen science projects are published via alternative dissemination platforms to reach the general public, rather than peer-reviewed scientific journals (Gadermaier et al. 2018). Although gaining citizen scientists' permission to be listed as co-authors can be challenging, research participants may have an active stake in the production of data, their engagement might be time and effort intensive, and their contribution might be quite substantial (Riesch and Potter 2014). Also, formal acknowledgements and attribution are crucial motivational factors (Rotman et al. 2012) that can potentially help attract and retain volunteers (Piwowar and Vision 2013), as well as improve research accountability. It is therefore important to discuss potential co-authorship or formal acknowledgment directly with participants as early as possible in the research process.

Licensing of data and other research materials constitutes a further practice that formally defines ownership and re-use conditions. In terms of the data set, a license specifies how the data can be used by the involved partners or even the public under an open license. A common license for *open data* is the Open Database Licence or ODbL,[1] which allows the use of the data without needing to cite every contributor individually.

In terms of content elements, like photographs or written text by users, intellectual property laws apply. In a European context, the authorship of a unique content item is owned by the author automatically. The author can only grant usage rights to the project, or the public, by applying a license. In most cases, this is done automatically at the point of user registration via accepting the terms of use with a checkbox in the registration form. The license, under which 'unique creative works' are published by a user, can vary from specified rights to use just by the project to more open licenses, like the various forms of Creative Commons (CC) licenses which allow sharing, define the needs of author citation, and specify how the creative work can be used. With the different forms of the CC BY license, the author must always be cited when content is used within the project or, for example, on a website or in social media.[2] At the opposite end of the available spectrum, the CC0 license, also known as Public Domain, allows anyone the free use of content without citations or restrictions.[3] In addition to the aforementioned licenses, there are many others available for use by projects from the outset. However, licenses are not restricted to pre-existing ones; everyone can create a new type of license and apply it to the data or content elements within a citizen science project, but normally

[1]Open Data Commons Open Database License (ODbL): https://opendatacommons.org/licenses/odbl/index.html

[2]See further CC licenses and examples: https://creativecommons.org/share-your-work/licensing-types-examples/

[3]See further on public domain licensing: https://creativecommons.org/share-your-work/public-domain/

it is advised to use licenses already in use, not only because of efficiency, but also be sure that the significant legal aspects are covered.

Types of Informed Consent

There is currently access to more information than ever before, and many people express the desire to participate in the scientific process, either passively by providing (personal) information or actively by, for instance, participating in a citizen science project. What in former times was some kind of *implicit* consent, meaning consent that was not expressly granted by someone, now becomes increasingly *explicit*. With the rise of Web 2.0 user-oriented technologies and the big data era, *research ethics 1.0* has been revisited and subsequently has been replaced with *research ethics 2.0* where appropriate (Tauginienė 2019; Fig. 20.1). This shift mostly affected the role of informed consent. In research ethics 1.0, informed consent referred to regularly informing participants about the purpose of research, the risks and benefits of being involved, and the right of a citizen to withdraw from the research at any time (Brall et al. 2017). As such, informed consent was paper based and reflected conventional models of involving human subjects used in 'Engagement 1.0' (Teare et al. 2015). In this instance, a citizen was a passive subject. However, in research ethics 2.0, the balance between a researcher and a citizen in

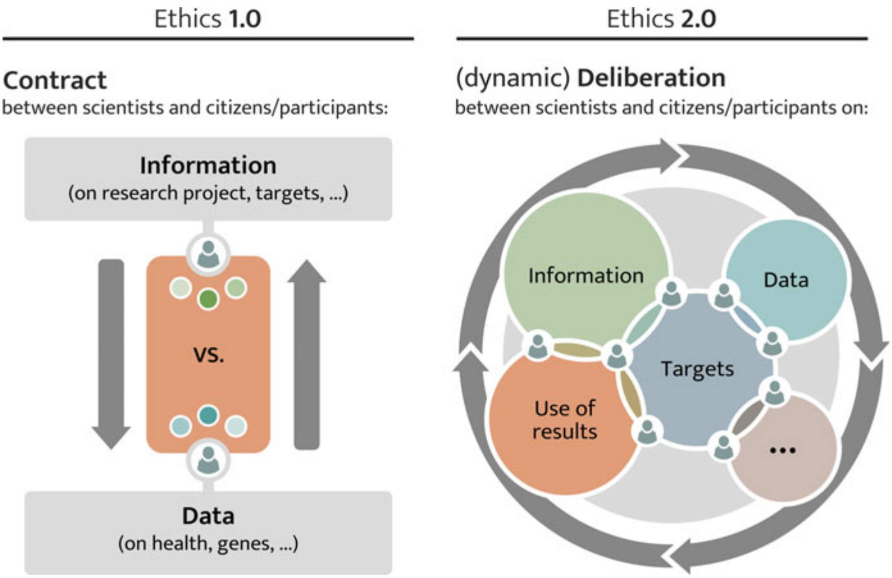

Fig. 20.1 The difference between informed consent in research ethics 1.0 and 2.0. Whilst, traditionally, informed consent is understood as a kind of contract, in ethics 2.0, there is a continuous – dynamic – interdependence between initiating researchers and participating citizens

informed consent has been reconsidered, giving more attention to greater transparency between actors, and giving citizens more control over their own data, as well as continuous updates on the reuse of his/her data in specific research projects (Kaye et al. 2015; Woolley et al. 2016). In this sense, in research ethics 2.0, a citizen is an active subject who interacts with a researcher (who is the keeper of the citizen's data) (see, e.g. Fig. 20.1).

Given the effects of different types of ethical stances on research, it is important to describe what consent is and what types of consent have been used so far. In general, consent is characterised as FPIC. FPIC is a process that allows for a deeper understanding of the power relationships at play in particular contexts and for frequent discussions with all those involved in a project, to understand the local context and to subsequently address the potential issues that might arise. FPIC focuses on harmonising and equalising relationships between groups of different power and means (Lewis 2012). To achieve this, the following facets should be carefully taken into consideration: transparency, access to expertise, data access and control, the right to withdraw, relevance, beneficence, responsibility, flexibility, and inclusivity (see more in Grant et al. 2019).

Whilst we focus on the benefits of dynamic informed consent in more detail in the next section of the chapter, it is useful to briefly introduce five types of informed consent here, by stating their core characteristics: broad, blanket, open, portable legal, and meta. It is also crucial to iterate that this typology is not exhaustive; in the scientific literature, other types of consent are also described (see more in, e.g. Hofmann 2009).

Broad consent is used for a single research project; in other words, it is not designed to be repurposed or reused in a different way in another research project (Cheung 2018). Usually a research participant is passive when broad consent is used in research, meaning that the assurance of the participant being properly 'informed' is questionable (Cheung 2018). Broad consent also fails to explicitly detail the use (and potential reuse) of collected data (Steinsbekk et al. 2013); it is, therefore, hard to apply this type of consent for data of multiple use (Budin-Ljøsne et al. 2017). Also, broad consent lacks flexibility when legal regulations are revised (e.g. EU GDPR 2016) and cause unanticipated concerns (Budin-Ljøsne et al. 2017).

Blanket consent has an indefinite range of options and mostly respects the autonomy of a research participant (Hansson et al. 2006). However, it is 'impractical to renew [blanket] consent' (Hofmann 2009, p. 126) as it contains future unspecified data use (Ploug and Holm 2015).

Open consent requires an entire disclosure of privacy from research participants who, in doing so, should 'demonstrate comprehension of the nature of the research and the risks involved prior to enrolment' (Ball et al. 2014 as cited in Cheung 2018, p. 26). It excludes recontact and withdrawal and has other limitations (Caulfield et al. 2003). This type of consent seems the least realistic to use in some fields of science, such as the biomedical sciences.

Portable legal consent refers to the right of a research participant to decide what kind of data (e.g. genetic sequences, medical records, patient reported outcomes) to donate to and share for research purposes (Cheung 2018). This type of consent is detached from any specific scientific research.

Meta consent allows a research participant to choose which type of consent they are willing to give for which type of data, as well as how, and when, they wish to give consent (Budin-Ljøsne et al. 2017; Cheung 2018). Such specifications can also be applied across diverse stakeholders (e.g. doctors, industries, researchers) (Ploug and Holm 2015). This type of consent facilitates the articulation of types of informed consent and data, as well as context-driven communication.

Dynamic Informed Consent

In health research (viz., in *biobanking*, or the collection of health and biological data), the processes needed to reach informed consent are now called dynamic informed consent (Kaye et al. 2015). The need to revise regular-informed consent comes from demands to update and customise preferences of consent and to have more actively engaged citizens in biobanking, as well as to provoke 'system-wide behaviour change' (Teare et al. 2015, p. 9). This is achieved through dynamic informed consent, all parties – citizen scientists and researchers – acknowledge interdependence and social identity, or what can be understood as their belongingness to society (Christensen 2012; Johnsson and Eriksson 2016). After only a short space of time, dynamic informed consent has become a determinant of social innovation in citizen science and research ethics that requires these changes in the behaviour of the community of researchers, as well as of citizens.

Wee et al. (2013) distil the key elements of informed consent to the following: (1) communication between a researcher and a research participant, (2) adequately informing a research participant, and (3) a deliberate choice by a research participant to decide on their level of involvement in research. All these elements are also inherent in dynamic informed consent. However, whilst all these elements are reached at the initial stage of research using broad consent, with dynamic informed consent, additional elements occur – such as continuity in relationship maintenance and high levels of interaction through multiple contacts and ongoing communication (Wee et al. 2013). Therefore, we suggest adopting dynamic informed consent not only in health research but also in citizen science in general, to reflect the real-world iterative research process. This is to say that dynamic informed consent requires live iteration, by returning to participants to obtain consent throughout the research process as it develops, or as more information becomes available, or as needs emerge. As a result, such consent requires citizens to be more engaged in the process.

In general terms, informed consent is one of the key elements to ensure ethical research practice, as well as being 'part of a framework of research governance' (Steinsbekk et al. 2013, p. 899). To obtain informed consent from a citizen before the start of research is a fundamental ethical research principle, as stated in the *Declaration of Helsinki* (World Medical Association 1964). However, this social contract evolved when citizen science became immersed in other disciplines. In addition to this, *General Data Protection Regulation* (EU GDPR 2016, Art. 17), which refers to the right to erasure ('right to be forgotten'), means that data can no longer be stored without a clear purpose for an unlimited period of time. It seems that regular-informed consent is no longer sufficient to deal with such issues, whereas dynamic informed consent might be a sensible solution in the twenty-first century.

Though dynamic informed consent has been foremost in the debates in the biomedical sciences, the discussion of its potential in the context of citizen science is best encapsulated in the framing of the Ensuring Consent and Revocation (EnCoRe) project. The EnCoRe project sets out to give individuals more control over their personal information, by improving the ease, reliability, and rigour with which individuals can grant and, more importantly, revoke their consent to the use, storage, and sharing of their personal information by others. In this way, dynamic informed consent may reconcile a few types of consent at once (Budin-Ljøsne et al. 2017; Kaye et al. 2015). More specifically, dynamic informed consent refers to the deliberative decision-making process about citizen-generated data using a web-based platform that allows citizens (research participants) to interact with the keeper of their data. The essential points here are that this entails the proper informing (provision of detailed and specified information) and a personalised interaction, which reduces the risk of instrumentalisation. These are achieved through the sustained recontacting of citizens in order to provide them with the latest relevant information about a project and, in turn, to receive their consent/dissent. As such, a bidirectional interaction between participants and researchers allows for the *autonomy* of citizens to be encapsulated, that is, citizens can decide in which research, and to what extent, their data can be reused or not (Steinsbekk et al. 2013). Furthermore, citizens can have more control over the use of their data (Wee et al. 2013); in this way, keepers of citizen-generated/shared data testify their respect for those who have generated the data. This control can be expressed using a variety of types of informed consent, so as to fulfil citizens' preferences. Also, citizens receive more detailed and specific information about the research; therefore, *integrity* is better maintained (Johnsson and Eriksson 2016), and payment becomes less of an issue.

The core benefit of dynamic informed consent for researchers relates to its sustainability – including less costly recruitment of participants, enhanced communication with participants, and reduced paperwork, which is ultimately less time-consuming (Kaye et al. 2015; Stoeklé et al. 2017). Budin-Ljøsne et al. (2017) clarify these benefits in more detail: being around electronically stored records and their updates (reliable track record), instant confirmation of the consent status, as well as the potential for an audit and review of standard operating procedures. Among the benefits of dynamic informed consent for research participants are the potential to be re-contracted when they are in a potentially less stressful frame of mind (e.g. after surgery) and their increased scientific literacy due to being better informed about the issues at stake (Kaye et al. 2015; Teare et al. 2015).

Challenges for Practical Ethical Citizen Science

Dynamic informed consent will clearly require a great shift in both the culture of research ethics and the culture of academia itself. These will result in the updating of research ethics policies, as well as the refining of existing standard operating procedures and their operationalisation (e.g. IT solutions, customised training, etc.). However, this shift will also bring with it additional challenges. The first challenge is around how to strike a balance between the risk of a greater burden on research participants and their willingness to be cognisant about the use of their data. In developing dynamic informed consent, contact with research participants becomes easier. However, there is also a risk of consultation fatigue amongst research participants as a result of multiple and frequent contact from researchers, which might result in lower levels of successful recruitment to a project. Another issue related to the frequent contact of participants using dynamic informed consent is that the ties with the citizen, as the owner of personal data and other data held by them, should be established over a longer period. The need for such ties might conflict with standard purposes of safeguarding data, as described by the European personal data regulation (according to the EU GDPR). To fulfil this need will require the redefinition of the purposes of safeguarding data for a longer period if dynamic informed consent is used (Cheung 2018). Meanwhile, the need to have control over their own data might motivate citizens to become more engaged in research, but, conversely, demotivate them from continued participation.

The second challenge relates to the reuse of citizens' open data. Open data is often promoted at the European level, not only to give wider society access to data but also for research integrity. However, it remains unclear whether open data should be reused without (dynamic) informed consent. It goes without saying that there is a clear tension between the ideals of openness and accessibility that citizen science promotes and participants' interests related to data protection (Suman and Pierce 2018). This is something that will continue to be negotiated and worked out as the field develops further.

The third challenge relates to democratic maturity. It is assumed that societies with deliberative democracy can entrust research ethics in citizen science to citizens. However, there is a complex maze of issues that might become manifest, particularly when considering the uneven distribution of citizens in deliberations (Parvin 2018), and citizens' unevenly distributed knowledge about science. Furthermore, such complexities continue when considering participants' skills in making informed decisions, as well as the role of research ethics committees/IRBs in such contexts. It is still difficult to define how responsibilities in ensuring research ethics will be managed, perhaps by evenly sharing such responsibilities amongst all parties, or by reducing one party's role (Kaye et al. 2015; Steinsbekk et al. 2013; Wee et al. 2013), or indeed by altering the focus of research ethics committees/IRBs from the type of consent to the functionalities of tools (e.g. apps) (Budin-Ljøsne et al. 2017).

The Future

To foster the ethical engagement of citizens in science as well as to ethically accomplish citizen science, we conclude with a set of practical and specific recommendations about how to tackle some of the ethical issues related to dynamic informed consent. These serve as practice guidelines about how to deal with ensuring that participants are both informed and consenting. Hence, the recommendations will help to understand how to create a culture of research integrity and thereby improve the 'dynamic' aspects of dynamic informed consent in citizen science (Fig. 20.2).

We recommend using and exploring dynamic informed consent further whilst acknowledging that it is not a new phenomenon. However, we perceive its renaissance, particularly due to the EU GDPR applied in all EU countries, and as the best solution in the current context to avoid the stigmatisation of citizen science, and science in a general sense. To achieve this, an overall *increase in ethical literacy* is needed, by encouraging public reflections on ethical concerns in citizen science (Rasmussen 2019). This could be done by discussing with citizens what knowledge and information dissemination, as well as acknowledgments, they prefer (Kaye et al. 2015; Resnik 2019; Teare et al. 2015; Wiggins and Wilbanks 2019). Such interactions allow for an increase in the responsibility and accountability of a researcher, as well as avoiding any potential conflicts of interest (so upholding transparency of research) and questionable research practices from the outset.

The *efficiency of communication* in citizen science can be improved by providing hyperlinks to various alternative forms of presenting project and ethical information. This is particularly useful for vulnerable groups of potential participants, such as children, and others (Kaye et al. 2015), and has the potential to assist with increasing the transparency of research.

Furthermore, *issues of data protection* in citizen science need to be addressed from a praxis standpoint. For example, identity protection must be upheld at all times with particular consideration given to the potential for re-identification of participants in the research process (Cheung 2018). Written permission to use photos where citizen scientists can be identified (e.g. from discussions, meetings) in a research report/scientific paper must be obtained (Resnik 2019). User privacy should be taken seriously, and the necessary tools of the EU GDPR should be provided,

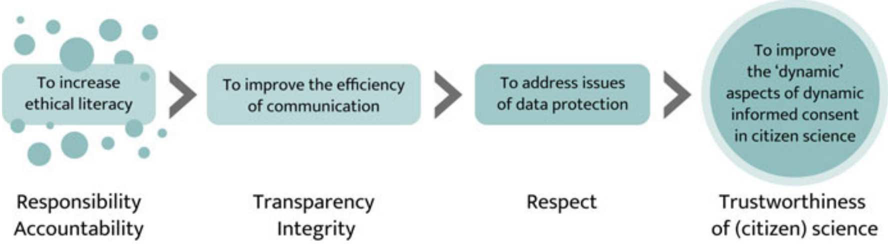

Fig. 20.2 The core 'dynamic' aspects of dynamic informed consent in citizen science

such as consent boxes and account deletion options – these will all help to properly respect privacy.

Such factors help promote the veracity and truthfulness of (citizen) science through responsibility, accountability, transparency, respect, and integrity, not only when drafting dynamic informed consent but also through the entire citizen science research process.

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Part III
Citizen Science in Practice

Chapter 21
Finding What You Need: A Guide to Citizen Science Guidelines

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Abstract In line with the growth in citizen science projects and participants, there are an increasing number of guidelines on different aspects of citizen science (e.g. specific concepts and methodologies; data management; and project implementation) pitched at different levels of experience and expertise. However, it is not always easy for practitioners to know which is the most suitable guideline for their needs. This chapter presents a general classification of guidelines, illustrating and analysing examples of each type. Drawing on the EU-Citizen.Science project, we outline criteria for categorising guidelines to enable users to find the right one and to ensure that guidelines reach their intended audience. We discuss challenges and weaknesses around the use and creation of guidelines and, as a practical conclusion, provide a set of recommendations to consider when creating guidelines.

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Introduction

This chapter is not new guidance about how to 'do' citizen science; rather, it is a *guide to the guidelines*, explaining why and how guidelines should be classified. We mainly focus on citizen science guidelines provided online and in English, while noting that there are others (e.g. print only, in other languages). Furthermore, we consider guidelines that refer not only to scientific methodologies but also to the implementation and maintenance of citizen science projects.

The chapter is aimed at anyone involved in citizen science projects, as well as those planning to produce their own guidelines. We start with a review of existing guidelines, which draws on our experience of participating in and/or managing citizen science projects. As well as elaborating on what makes guidelines useful, we also aim to facilitate greater access to them. We go on to outline how to ensure guidelines can be made more findable through the use of metadata. To conclude, we consider some of the challenges of using and creating guidelines and weaknesses in the existing selection, which point the way to improvements and subjects that should be covered in future iterations.

The Value and Diversity of Guidelines in Citizen Science

Citizen science is a rapidly growing field, with numerous projects around the world (EC 2019). These are having widespread impacts in diverse areas, such as social media (Bautista-Puig et al. 2019), environmental policy (Turbé et al. 2019), and many scientific fields (Follett and Strezov 2015; Kullenberg and Kasperowski 2016; Bautista-Puig et al. 2019). This diversity is also evident in terms of the methodologies used, project duration, the number and type of participants, the range of activities undertaken, the levels of documentation, and the degrees of achievement.

However, with such diversity, knowledge can be forgotten, overlooked, or lost in the enormity of the Internet, because projects lack a powerful, flexible tool to correctly index them and make them visible. One way to counter this, and capture the knowledge and lessons emanating from citizen science projects, is to document these lessons and knowledge in guidelines (see Box 21.1).

Box 21.1: What Is a Guideline?

Guideline: Information intended to advise people on how something should be done or what something should be. Cambridge Dictionary (n.d.)

(continued)

Box 21.1 (continued)

Guidelines are one way in which we capture and share information, and they have been written for numerous subjects. Generally, they are less discursive documents and more directive: What to do (and why); how (best) to do it; and, in many cases, step-by-step instructions that can be followed or adapted.

Several guidelines exist on different aspects of citizen science. These cover, among other subjects, how to set up a project; how to attract, motivate, and retain participants; how to store and manage data; and how to influence policy. They take many forms, such as training manuals, case studies, best practice examples, and how-to guides. And they can be presented in different media: books and printed materials, online materials, videos, and audio broadcasts.

But what are guidelines for? By referring to a guideline, people involved in citizen science projects – whether professional scientists, project managers, or participants – can learn from the lessons, mistakes, and experiences of others. In this way, they can avoid wasting time and resources by repeating common mistakes; they can decide how best to allocate resources; and they can locate ideas and inspiration for how to improve their activities, even if already successful.

However, it is not always easy for people to know which guideline is the most suitable for their needs (Skarlatidou et al. 2019), nor will it solve every problem. For example, knowing how past projects have successfully recruited citizen scientists does not mean this can be replicated in other projects.

Despite this, guidelines – whether *conceptual* or *methodological* – are an essential component of successful citizen science (see Box 21.2 for some good examples). It is always important to gain an understanding of the fundamentals of the scientific process, such as defining the problem and the right methodology to address it. Referring to relevant guidelines can support this and should therefore be an initial undertaking for any project – one repeated throughout its duration.

For those whose projects have provided insights that could benefit others, guidelines can be a communication tool to share, among other aspects, the project methodology, its lessons, and its successes.

Box 21.2: Good Examples of Citizen Science Guidelines

One leading example of a citizen science guideline is *Choosing and Using Citizen Science: A Guide to When and How to Use Citizen Science to Monitor Biodiversity and the Environment* by Pocock et al. (2014). This was prepared for the staff of the Scottish Environmental Protection Agency (SEPA) to understand when and how to use citizen science. The guideline provides an introduction to citizen science in environmental monitoring, along with advantages and disadvantages of using this approach. At its core is a decision framework on where and how to choose a citizen science methodology (that is, which issues are suitable and which are not).

(continued)

Box 21.2 (continued)

Further best practice examples can be found in the many local, national, and international citizen science platforms. For example, the Spanish platform *Ciencia Ciudadana en España* hosts more than 20 educational guidelines on citizen science, many of which can be used in both formal and non-formal education.

In the international field, the selection of guidelines carried out by the Doing It Together Science (DITOs) project, currently available on the ECSA website,[1] should be highlighted. These show the relationship between resources used in the *responsible research and innovation* approach. Among these resources, is the advice paper from the League of European Research Universities (LERU), which is addressed to scientists and institutions who want to incorporate or foster citizen science methodologies (Wyler et al. 2016). Other noteworthy examples include the two guidelines edited by the Citizen Science Foundation of Chile,[2] which are particularly useful for the Latin American community.

Historical Citizen Science Guidelines

In citizen science, guidelines have likely existed for almost as long as the field itself. Yet there are two main difficulties in locating them. Firstly, the term ‘citizen science’ is not useful for identifying the thousands of activities throughout history that match this concept. Secondly, the term ‘guidelines’ does not sufficiently cover the many tools that fulfil the recording function in these activities. Conducting such an extensive review of historical citizen science is beyond the scope of this chapter, but we offer some representative historical examples.

One significant example comes from the history of meteorology in the USA. The ‘meteorological crusade’ took place between 1834 and 1859 and sought to explain the causes of storms, their phenomenology, and the most appropriate research methodologies. The ensuing scientific conflict led to the development of an observational project by the Smithsonian Institution, together with the American Philosophical Society, the Franklin Institute, the Army Medical Department, and the Navy Department. In 1848, the American System of Voluntary Observers in Meteorology was founded under the direction of Joseph Henry, a renowned physicist and a member of the Smithsonian Institution. The number of project participants reached 600 observers in 1860. As Millikan (1997, p. 15) notes, ‘the volunteers mailed monthly reports that included several observations per day of temperature, barometric pressure, humidity, wind and cloud conditions, and precipitation amounts’. For accurate measurement by the volunteer observers, ‘the Smithsonian Institution provided standardized instruments, uniform procedures, free publications, and a sense of scientific unity that went

[1] https://ecsa.citizen-science.net/blog/collection-citizen-science-guidelines-and-publications

[2] https://ciencia-ciudadana.es/category/recursos-del-observatorio/guias-y-metodologias/

far beyond the normal scope of local universities and academic societies' (Fleming 1997, n.p.) – an early example of a citizen science guideline.

Also in the nineteenth century, ocean science was consolidated through diverse collaborations, in this case between the British Admiralty, the scientific community, and the maritime community (Reidy 2008). The history of the 'great tidal experiment', conducted under the coordination of William Whewell in 1835, is an emblematic scientific project: it was carried out simultaneously by thousands of people from nine countries and colonies at more than 650 stations on both sides of the Atlantic. Whewell's instructions for recording measurements were undoubtedly intended for use by all those who, with or without previous training, participated in the great experiment. In the document *Memoranda and Directions for Tide Observations (1833)*, there are instructions for how to measure the tides, either continually in one place or at different observation stations. As such, it can be considered one of the earliest historical examples of citizen science guidelines. The sixth series of Whewell's philosophical transactions contains methodologies as well as the results of the experiment and, while initially addressed to the professional scientific community, was also consulted by ship captains who, together with members of their crews, continued to report measurements for later experiments (Washington 1842*).*

Guidelines on methodologies, and the collection and recording of data of diverse types and scopes, have an even longer history. This includes activities originating from an authority (academy, government, etc.) that requested the population to collect data. Clavero and Revilla (2014, p. 15) state that diverse 'historical data on biodiversity have been widely collected over several hundred years through initiatives that today would be described as citizen science'. They illustrate this statement with an example from 1575, when the Spanish government distributed questionnaires, known as *topographical relations*, in which the more informed inhabitants of each locality had to provide a compilation of their local knowledge, in particular about its natural heritage. Clavero and Revilla (2014, p. 15) detail that 'the 637 questionnaires that are preserved include information on some 190 species of wild animals and plants, collected in more than 4,300 individual records'. The questionnaires – reproduced in Campos y Fernández de Sevilla (2003) – also included information on economic, cultural, geographical, and legal issues, among many others. The letters written by King Philip II, which ordered the creation of a catalogue together with the questionnaires, constitute a meticulous guideline for the registration of these data. Similar historical data sets exist in China and in most European countries and their former colonies (Clavero and Revilla 2014).

A Guide to the Guidelines

The Need to Classify Guidelines

Beyond academic research, there are two main reasons for classifying guidelines. Firstly, there are numerous guidelines available, but it is not always easy for citizen science practitioners and project managers to find the right resource when many cover similar themes and practices. Secondly, people looking for a guideline on citizen science often have diverse needs and interests, which can be specific (e.g. for a niche branch of citizen science). A thorough system of classification helps people to find the right guideline for their needs and increases the accessibility and usefulness of guidelines. The next step for classifying citizen science guidelines will be according to the metadata (the information about the guidelines).

Types of Guidelines

Establishing an exhaustive classification of all types of citizen science guidelines is beyond the scope of this chapter, but it is worth distinguishing between the two main types of guidelines. Firstly, those that refer to *general* aspects of citizen science; these can be defined as *lessons learned* for use across a range of citizen science projects. Secondly, there are guidelines focused on *specific* citizen science projects. Each type of guideline can be subdivided between those that cover all aspects of citizen science and those that focus on certain (one or more, but not all) aspects. Table 21.1 outlines this classification system, along with examples to illustrate it.

General Guidelines: All Aspects

Although citizen science is an increasingly diverse field, general guidelines on citizen science continue to be produced. One reason is that the concept of citizen science needs to be clarified, as there is not (yet) a widely agreed definition, and, arguably, such a definition is not necessarily useful (see Haklay et al. 2020, this volume). General guidelines address issues common to almost any project, such as those detailed below.

Although most citizen science resources are written in English, two good examples of general guidelines are in German and Spanish. *Citizen Science für alle – Eine Handreichung für Citizen Science-Beteiligte* (GEWISS Consortium 2016) was written for a German-speaking audience in Germany, Austria, and Switzerland but has been translated into English and is equally useful in many other geographic locations. It describes how citizen science can be used in different fields, such as education, conservation, and the arts and humanities, and targets a wide range of end users from scientists to society-based groups to NGOs. It also provides a relevant set of further resources and references: many of these are only available in German, but some are also accessible in English.

Similarly, *Ciencia ciudadana: Principios, herramientas, proyectos de Medio Ambiente* (Acevedo 2018) can be considered a general guideline, even though its title makes explicit reference to the environment. The guideline includes a wide variety of tools and resources applicable in any field. It is also a practical text, with abundant examples and methodological tools based on the *Canvas model*, (which

Table 21.1 Classification of types of citizen science guidelines

Type	Subtype	Topic	Examples
General – covering aspects common to all citizen science projects	All aspects		*Citizen Science for All. A Guide for Citizen Science Practitioners* (GEWISS Consortium 2016)
			Ciencia ciudadana: Principios, herramientas, proyectos de Medio Ambiente (Acevedo 2018)
	Focused on certain aspects	Ethics	*Managing Intellectual Property Rights in Citizen Science. A Guide for Researchers and Citizen Scientists* (Scassa and Chung 2015)
		Communication	*A Guide to Communications in Citizen Science* (Veeckman et al. 2019)
		Data	*Guiding Principles for Public Engagement* (UCL n.d.).
		Methodology	*Data Management Principles* (UKEOF n.d.)
			Citizen's Guide to Open Data (Geothink 2016)
			'Statistical Solutions for Error and Bias in Global Citizen Science Datasets' (Bird et al. 2014)
Specific – related to one project	All aspects		*Artportalen Basic Principles* (Artportalen n.d.)
			Manual de Usuario/a de Biodiversidad Virtual (Biodiversidad Virtual Manual) (Biodiversidad Virtual 2014)
	Focused on certain aspects	Ethics	*Debian Code of Conduct* (Debian n.d.)
			Código ético de la fotografía en la naturaleza (Ethical Code) (Biodiversidad Virtual n.d.)
		Methodology	Tutorial on the protocol for capturing an insect properly (Mosquito Alert n.d.).
			Celebrate Urban Birds (Cornell Lab n.d.)
			Unidad didáctica OdourCollect (Ibercivis 2019)
		Science	Tutorial on Galaxy Zoo (Galaxy Zoo n.d.)

helps users to establish a logical relationship between all the components of a project and the variables that influence its success). At the same time, it embodies the *ECSA 10 Principles of Citizen Science* (ECSA 2015), adapting them to the Chilean context.

General Guidelines: Focused on Certain Aspects

Many guidelines refer to one or more of the many aspects that are relevant to citizen science projects, including ethics, communication, data collection, data analysis and management, scientific methodology, and funding. The depth of coverage is also varied, ranging within the same topic from academic studies to introductory guides. *Managing Intellectual Property Rights in Citizen Science: A Guide for Researchers and Citizen Scientists* (Scassa and Chung 2015) presents an extensive study of ethical issues in citizen science as a guideline for both researchers and citizens. In their research, they discuss issues of copyright, patents, trademarks, and trade secret laws, as well as the protection of traditional knowledge, all in the context of citizen science. They also include examples of best practices in the field.

Although not presented as a guideline (but fulfilling the functions of one), the academic paper 'Statistical Solutions for Error and Bias in Global Citizen Science Datasets', by Bird et al. (2014), describes different methods for reducing bias and error in citizen science databases. The authors conclude that issues related to error and bias found in citizen science data are similar to those found in other large-scale databases and outline some of the tools available to combat them. For example, they explain some statistical approaches used in ecological contexts that are available in free software packages.

Specific Guidelines: All Aspects

Many projects produce comprehensive documents that gather all the relevant information about their activities, for example, as manuals for users or participants or final project reports. Comprehensive project websites can also fulfil the function of a project guideline.

Biodiversidad Virtual's website is one example. Not only it is an open system for users to search for and record sightings (e.g. of plants, fungi, animals, landscapes); it also provides instructions for how to do so and an ethical code for interacting with the environment, thereby acting as a guideline for users as well as other projects. Furthermore, the website stimulates interest in, and increases public understanding of, conservation measures, leading to greater efficiency in conservation efforts and a self-sustainable community.

Specific Guidelines: Focused on Certain Aspects

There are countless guidelines in this category, which is unsurprising given the enormous number of citizen science projects around the world and the many aspects that need to be addressed in each. For example, guidelines to species recognition are sometimes grouped and/or focused on a defined region (e.g. deciduous trees in Europe, day butterflies in New England); while others are even more specific, such as guidelines and tutorials about how to recognise individuals of a particular genus or species. Their prevalence will only increase as citizen science is applied to a growing number of scientific fields.

The Cornell Lab has a long history of citizen science, and one of its flagship projects, Celebrate Urban Birds, has produced bird identification guidelines that seek to make citizen science more inclusive. They are available online and offline, in English and Spanish, making them accessible to a large number of people and communities in the American continent.

Navigating the Diversity of Citizen Science Guidelines

There is a huge diversity of guidelines available, for example, around a particular subject or methodology, but, to the best of our knowledge, there has not been an exhaustive academic review or evaluation of their production and use. As their number continues to grow, in line with the increasing number and diversity of citizen science projects, research of this nature would improve the quality of future guidelines. It would also help to ensure that they address gaps in the field and meet the needs and demands of those working in the field (see Box 21.3).

Box 21.3: Guidelines for Environmental Digital Projects
Skarlatidou et al. (2019) noted that in the field of environmental digital projects, 'hundreds of citizen science applications exist, [but] there is a lack of detailed analysis of volunteers' needs and requirements, common usability mistakes and the kinds of user experiences that citizen science applications generate' (p. 1). This suggests that there is a need for further citizen science guidelines to be developed. To address a systematic review of articles related to user issues in environmental digital citizen science, the authors provide a set of design guidelines, assessing them by means of cooperative evaluation. In particular, they seek to 'assist scientists and practitioners with the design and development of easy to use citizen science applications' (Skarlatidou et al. 2019, p. 1).

Metadata

The problem of how to find material is not exclusive to citizen science. It is intrinsic to the nature of the Internet and will undoubtedly be one of the main challenges in the coming years. In an effort to tackle this, the World Wide Web Consortium (W3C) is promoting the *semantic web*, an extension of the existing web that aims to be a new standard for data formats and data exchange online. This concept, conceived by Tim Berners-Lee, was adopted by more than 4 million domains in 2013. With the semantic web, it is possible to indicate, in a way that search engines can understand, what we are talking about at every moment. As an example, citizen science projects can indicate their duration, number of participants, research branch, et cetera; while citizen science guidelines can indicate their target end users, types of licence, et cetera. So, with a simple search, someone can see all the citizen science projects executed in 2016 in Austria that involved 100–150 participants or all the guidelines in English about citizen monitoring of freshwater resources.

The task of classifying projects and guidelines is not easy, however. First, it is necessary to define the ontology with which to mark them. In addition, the web pages of citizen science projects and guidelines need to adopt the extension *www3* by including it in their code. Ideally, metadata should also be defined and created in a consensual way by those that participate in citizen science and those that produce its guidelines. Metadata must also be consistent with Internet standards, such as those provided on Schema.org.

An Approach to Classifying Guidelines: EU-Citizen.Science

An initiative to classify the existing array of guidelines for citizen science has been taking place in the EU-Citizen.Science project. This project has received funding from the European Union's Horizon 2020 Framework Programme for Research and Innovation. Its ambition is to build, fill, and promote a sustainable platform and mutual learning space providing different tools, best practice examples, and relevant scientific outcomes that are collected, curated, and made accessible to different stakeholders – ranging from interested citizens to scientific institutions, politicians, and the media – in order to mainstream citizen science in Europe.

Repositories exist for citizen science resources, including guidelines (see Box 21.2). However, they have some limitations, for example, infrequent or no updates, unclear selection criteria, difficulty in understanding their usefulness for the community, et cetera. To address these gaps, the EU-Citizen.Science project aims to develop criteria to define and identify (1) citizen science resources and best practices and (2) the relevant criteria used to select them. This section summarises the approach adopted by EU-Citizen.Science to identify high-quality citizen science resources, including guidelines, for the EU-Citizen.Science platform.

Initial Steps

Once the process of classifying citizen science resources began, the EU-Citizen. Science project partners realised that the definition of citizen science resources and how to categorise them was challenging. This challenge was further complicated by the fact that these resources include, but are not limited to, sensors, software, apps, guidelines, websites, podcasts, videos, figures, diagrams, publications, reports, et cetera. To address this challenge, a simple categorisation was chosen for resources, namely, (1) tools, (2) guidelines, (3) training resources, and (4) other materials. As part of this process, guidelines were defined as 'a set of rules and instructions that could be helpful in designing, implementing or evaluating citizen science initiatives or initiatives relevant to citizen science' (Fraisl et al. 2020, p. 22).

Based on the understanding that guidelines are created for use by a diverse community, two classification processes were established: (1) a *top-down approach* to establish criteria for building a repository of resources – including guidelines – relevant to citizen science and (2) a more democratic, *bottom-up approach* to allow users to collaborate in the process of guideline creation, selection, and inclusion.

A Top-Down Approach to Defining Criteria for Resources Relevant to Citizen Science

Based on a SWOT (strengths, weaknesses, opportunities, and threats) analysis, the project partners decided to (1) determine overarching criteria applicable to all categories of resource; (2) identify a set of *specific* and *supporting* criteria for determining 'good-quality' resources; and (3) implement a rating system that helps the community decide which resources are most useful and to provide feedback on them. This approach was agreed to be the best way to address the wide-ranging needs and expectations of the platform's diverse target audiences. Note that some guidelines may prove useful for one particular case or a target group but not in other contexts. Therefore, this process requires community ownership to facilitate and encourage user input in order to make it sustainable and dynamic.

Overarching Criteria for Citizen Science Resources

The EU-Citizen.Science project partners identified three overarching criteria that are applicable to all categories of resources, including guidelines. These are described below.

Criterion 1 (Required): The Resource Is About or Relevant to Citizen Science There are guidelines created specifically for citizen science, covering themes such as initiating and maintaining a project (e.g. GEWISS Consortium 2016); designing research (e.g. Mindell et al. 2017); engaging citizens (e.g. Wald et al. 2016); and evaluating the outcome of citizen science initiatives (e.g. Illinois Library 2019). There are also guidelines not created specifically for citizen science but which can still be useful, such as the *Guiding Principles for Public Engagement* (UCL n.d.).

This criterion requires consensus from the moderators of the EU-Citizen.Science platform and the global citizen science community regarding what constitutes citizen science. The *ECSA 10 Principles of Citizen Science* (ECSA 2015) have already been

Table 21.2 Proposed metadata for classifying citizen science guidelines and other resources

Basic information (required fields in bold)	Description
About	The subject matter of the content
Abstract	A short description that summarises the guideline
aggregateRating	The overall rating, based on a collection of reviews or ratings
Audience	An intended audience, i.e. a group for whom something was created
Author	The author of the content or rating
datePublished	Date of first publication
inLanguage	The language of the guideline
Keywords	Keywords or tags used to describe the guideline
License	A license document that applies to the content, typically indicated by URL
Publisher	The publisher of the guideline
Image	An image of the guideline
Name	The name or title of the guideline
Url	The URL of the guideline

well received and adopted. However, they remain generic and can be interpreted in different ways. Therefore, the EU-Citizen.Science consortium is currently identifying a set of characteristics for citizen science through an inclusive approach, including perspectives from the global citizen science community and other fields (Haklay et al. 2020), which will inform the guidelines classification process.

Criterion 2 (Required): The Resource Includes a Standard Set of Metadata Robust metadata will help to establish a standardised approach to classifying and searching for citizen science resources. The EU-Citizen.Science project partners, following the standards from Schema.org for DigitalDocument,[3] identified a set of metadata that can be applied to guidelines and other resources to increase accessibility and usefulness, listed in Table 21.2.

Criterion 3 (Suggested): The Resource Engages with the *ECSA 10 Principles of Citizen Science* By using adherence to these principles as an important criterion, any resource – including a guideline – is encouraged to align with the general ideas embodied therein. This criterion is suggested instead of required, because the ten principles may not be applicable to all resources; for example, water quality monitoring equipment might be useful for citizen science but does not necessarily need to engage with the ten principles. The complexity of a resource is also a factor, since a repository on citizen science can include numerous resources, which makes it difficult and time-consuming to check them all.

[3] https://schema.org/DigitalDocument

Specific and Supporting Criteria for Citizen Science Resources

After applying the overarching criteria, each resource then needs to be assessed against relevant specific and supporting criteria. There are nine *specific criteria* or questions that have been identified and agreed by the project partners.[4] The characteristics of each resource will be considered when deciding which of the nine criteria are relevant. These questions include: is a resource easy to access? is it clearly structured? and is it written using clear language, considering the intended users? The answers to these questions range from 'strongly agree' to 'strongly disagree' on a five-point scale. If the total rating exceeds the threshold, it will be listed on the platform.

Relevant *supporting criteria* include two evaluation and two impact-related criteria. The supporting criteria include questions to help moderators decide whether a resource should be listed on the platform, but the answers are not included in the rating system. Instead, the moderator is encouraged to use them to strengthen their argument on whether the resource should be included on the platform.

A Bottom-Up Approach to Classifying Guidelines

While the project partners agreed on the need to implement a framework that defines quality, they also agreed on the importance of avoiding the application of strict criteria. The purpose of this exercise is not to be exclusive, while at the same time applying certain standards. Different resources can be helpful in specific contexts, and thus the quality of a resource can be context dependent and subjective.

In light of this, there is also a need for the EU-Citizen.Science platform to allow the citizen science community to define the resources that are useful for them and add these to the platform, as well as to provide feedback on the resources already there. As part of this bottom-up approach to classifying guidelines, participants can therefore upload their own guidelines and other useful resources to the EU-Citizen.Science platform, using the same criteria identified by project partners. They can also rate the existing resources on the platform based on their own experiences and leave detailed comments on the challenges or opportunities of using a particular guideline or any other resource.

Next Steps

The project partners hope that these criteria are useful for other citizen science platforms in Europe and beyond and should be used as a starting point for future

[4]The full list of criteria is available in Fraisl et al. (2020), pp. 28–29.

classification processes. However, the EU-Citizen.Science project also recognises the limitations of such an approach. It is not easy to reach a consensus on a process that is inclusive and bottom-up but which also meets the needs and expectations of different target groups of the platform. The project partners are at the stage of implementing this process and agreeing on the curated resources on the platform. It is important to highlight that this process will continue to be improved over the project's lifetime and beyond, considering the dynamic nature of citizen science.

Challenges in the Use of Guidelines

Despite their many uses, guidelines for citizen science are not a 'silver bullet' that can fix every problem a project or practitioner may encounter. For example, even if you identify a guideline for your chosen field (e.g. freshwater monitoring), the advice and instructions may not be replicable in, or adaptable to, all contexts: they may be too costly or subject to limitations. Some recommendations in a guideline may not be implementable in certain locations due to cultural reasons. Further, while citizen science is a strong advocate for open access online, some guidelines may be inaccessible to some due to the costs of downloading or buying them. It is beyond the scope of this chapter to discuss all the challenges in using guidelines. Instead, we describe two of the common challenges, with suggestions for how to mitigate them.

The Need to Revise and Update Guidelines

Guidelines are usually static and all too often created in a top-down manner. This is, to an extent, inherent in their creation and purpose. They should be written from a position of experience and expertise and will often be based on the collated lessons from a number of projects, brought together in one 'final say' on a subject or practice – one that should contain a degree of sustainability and longevity.

Yet there are few guidelines that cannot be updated by feedback from new or other experts in the field or improved with feedback from those who have put their recommendations into practice. As the digital age progresses and channels for communication become ever more intertwined with our lives, can we imagine a form of *living guideline*, one that is constantly being tweaked and revised and adjusted?

On the one hand, such an iterative, cyclical process might lead to citizen science guidelines that are always up to date, representing the current thinking and recommendations on an issue or process. On the other hand, it could lead to a situation in which users are never sure how long term the recommendations in a guideline are, leading to a loss in their credibility and usefulness.

It seems unlikely that guidelines will move to a fully iterative format (i.e. a wiki); there will remain a need for an authoritative statement on many citizen science practices. However, we advocate for all citizen science guidelines to provide an option for users to provide feedback, both on the guideline itself and their experiences in putting its recommendations into practice. Further, in many cases, guidelines should come from, or be co-created with, nonacademic communities (in terms of their content, format, language, etc.), so that their perspectives and expertise are represented in the growth and development of citizen science as a practice. As with citizen science projects, cooperation between different stakeholders is necessary and will help to ensure that guidelines remain true to the core citizen science principles of *inclusivity* and *openness*.

Language

Many citizen science guidelines are in English. This represents a barrier to those who are not fluent in English or lack the resources to translate guidelines into their own language(s). Language can also be a limitation when searching online: the best guidelines may not come up in search results if they are not in the same language as the search. Platforms and repositories such as EU-Citizen.Science have an important role to play in minimising this barrier. By curating a collection of carefully selected guidelines, they point users towards a peer-reviewed selection, thus narrowing the scope of their search and suggesting possible resources that can, if required and feasible, be translated.

The style of language used – the complexity, terminology, and tone – is another factor influencing which is the most appropriate guideline for a particular individual or project. This can also be an issue for those creating guidelines: by trying to make their texts as accessible as possible, they may lose some of the accuracy, detail, or nuance of the information they are sharing. One way to counter this is to elaborate the guideline with specific audience(s) in mind and provide links within it to documentation that explores specific issues more comprehensively (these should be open access, to ensure everyone can read them). The examples we have presented in this chapter are some that we consider as striking the right balance between complexity and accessibility, although this will of course vary among users and projects.

Future Trends and Recommendations

According to the current trend, citizen science is likely to continue to grow, in terms of the number of projects and participants, as well as the range of topics it covers. As the field expands, so will the number of guidelines devoted to different aspects of it. These should play a central role in ensuring that citizen science strengthens as it develops, through the sharing of best practices and lessons learned, and in turn become increasingly valued as a source of data and expertise.

As the number and scope of citizen science guidelines also grows, it is increasingly important to ensure that they remain easy to use and easy to find. Without a widely used and interoperable system of classification, there is a risk of a crowded, overlapping field, a situation that will leave users confused and unable to find what they need. The criteria proposed in this chapter, building on research by the EU-Citizen.Science project, present one approach to classifying guidelines for citizen science. While acknowledging that this approach is as yet unproven, we urge practitioners in the field to apply it. We also propose the EU-Citizen.Science platform as a place to upload and showcase guidelines – although we note other platforms are also suitable places (and all guidelines can, of course, be linked to from more than one site).

In conclusion, and based on this initial research into citizen science guidelines, we provide a set of practical recommendations for practitioners to consider when creating future guidelines:

1. Review what is out there to avoid recreating existing guidelines.
2. Consider who your guidelines are for, and ensure they are targeted to the needs of those audiences.
3. Ensure that lessons learned and instructions are provided in a format that can, where possible, be adapted to different sectors and contexts.
4. Be honest about what worked well – and what did not work well.
5. Use appropriate metadata to ensure that they can be found by those who will benefit from them.
6. Be open to feedback and suggestions about how to improve or update your guidelines.

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Chapter 22
Citizen Science Platforms

Hai-Ying Liu, Daniel Dörler, Florian Heigl, and Sonja Grossberndt

Abstract Adequate infrastructure for citizen science is constantly growing and has become increasingly important in providing support to citizen science activities, both nationally and internationally. Many types of citizen science infrastructures exist, with different functionalities. This chapter focuses on current citizen science platforms. The platforms addressed in this chapter are those which display citizen science data and information, provide good practical examples and toolkits, collect relevant scientific outcomes, and are accessible to different stakeholders, ranging from interested citizens to scientific institutions to authorities, politicians, and public media. We present current citizen science platforms in Europe and associated (inter)national citizen science networks and discuss how these platforms have become increasingly vital within citizen science. Based on these examples, we elaborate on challenges for citizen science platforms, such as establishing and financing platforms, designing user interfaces, maintaining platforms, promoting the usage of platforms, etc. We conclude with an outlook into potential development needs of citizen science platforms in the future.

Keywords Infrastructure · Knowledge sharing · Public participation · Networks

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Citizen Science Platforms: Important Instruments to Support Citizen Science

With the boom in citizen science, there is a growing need for adequate infrastructures to support citizen science activities. A range of digital infrastructures (e.g. mobile apps, low-cost sensors, games, and gamification) have been developed to facilitate interaction and communication between citizens and scientist and to expand the scale and scope of project and protocol design, data collection, information delivery, data processing, and visualisation (Newman et al. 2012; Bowser et al. 2013; Eveleigh et al. 2014). Furthermore, a wide range of resources, guidelines, and handbooks have been published for data and metadata management (Wiggins et al. 2013; Schade and Tsinaraki 2016), the establishment of data and metadata standards (Cavalier et al. 2015), data quality assurance and control (EPA 2019), and ethical data practices (Lynn et al. 2019). It is obvious from the growing number of new technological developments that citizen science infrastructures are increasingly in demand. One important aspect of citizen science infrastructures is citizen science platforms.

The term *platform* is now in common usage and has begun to creep into many fields across the sciences, humanities, governance, and more (Ansell and Gash 2018). A platform may refer to a technology (e.g. computing platform, web platform); physical objects and features (e.g. diving platform, oil platform); politics (e.g. party platform, European politics platform); the arts (e.g. novel platform, art group platform); and a range of other areas (e.g. economic platform, business model platform) (Wikipedia Contributors 2020). What we might once have called a meeting, conference, partnership, or a network may now be branded as a platform – as in the case of the collective awareness platforms (CAPS)[1] for sustainability and social innovation (Bellini et al. 2016); the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Bongaarts 2019); and the Knowledge base for the Sustainable Development Goals (KnowSDGs) platform, from the European Commission (EC), among others. For the purpose of clarity, we use the term *citizen science platforms* in this chapter with the following definition. Citizen science platforms are web-based infrastructures with one single entrance point that contain one or several of the following functionalities: (1) present active citizen science projects and activities; (2) display citizen science data and information; (3) provide overall guidelines and tools that can be used to support citizen science projects and activities in general (e.g. recruitment strategies including motivational and marketing approaches, data quality assurance and control methods, guidelines for dealing with data security issues, resources, and opportunities to network with other relevant activities and upscale the project results); (4) present good practice examples and lessons learned; and (5) offer relevant scientific outcomes for people who are involved or interested in citizen science.

[1] https://ec.europa.eu/digital-single-market/en/caps-projects

Using this definition, the earliest citizen science platform can be tracked back to Zooniverse and a project called Galaxy Zoo in 2007. The project asked the public to help the research team, based in the Department of Astrophysics, Oxford University, to classify images of fully formed galaxies based on their shape. Since the day Galaxy Zoo started, Zooniverse has become the world's largest and most popular people-powered research platform and hosts more than a hundred citizen science projects. Since then, other platforms presenting multiple projects have appeared, such as SciStarter (US) in 2011, *Bürger schaffen Wissen* (Germany) in 2013, *Österreich forscht* (Austria) in 2014, *Schweiz forscht* (Switzerland) in 2014, the Australian citizen science association in 2014, and the Danish citizen science network in 2018. In the last few years, the number of national citizen science platforms increased significantly.

Today, there are many citizen science platforms being developed and made accessible for a range of stakeholders, including citizens, scientific institutions, public administrations, policymakers, and the media, with an overall aim to mainstream citizen science projects and activities at city, regional, national, and international levels. According to Sprinks et al. (2015), citizen science platforms allow nonscientists to take part in scientific research across a range of disciplines. What these platforms ask of volunteers varies considerably in terms of task type, level of user required, and user freedom (Sprinks et al. 2015). Lichten et al. (2018) addressed the fact that citizen science platforms host a range of projects to help with project building and hosting capabilities (e.g. CitizenGrid, Zooniverse). These platforms are a useful resource for members of the public who want to discover projects and choose projects to participate in or for researchers who want to create projects (Lichten et al. 2018). Many project-based citizen science platforms have been developed for a range of end users who have a variety of aims and goals (e.g. hackAIR, CAPTOR). According to Sturm et al. (2018), citizen science platforms can be developed as a technical framework designed for one or more applications to run and to store data and information. Citizen science platforms can also be designed with a functionality that enables the participants to interact with the project data (e.g. adding and/or verifying), such as mapping and sharing observations of air quality (e.g. hackAIR, Luftdaten.info), measuring biodiversity (e.g. iNaturalist), and in many fields across the sciences, humanities, and more (e.g. Zooniverse). In addition, citizen science platforms can function as a mutual learning space providing useful resources about citizen science, including tools and guidelines, good practices, and training modules, such as CitSci.org (Lynn et al. 2019), SciStarter, and the Austrian citizen science platform *Österreich forscht*. Another category of citizen science platforms is comprised of those platforms that are commercially available, such as SPOTTERON and CitizenLab, which combine both technology aspects and tools. Looking at the different categories, we can summarise that citizen science platforms seem to be important tools to share citizen science knowledge, facilitate mutual learning and multi-stakeholder collaboration, get inspiration, integrate existing citizen science activities, develop new citizen science initiatives and standards, and create social impact in science and society.

The present chapter focuses on citizen science platforms that provide services for existing and potential citizen science projects and activities with the ultimate goals of (1) providing multi-level intermediation between local citizen science projects and national or international resources and public administrations; (2) exchanging knowledge and know-how of creating synergies in order to use resources efficiently, such as the combination/integration of data and/or the presentation of citizen science projects to interested stakeholders, including the public; and (3) promoting multiple, ongoing stakeholder collaborations, facilitating the adaptation of many collaborative citizen science projects over time. In general, this chapter on citizen science platforms as a meeting point for citizen scientists has a lot of synergies with other chapters in this book, in particular, Lemmens et al. (this volume, Chaps. 9 and 23) about citizen science in the digital world of apps (e.g. an app can be a platform or a part of a platform); Garcia et al. (2020, this volume) about citizen science guidelines (citizen science guidelines need to be included in citizen science platforms); Tauginienė et al. (this volume, Chap. 20) about ethical considerations (ethical considerations have to be included in a citizen science platform to assist potential citizen scientists and others working with citizen science); and Balázs (this volume, Chap. 8) about data quality (a citizen science platform that displays citizen science data needs to do a quality analysis before the data are published).

Current Citizen Science Platforms in Europe

In this section, we give an overview of current citizen science platforms in Europe, with a few concrete examples that meet our definition of citizen science platforms.

Currently, there are many citizen science platforms in Europe. They can be categorised into five types, including (1) commercial platforms for citizen science initiatives; (2) citizen science platforms for specific projects; (3) citizen science platforms for specific scientific topics; (4) national citizen science platforms; and (5) EU citizen science platforms (see Table 22.1).

An important point is the fact that commercial platforms are offering their services (ultimately) for profit, whereas the other types of platforms are offering their services either for free or only covering their costs. Also, a commercial citizen science platform often brings together a willing buyer and seller to facilitate a bilateral market exchange, while other types of citizen science platforms have great potential to orchestrate a multilateral (as opposed to bilateral) collaborative relationship (as opposed to market exchange) (Ansell and Gash 2018).

Type 1: Commercial Platforms for Citizen Science Initiatives

Commercial platforms offer their services to customers for profit. Several commercial platforms for citizen science (e.g. SPOTTERON and CitizenLab) have started

Table 22.1 Types and examples of citizen science platforms in Europe

Type	Available resources	End users	Examples
Commercial platforms for citizen science initiatives	Data collection tools	Scientists	SPOTTERON
	Data infrastructure including handling and storage	Citizen scientists	CitizenLab
	Data protection and security	Individuals or institutions that want to start citizen science initiatives	
	Toolkits for communities and user motivation		
Citizen science platforms for specific projects	Information on the topic	Scientists	hackAIR (collective awareness about outdoor air pollution)
	Toolbox on how to collect data	Citizen scientists	Galaxy zoo (crowdsourced astronomy)
	Option to upload data	Individuals or institutions that want to start citizen science initiatives	CAPTOR (collective awareness about tropospheric ozone pollution)
	Data visualisation	Public media	Zooniverse (any type of scientific project that relies on collective intelligence)
	Links to similar initiatives	Policymakers and decision-makers	Foldit ('solve puzzles for science')
Citizen science platforms for specific scientific topics	Information on the topic	Scientists	*Artportalen* (species observation system, Sweden
	Instructions on how to collect data	Citizen scientists	SPOTTERON (air quality measuring system)
	Option to upload data	Public media	The 'big butterfly count' (butterfly counting system)
	Data visualisation	Policymakers and decision makers	
	Links to similar initiatives		
National citizen science platforms	Information on citizen science in national language	Scientists	*Iedereen wetenschapper* (Belgium)
	Access to a large number of national citizen science activities	Citizen scientists	*Scienza Collaboratva* (Italy)
	Tools and guidelines	Individuals and institutions that want to start citizen science initiatives	*Österreich forscht* (Austria)
	Collaboration opportunities on specific citizen science topics	Public media	*Bürger schaffen Wissen* (Germany)
	Additional information	Policymakers and decision-makers	*Citizen Science Portalen* (Denmark)

(continued)

Table 22.1 (continued)

Type	Available resources	End users	Examples
	Access to national citizen science network	National citizen science network	*Schweiz forscht* (Switzerland)
	Organisation of events		*Ciencia Ciudadana en España* (Spain)
EU citizen science platforms	Tool to be used to launch data collection activities (including citizen science contribution) to extend the evidence base for European policies	Scientists	JRC citizen science platform
	Resources about citizen science, including tools and guidelines, best practice, and training modules	Citizen scientists	EU.Citizen-science
		Public media	
		Policymakers, decision-makers	
		EU citizen science networks	

over the last couple of years. Most of them offer services in programming and designing websites and/or apps for citizen science projects, data handling, and storing infrastructure in combination with data protection, security services, and community services (e.g. gamification toolkits, online interaction). They mainly target citizen science project leaders (i.e. scientists, institutions, citizens that want to start their own projects, etc.). These project leaders benefit from the professional handling in programming and web design of commercial platforms to create easy to use, attractive, and reliable technical infrastructure for their projects. In Box 22.1 we provide an example of a commercial platform for citizen science initiatives, SPOT TERON.

Box 22.1: SPOTTERON

SPOTTERON is a well-known commercial citizen science platform in Europe. SPOTTERON has coevolved with the Austrian citizen science community since 2014 and offers several packages of website and app development and hosting, together with optional add-ons that focus on community services, interactive maps, and data quality. Over the years, SPOTTERON has developed a whole ecosystem of apps and functions, which is strengthened by its business plan. In this plan, add-on functions financed by one project are made available for free to all other projects that use SPOTTERON. Furthermore, S POTTERON offers the creation of image and event videos. Today SPOTTE RON hosts a wide range of projects that, in addition to Austria, now also come from Australia, Switzerland, and Sweden.

Type 2: Citizen Science Platforms for Specific Projects

Citizen science platforms have also become popular as a central tool in research and innovation projects. In this context, the platform serves as central element for citizen scientists to both contribute with and access data/observations. Many existing citizen science platforms have been developed as a task and/or overall outcome from a specific project. For example, some citizen science platforms (e.g. hackAIR, CAPTOR, SOCRATIC, POWER) have been developed under the EU H2020 ICT call for Collective Awareness Platforms for Sustainability and Social Innovation (EU 2015–2017). In Box 22.2, we provide an example of a citizen science platform for a specific project, hackAIR.

Box 22.2: hackAIR Citizen Science Platform

The hackAIR platform has been created by six European partner organizations as a key element of a EU-funded project of the same name on Collective Awareness Platforms for Sustainability and Social Innovation (2016–2018). Although it has officially ended, the hackAIR platform is still in use and has been adopted by the CAPSSI initiative. The hackAIR platform is a repository of air quality information from open data sources, displayed on a map. It is an open technology platform that participants can use to access, collect, and improve air quality information in Europe. At the moment, it displays air quality data from OpenAQ, Luftdaten.info, and low-cost air quality sensors (Liu et al. 2019). OpenAQ aggregates physical air quality data from public data sources provided by the government, researchers, and other sources. Their application programming interface (API) provides easy access to official air quality data, the same data that powers the European Environmental Agency (EEA) official Air Quality Index (AQI).[2] Luftdaten.info has designed a do-it-yourself (DIY) air quality sensor which is promoted to interested individuals. Their API automatically uploads data from all Luftdaten.info sensors to the hackAIR platform. It is possible for citizen scientists to contribute with their own air quality measurement data through the hackAIR restful application program interface (REST API).[3] A tutorial is available on the web pages for building measuring devices and uploading measuring results to the hackAIR platform.

During the project phase (2016–2018), it was also possible to take pictures of the sky with the hackAIR smartphone app (Kosmidis et al. 2018). Its technology enabled the estimation of air quality based on sky-depicting images. This data was also made available through the hackAIR platform.

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[2]https://www.eea.europa.eu/themes/air/air-quality-index/index

[3]https://api.hackair.eu/docs/

Box 22.2 (continued)
Another tool to estimate particles pollution levels was the hackAIR cardboard sensor. This was a low-cost sensor that was easy to build with a milk carton and petroleum jelly. A picture of the jelly, taken with a macro lens attached to the smartphone camera, was then analysed in the hackAIR app, and the results were also uploaded to the hackAIR platform. The last category of data that was uploaded to the hackAIR platform was data on personal perceptions of air quality. A function in the hackAIR app made it possible to submit information on how the user perceived air quality right wherever they were. This data was also visualised on the hackAIR platform.

Type 3: Citizen Science Platforms for Specific Scientific Topics

Citizen science platforms for specific scientific topics are those platforms that have been developed with a special focus (e.g. air pollution, water quality, biodiversity, etc.). These platforms are used as a repository for different data types that are used not only by interested individuals but also by scientists and authorities. Here, we give two examples, *Artportalen* (Box 22.3) and Luftdaten.info (Box 22.4).

Box 22.3: Artportalen
Artportalen is a Swedish species observation system. On *Artportalen*, the users can submit sightings for all plants, animals, and fungi in Sweden. The platform has been developed by the Swedish Species Information Centre at the Swedish University of Agricultural Sciences,[4] on behalf of the Swedish Environmental Protection Agency. Data from *Artportalen* are used by professionals and NGOs for conservation activities but also by the Environmental Court and Ministries (Personal communication). By 25 October 2019, more than four million observations had been reported since the beginning of the year.[5]

Box 22.4: Luftdaten.info
The platform Luftdaten.info is a good example of a local bottom-up initiative that has been grown into a platform on air quality data that is recognised

(continued)

[4]https://www.slu.se

[5]https://artportalen.se/ReportingStatisticitizenscience

Box 22.4 (continued)
worldwide. The OK lab Stuttgart[6] utilised their coding skills and capacities to develop DIY air quality sensors to measure particulate matter (PM) in outdoor air. The platform contains information on air quality, building and coding instructions for DIY air quality sensors, and instructions on how to connect the sensor to the Luftdaten.info platform. The platform displays data from all users on an online map with options to filter $PM_{2.5}$ and PM_{10} values, AQI, temperature, relative humidity, air pressure, and, recently, noise.

The platform publishes news related to air quality and noise and information about upcoming workshops where interested citizens can build their own sensors. The platform also offers support for all users. This platform had spread over the whole of Germany and is now well established, with 'sister' platforms in many other European countries, such as Belgium, Bulgaria, and Sweden.

Type 4: National Citizen Science Platforms

In several countries across Europe, national citizen science platforms have been developed by different stakeholders with the ambition to present the diversity of citizen science projects in the respective countries. In many cases, they are hosted by or offer access to national citizen science networks, which have the overarching goal to foster citizen science in their respective countries. A key property of all these platforms is that they use their respective national language to communicate projects or information on citizen science to interested users (e.g. citizen groups, the general public). The focus of these platforms lies in the presentation of many citizen science projects and activities for interested users. Additionally, they also offer general information on citizen science, tools, and guidelines, and, in many cases, they also organise events (e.g. networking events, conferences, workshops). Furthermore, some of them also offer the opportunity to collaborate in working groups on specific topics, such as legal or ethical aspects in citizen science. They target diverse stakeholders, such as interested citizens, project leaders, institutions, media, policymakers, and decision-makers.

Such platforms entered the stage early on in the German-speaking countries (Germany, Austria, and Switzerland) with *Bürger schaffen Wissen*, *Österreich forscht*, and *Schweiz forscht*. In the following years, Belgium, the Netherlands, Spain (*Ibercivis*), Denmark, and Sweden (ARCS) also established such platforms, while several other countries are still in the development stage (e.g. Portugal and Italy). In Box 22.5, we provide an example of a national citizen science platform, *Österreich forscht*.

[6]https://www.codefor.de/stuttgart

Box 22.5: Österreich forscht

Österreich forscht is the platform associated with the national Citizen Science Network Austria. The main focus of *Österreich forscht* is the presentation of a wide variety of current citizen science projects (*Projekte*) to an interested public. Additionally, in a project archive, individuals who want to start a new citizen science project can find information on and can get into contact with project leaders from successfully completed projects. Potential participants can find brief information about current projects from various disciplines and are guided to the respective projects' websites. As a complementary feature, the projects can also be filtered according to topic, location, and form of participation. Project leaders can find information on working groups (*Arbeitsgruppen*), they can collaborate on and open calls for proposals and funding opportunities (a subsection of *Allgemeines*), as well as access guidelines, tools, and publications (*Literatur*). Media representatives can find general and up-to-date information on citizen science. Policymakers and decision-makers and institutions, who are mainly interested in the network and its members, can also find information on the network's goals, etc. (*Netzwerk*). Furthermore, *Österreich forscht* also serves as the main portal for the annual Austrian Citizen Science Conference (*Konferenz*).

Type 5: EU Citizen Science Platforms

There are currently two citizen science platforms at EU level. One has been developed by the EC's Joint Research Centre (JRC) (see Box 22.6). The other one is still being developed by the project EU-Citizen.Science at the time of writing (see Box 22.7).

Box 22.6: JRC citizen science platform

The JRC Citizen Science Platform is a service for science and knowledge through research with the aim of providing independent scientific advice and support to EU policy[7] by connecting scientific knowledge where the JRC acts as an EU *science hub*. To support this function, the JRC started the process of creating a citizen science platform. The aim of this platform is to improve the relationship between citizens and European policymaking by offering new ways to contribute to the supporting scientific processes.[8] Currently, in its initial phase, the JRC Citizen Science Platform is investigating smartphone

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[7] https://ec.europa.eu/jrc/en

[8] https://digitalearthlab.jrc.ec.europa.eu/about-campaigns/57830

Box 22.6 (continued)
apps as a tool for engaging citizens in citizen science processes and, thus, gather evidence for European policymaking by targeting areas with clear policy relevance (e.g. invasive alien species in Europe). The JRC Citizen Science Platform is applying a value chain approach, including the following steps: (1) innovation in data gathering; (2) validation and quality control; (3) analysis and data management of the data gathered from new data sources; (4) integration of new knowledge in established decision-making processes; (5) communicating policy-related reactions to this knowledge; and (6) monitoring the impacts of these reactions (closing the loop).

The JRC Citizen Science Platform is currently focusing on invasive species, offering citizen scientists all over Europe to participate with their own smartphone apps. All contributions will be visible on a web-based map as soon as they are registered. The long-term aim of the JRC Citizen Science Platform is to expand the citizen science activities to other topics that are identified as supporting policy needs.

Box 22.7: EU-Citizen.Science
The citizen science platform of the project EU-Citizen.Science is still under development. The project is funded under the EU Horizon 2020 Framework Programme for Research and Innovation and runs from 2019–2021. The aim of this project is to build a central platform for citizen science in Europe to share useful resources about citizen science, including tools and guidelines, best practices, and training modules. The platform will make knowledge created by citizen scientists in Europe visible and accessible and encourages platform visitors to learn more about citizen science and eventually initiate their own citizen science activities. The long-term plan is to hand over the platform to the European Citizen Science Association (ECSA) for maintenance and continuation after the project ends. The project team consists of 14 partners and 9 third parties, including the ECSA. Currently (October 2020), the actual platform is online but still in the testing phase.

Connections Between Citizen Science Networks and Platforms

The Role of Citizen Science Networks

As mentioned above, today, many countries across Europe have national citizen science networks that host their associated national citizen science platforms. Often such networks can act as catalysts for citizen science in their respective countries, since they bundle up diverse and sometimes widespread initiatives and showcase the diversity of citizen science (Pettibone et al. 2017). Due to the networks' appeal to a broad target audience, the associated platforms often offer very elaborate information on citizen science, suitable for many different interests and backgrounds, forming national citizen science information hubs. The citizen science networks usually combine different scientific disciplines and aim to (1) promote the recognition of citizen science in science and society; (2) create social impact through transdisciplinary work, bringing together science and society; (3) establish new citizen science initiatives; (4) establish a platform for knowledge exchange and mutual learning; and (5) improve the quality of citizen science initiatives and enable research on citizen science (Pettibone et al. 2017; Richter et al. 2018; Dörler and Heigl 2019).

In order to meet these aims, citizen science network activities must be carried out continuously. A good way to do so is to set up working groups for different topics, as has been done in Austria with working groups on 'Quality criteria for citizen science projects', 'Open biodiversity databases in citizen science', 'Citizen science in schools', 'Legal aspects of citizen science', 'Open science trainings', etc. Keeping the participants of the citizen science network engaged in these working groups will increase the benefit not only for the network itself but also for each participant. Physical network meetings once or twice a year will also help to keep the work ongoing and foster data/information exchange.

As the citizen science networks grow, their tasks and responsibilities grow too, resulting in citizen science platforms that offer more services and new modes of interaction and cooperation. To pick up the example of *Österreich forscht*, when Citizen Science Network Austria decided to establish quality criteria for citizen science projects on *Österreich forscht* (Heigl et al. 2018a) collaboratively, it involved feedback from citizens, offering to post their feedback in a section called *Diskutier mit!* (Join the discussion!) on the platform.

Another main task of most citizen science networks is to organise events. For example, Citizen Science Network Austria has been organising the annual Austrian Citizen Science Conference since 2015, with about 200 registered participants each year. This conference is the central event to promote personal exchange within the citizen science community in Austria. In recent years, this exchange has also been recognised internationally. Therefore, representatives of the German and Swiss networks are now participating in the scientific committee of the conference to further deepen the knowledge exchange. In order to make the contents accessible to a broader international community, proceedings from these conferences were published in an open access format (Heigl et al. 2016; Dörler et al. 2017; Heigl et al. 2018b).

Furthermore, another goal of citizen science networks is to pause and reflect on the current state of citizen science and to outline a strategy for its future at national and international levels. In Germany, there is a growing importance of citizen science networks in science and policy. From a purely normative perspective, citizen science networks are driven by scientific questions and curiosity, contributing new knowledge, and aiming to provide benefits for contributors and added value for society. Citizen science and its networks offer new pathways of cooperation and mutual learning between lay and professional actors and between citizens, scientists, politicians, and the private sector, and it opens new ways for doing research (Vohland et al. 2019).

Impacts of Citizen Science Platforms

Since most citizen science platforms are still in their infancy and at an early developmental stage, there is little information on the impact of such platforms available. As mentioned before, platforms can act as catalysts for citizen science in a country by bundling diverse and widespread initiatives and therefore inspiring others to start their own projects. However, to the best of our knowledge, a systematic evaluation of the impact of such platforms has not yet been undertaken.

In the case of *Österreich forscht*, we have some information on aspects that can describe the impact of such platforms. In 2017, the coordinators of *Österreich forscht* asked all the project leaders who had listed projects on the platform how many participants they had. The result was that more than 100,000 citizen scientists were participating across all the projects in 2017, a huge number for a small country with only eight million inhabitants. Furthermore, cross-project collaboration has been facilitated several times by organising networking events and conferences within Citizen Science Network Austria.

Challenges and Successes

User Interface and Experience Design of Platforms

The main challenge for citizen science platforms lies in their usability and design (Giuliana 2017; Leeuwis et al. 2018; Skarlatidou et al. 2019; Pejovic and Skarlatidou 2020). They need to work smoothly and look modern. In a world where a plethora of platforms, apps, and websites are courting users' attention, competition is fierce, and without proper design or functionality, platforms will not be used. The *design rules*, especially for designing *interfaces* for the institutional framework in which many stakeholders' interactions are orchestrated, are key to ensuring a degree of integration or at least effective adjudication (Hagiu and Wright 2015; Ansell and Gash 2018). Furthermore, studies showed that participants find the more guided, less autonomous user interfaces frustrating, while the less complex, repetitive user interfaces result in greater data coverage (Sprinks et al. 2015).

According to Ansell and Gash (2018), a key design issue is the relative openness of the platform. With respect to collaborative platforms, greater control over access and participation can reduce transaction costs and facilitate negotiation and coordination, but it can also undermine legitimacy, discourage fresh ideas, and limit possibilities for synergy (Ansell and Gash 2018). Boudreau (2010) discovered that devolving a degree of control over the platform can produce positive innovation effects and create a community and by doing so lowering transaction costs, increase reach, and enable some level of control by users (Janssen and Estevez 2013).

The engagement of volunteers on citizen science platforms can be considerably influenced by an intuitive and motivating user interface (Giuliana 2017). An investigation has shown that it is very difficult to create a general design approach, ideally applicable to any citizen science platform, since every citizen science project has individual resources, requirements, and objectives (Giuliana 2017). It is important to convey a concept which can be adapted to individual cases, such as collaborative citizen science platforms and human-centred conception of platforms (Giuliana 2017; Ansell and Gash 2018). In addition, it is important to be aware of the continuous process of adjustments while implementing a complex online platform. The technical components should always be state of the art (Giuliana 2017). It is essential that citizen science platforms leverage the complementary strengths of humans and machines to take full advantage of the onslaught of data being experienced across the disciplines (Trouille et al. 2019). Furthermore, it is essential to observe how the platform is adopted by its users and whether some functionalities are not used or if others require revision.

Establishing and Financing Platforms

There are several decisions that need to be made when establishing a platform. Defined decision-making processes need to be established that help determine the focus and the target audience of a platform. Technical requirements need to be identified and addressed in the development phase, often by hiring a commercial supplier of citizen science platforms. Responsibilities in setting up and running a platform need to be negotiated or delegated. All these decisions can be made either bottom-up (e.g. a network of members on equal footing decides in a democratic process) or top-down (e.g. an institution or funder decides what will be the focus of the platform).

When choosing a bottom-up approach, all members are invited to be involved in the decision-making process and can develop a sense of ownership for a platform, ensuring the use of the platform by its members. However, the process of reaching a decision can be difficult and tedious, and such a platform can lose its flexibility when numerous stakeholders are involved. Furthermore, the financing of such a bottom-up platform can also be challenging when no decision on a hosting institution can be reached.

A top-down approach enables a fast decision-making process and very often also good funding opportunities. However, creating ownership in such a platform is more challenging when there is no collaborative approach applied.

Based on communication with (national) citizen science platform operators, the most prominent challenge is the acquisition of financial support, not only to establish a citizen science platform, but even more, to maintain the platform and its services in the long run. The *Österreich forscht* platform receives permanent funding from the University of Natural Resources and Life Sciences in Vienna. This, however, seems to be the exception. In most cases of national citizen science platforms, it is a challenge to obtain permanent funding. It could be advantageous to establish and keep close contact with public authorities and try to promote the national citizen science platform as a fundamental prerequisite for national citizen science projects and activities.

Challenges to finding funding sources are also relevant to project-related citizen science platforms where the funding usually ends after finalising the project. Thus, a business plan for exploiting the platform beyond the project's afterlife must be designed. For commercial citizen science platforms, funding is a question of commercialising and promoting the products as efficiently as possible.

To conquer the challenges of establishing and financing a citizen science platform, building on an organisation theory approach, the concept of collaborative platforms (Ansell and Gash 2018), defined as organisations or programmes with dedicated competences and resources for facilitating the creation, adaptation, and success of multiple or ongoing collaborative projects or networks, could be a solution.

Communication and Up-Scaling of Platforms

To effectively draw attention to citizen science platforms requires a detailed examination of the project's target groups and tailor-made communication channels; platforms must act in a strategic manner (Ansell and Gash 2018). One key strategy for approaching target groups is to build on pre-existing efforts and motivations, for example, the importance of 'starting where the people are' – that is identifying issues that are of immediate concern to different target groups (Cheadle et al. 2005; Ansell and Gash 2018). A closely related strategy to communicating and up-scaling of citizen science platforms is customising different activities for different stakeholders. Ton and Vellema argued that 'platform facilitators need to maximize the possibilities for spin-off activities with sub-sets of members in the early stages of platform development, even when these may not be the most important activities in the long term for the group as a whole' (2010, p. 2). Borys et al. observed the strategic importance of the 'ability to generate social multiplier effects, such as through the involvement of stakeholders in "different forms of dialogue and partnerships" and "effective channels of communication"' (2012, p. 17).

Based upon the experience of *Österreich forscht* and other citizen science platforms in Europe, external communication from citizen science platforms is usually aimed at four different target groups: (1) people who want to participate in a project without necessarily having a scientific background; (2) people who are conducting a citizen science project or planning one (e.g. scientists); (3) science journalists; and (4) policymakers and authorities. These four target groups differ significantly in the *communication channel* that should be chosen to reach them.

Target Group 1 People outside the scientific community are usually the most difficult to reach for citizen science platforms because the so-called general public is very diverse. Therefore, a mix of communication channels has proven its worth here. A large part of the population aged 40 years and above is still reached preferably via *traditional media* such as newspapers, magazines, television, and radio. People younger than 25 can mainly be reached via *social media*. People between 25 and 40 can be reached by various channels. In general, the citizen science platform's *website* is the central hub for citizen science projects and activities and should be designed using plain and understandable language to present projects and citizen science activities.

Target Group 2 To reach this group of people, *personal communication* has proved particularly effective. At conferences and networking events, people belonging to this target group can learn about the different methods and ask questions directly. Personal contact was particularly important for *Österreich forscht*, as a certain amount of trust had to be built up with project leaders so they would join a fledgling platform. Project leaders can also be reached very easily via *Twitter*. Here, however, attention must be paid to the chosen language. If the communication is mainly in the respective national language, the platform will be perceived as less international. On the other hand, the respective national language can provide for a national community with information more effectively than by using English.

Target Group 3 For science journalists, the first entry point is usually the website. If the information here is well prepared, it is already a good basis for further communication. Journalists are always on the lookout for a new story. Therefore, the website should include specific contact details where platform coordinators can be reached for interviews. The platform coordinators should therefore have a good overview of current developments in the projects listed on the platform in order to be able to provide information quickly and competently and to connect to the right people.

Target Group 4 For policymakers, public administrations, and other authorities, it is important to obtain up-to-date information with clear policy relevance. Information from citizen science platforms can either contribute to establishing contact between a specific project/citizen scientists(s) and the target group or to obtain information on ongoing activities with sociopolitical relevance for the respective area. Citizen scientists can use the information about the citizen science platform to approach policymakers and authorities, emphasising the relevance of both citizen engagement and citizen science for their community.

Moreover, social media in general have a high potential for spreading project ideas and receiving attention by a wide audience (Giuliana 2017). Media can be approached actively, by promoting specific citizen science initiatives in different contexts, for example, if there has been much attention on water quality of a special lake, one could actively promote citizen science and citizen science projects where citizen scientists examine water quality and report back through an app. Robson (2012) investigates how *social networks* can be used for recruitment and promotion of a citizen science projects. Her results are based on a series of campaigns promoting the citizen science platform Creek Watch, including a participation campaign through local organisations, and a social networking campaign through a *Facebook* page and Twitter account. She concludes that social media campaigns represent a worthwhile method to increase the awareness of a project and reach participation goals.

Maintenance of Platforms

The maintenance of the citizen science platform can be a challenge even if funding is secured. Based on communication with national citizen science platforms operators, it seems to be challenging to keep the platform updated and to engage people to contribute to projects and other content on the platforms. The amount of citizen science projects is continuously increasing, and it requires quite some work to get an overview over ongoing activities and expand platform content. Here, it helps to have a national citizen science network where members can contribute with citizen science projects and content/news to the platform. However, it is also a challenge to motivate the network members to contribute. Transparency, two-way communication, and a *do-ocracy* approach[9] proved to be key elements in *Österreich forscht* involving members in the maintenance and regular update of citizen science platform. The literature on platforms indicates that the more developers and users contribute to a platform, the more others will also want to affiliate and contribute (Weber 2012; Ansell and Gash 2018).

Quality is another challenging issue. Ideally, platforms promote value-creating collaborations, which then feedback to motivate wider participation (Nederlof et al. 2011; Ansell and Gash 2018). To make a citizen science platform as useful as possible, both the citizen science projects and activities it displays, but also the additional materials available on the platform – such as information about citizen science, information about how to start a citizen science project, as well as information on ethical or juridical issues (Lynn et al. 2019) – need a certain level of quality (Heigl et al. 2018a, b). In addition, communication about the citizen science platform must also be of good quality to ensure consistent information uptake. Professional support could be the solution for these issues. Platforms strive to provide a stable and structured framework in which more dynamic and adaptable processes can evolve (Ansell and Gash 2018).

[9]https://communitywiki.org/wiki/DoOcracy

Conclusions

The rapid developments within citizen science in the last decade have resulted in the need for infrastructures to support citizen science activities. Progress in technologies means that most citizen science activities require Internet access and probably the use of smartphone apps for data collection and upload, information access, data processing and visualisation, and the communication of ideas and results. This requires stable and effective infrastructures with easy access – offered by citizen science platforms. Citizen science platforms can catalyse and foster stakeholders' collaborations and facilitate citizen engagement.

In this chapter, we have described different types of citizen science platforms, their characteristics, and challenges. Citizen science platforms seem to be a useful concept especially for national citizen science networks to display citizen science activities and useful information in their local language. Citizen science platforms have the potential to make science more visible and accessible to interested citizens but can go beyond pure provision of information. National citizen science platforms can be used to provide local, regional, and national authorities with necessary data and information on key (emerging) topics on national (and international) agendas. Citizen science platforms are also suitable for scientists to collect more data on citizen science and to conduct research on citizen science and for interested citizens to develop, lead, contribute, or participate in citizen science projects. Citizen science platforms tend to operate in a context of distributed citizen science activities, which means they can serve as an umbrella for many diverse citizen science activities and stakeholders and produce positive feedback effects by bringing together stakeholders with synergistic knowledge, skills, resources, and perspectives. Citizen science platforms also promote integration by creating interfaces that integrate diverse citizen science activities into an interacting system. Further, as a *meeting point* and *exchange hub* of citizen scientists, citizen science platforms have great potential to facilitate the maintaining, further implementation, and development of citizen science methodologies in similar citizen science initiatives.

It is not possible to predict how long the concept of citizen science platforms will succeed, but those involved must (1) ensure the technical components are always state of the art, (2) associate platforms with information and communication technology, and (3) keep a certain openness and flexibility in place to adjust quickly to the needs of citizen science and technology. Future development needs of the citizen science platforms should be focusing on (1) more collaborative types of platforms which facilitate multiple, ongoing stakeholder collaboration; (2) a more human-centred conception of platforms, providing useful data and information to reach a wider audience of end users; and (3) striving to provide a stable and structured framework and methodologies and act in a strategic manner, in which more dynamic and adaptable processes can evolve.

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Chapter 23
Citizen Science in the Digital World of Apps

Rob Lemmens, Vyron Antoniou, Philipp Hummer, and Chryssy Potsiou

Abstract In this chapter, we highlight the added value of mobile and web apps to the field of citizen science. We provide an overview of app types and their functionalities to facilitate appropriate app selection for citizen science projects. We identify different app types according to methodology, data specifics, and data collection format.

The chapter outlines good practices for creating apps. Citizen science apps need to ensure high levels of performance and usability. Social features for citizen science projects with a focus on mobile apps are helpful for user motivation and immersion and, also, can improve data quality via community feedback. The design, look and feel, and project identity are essential features of citizen science apps.

We provide recommendations aimed at establishing good practice in citizen science app development. We also highlight future developments in technology and, in particular, how artificial intelligence (AI) and machine learning (ML) can impact citizen science projects.

Keywords Mobile apps · Software development · Data collection

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Introduction

The widespread use of smartphones has created new opportunities in the field of *citizen science* (Silvertown 2009; Newman et al. 2012; Bonney et al. 2014; Wynn 2017). Mobile apps provide a new way to steer the data gathering process as part of the scientific method. Communication with and among participants is now possible at any time, as many people carry their smartphones with them almost constantly. In addition, smartphone sensors offer new possibilities for comprehensive and comparable data collection (Teacher et al. 2013).

The term *app* refers to a wide range of software, running on mobile devices, in browsers, on desktops, and even on smartwatches. In citizen science, applications are most commonly referred to as apps, either for smartphones (*mobile apps*) or for websites, accessed via desktops or laptops (*web apps*). These apps can form part of the support infrastructure in citizen science, so-called citizen science platforms (see Hai-Ying Liu et al., this volume, Chap. 22), which provides tools and facilitates communication and interaction between participants.

Apps dramatically extend the feature set of a classic website and increase interactivity and participation options. The smartphone has brought about a revolution in citizen science. With mobile devices, citizens now have constant access to what are effectively microcomputers equipped with sensors; these are connected to the web and are always ready for use. Mobile apps have enabled direct participation. They can also help to overcome the obstacles of location and time in certain citizen science tasks (Sturm et al. 2017). As smartphones and their *user interfaces* have become mainstream technology, people are able to interact more intuitively with their installed apps.

The Use of Apps in Citizen Science

Why Apps?

The revolutionary uptake of the smartphone has changed our daily lives in many respects. Mobile technology facilitates participation in interactive platforms and projects. For citizen science, the deployment of mobile apps means that participants can contribute observations in real time. To report relevant sightings immediately not only increases the quality of the provided data (in terms of timeliness) but also improves the connection of the observer with the subject and its environment, as the observer is immersed in the field and is aware of the context of their observations.

Furthermore, mobile apps are important digital tools that integrate data coming from sources in real time. They can enrich information provision, not only for the younger generations but also for the majority of the public. Especially for digital natives (the generation who grew up with digital technology), a mobile app offers the means of participation via using the interactive features of their smartphones.

More than Data Collection

According to the ECSA (2015), citizen science involves more than just *data collection*. While the data set is one of the main outcomes when running a citizen science (software) *toolkit*, this is often not the core focus. Citizen science is based on participatory principles, which not only position the public in a data collection role but also encourage volunteers to join in the quest of solving scientific challenges (Haklay 2013). Taking part in the scientific process stimulates open data access and reproducible and collaborative research, raises public awareness, and generally empowers citizens (Trojan et al. 2019). The level of participation in the scientific process depends on the citizen science approach utilised (e.g. raw data collection versus interpreting observations). In digital approaches, such as app toolkits, this diversifies the roles available for volunteers. Achieving this necessitates providing a wide range of interactive features within an app, for example, facilitating data entry via menus, free text, sensor interfaces, etc. The decision to use a mobile or desk-based data collection method depends on (1) if there is a need to capture field observations; (2) whether the application needs to be frequently accessible to the participant; and (3) how much data analysis is involved. In the first two cases, a mobile app is preferable; and in the last case, a web app is preferable.

As interactive digital apps with *user-generated content* (UGC), citizen science apps have strong links to social media approaches. Migrating social media elements to citizen science apps can significantly increase their effectiveness. For example, citizen science apps can mimic social media by allowing volunteers to create groups and subgroups depending on their interests. This can help to promote the aims of citizen science projects, such as allowing direct communication among users in order to clarify uncertainty about project processes, micro-management of niche processes, and sharing achievements with broader audiences to raise awareness (Ambrose-Oji et al. 2014; Luna et al. 2018).

Citizen science apps can also include external data, either from other digital sources or from attached sensors. With this approach, apps are used as visualisation interfaces for monitoring or viewing data, rather than for active data collection.

Like all apps, citizen science apps are subject to user expectations (Pejovic and Skarlatidou 2020) and should therefore incorporate the following core requirements:

- *Usability*: the ease of use for the participants
- *Look and feel*: the visual quality of an app
- *Performance*: the speed with which an app opens and operates
- *Security*: the level of technical security and encryption of sensitive data
- *Compatibility*: the range of operating systems and devices supported
- *User privacy*: compliance with the EU *General Data Protection Regulation* (GDPR)

Gamification can also be a valid approach for certain citizen science projects. Participant motivation can be fostered by applying game-like elements and inviting competition between users (Bowser et al. 2013). Examples are *bio-puzzles* like

Foldit, EyeWire, Stall Catchers, and others available on the Citizen Science Games platform.

Project Examples

Mobile apps are developed for many purposes. Some of the most common functionalities of mobile app-based platforms include:

- *Surveys*: often website based, surveys ask users a range of hierarchical questions about a specific topic.
- *Spotting*: map-based contributions of topic-related observations, most commonly logged by participants on smartphones.
- *Sensing*: sensor observations obtained with sensors internal or external to the mobile phone.
- *Image and video classification*: classification activities in an array of images or videos.
- *Gaming*: citizen science games for data generation, often with a competitive aspect.

In Table 23.1 we highlight some prominent examples of projects in which mobile apps play diverse roles.

Table 23.1 Examples of mobile apps in citizen science projects

App	Functionality
Mobile app: SpiderSpotter In the SpiderSpotter citizen science app, powered by SPOTTERON, users contribute observations of spiders and their webs to help research their adaptation to the environment. The app was launched with a highly successful campaign involving newspapers and radio stations in Belgium with thousands of app downloads in the first few days followed by many contributions from the public. The complete citizen science application consists of mobile apps, a web app for browsers, a data administration interface, and a special toolkit for data analysis and visualisation. This special toolkit allows users to record size and colour measurements of data collected by citizen scientists and to interactively visualise the analysed data on maps	Spotting
Citizen science game: Stall Catchers Stall Catchers is an online game that anyone can play without any prior experience. In the game, participants look at movies from the brains of mice and try to identify clogged blood vessels or stalls. The aim is to help facilitate Alzheimer's disease research at Cornell University	Gaming
Sensors: senseBox senseBox allows users and institutions to contribute their projects' sensor data. The data are used to help answer scientific questions and support citizen science projects from the local to the global. Data collected by senseBox can increase the measurement capacity of various environmental factors and can facilitate improved statistics in areas such as traffic, pollution, and climate	Sensing

App Architecture

There are many types of apps suited to different purposes, devices, and scientific fields. Most commonly, the term app is used for a mobile app, which can be installed on smartphones via the Apple (IOS) and Google (Android) app stores. However, in a broader sense, every type of software that can be installed on and run via a web browser is also an app. From a technical perspective, mobile apps and web apps are the most common in citizen science.

There are a wide range of mobile and web apps available – from mobile apps for monitoring and sharing observations on smartphones to image and video classification platforms to complex, interactive gaming apps.

There are also differences in how apps operate. Apps can be *stand-alone software*, managed by individual projects; or they can be based on an *app platform* that provides specific functionalities (not to be confused with citizen science platforms, the support infrastructure for citizen science projects; see Hai-Ying Liu et al., this volume, Chap. 22). Examples of app platforms include Zooniverse for image and video classification and the SPOTTERON platform which hosts map-based mobile apps. Furthermore, there are app platforms which operate just one app; these are often used for data collection – a practice generally employed in general species monitoring, one example being iNaturalist.

Common Structure of a Citizen Science App Software Toolkit

A common organisation scheme in interactive software is based on distinguishing between a *front end* (which users can see and interact with) and a *back end* (which only administrator accounts can access); see Fig. 23.1. This structure is also often used in citizen science toolkits and platforms. Generally speaking, the platform contains the core functionalities, but additional features can also be integrated. The system provides all the user functionality; users interact with it via a front end user interface. This front end can be accessed via a web browser (web app) or an app on a smartphone (mobile app).

Data contributions are stored in the platform's database. A database usually contains entries labelled by their ID, date, and category. An *application programming interface* (API) provides data access via defined parameters so data can be exchanged internally between the application server and the front end or externally with other servers. The API is also used to integrate external data in a citizen science toolkit, for example, sensors, which are prompted on a regular basis by the system.

Especially for more sensitive data, such as users' account information and personal data, safeguard mechanisms must be employed. Furthermore, all sensitive data traffic should be encrypted to protect the data from being accessed and misused.

While, for some citizen science apps, a constant Internet connection is required, others, such as field monitoring apps, also need to work offline. In that case, all

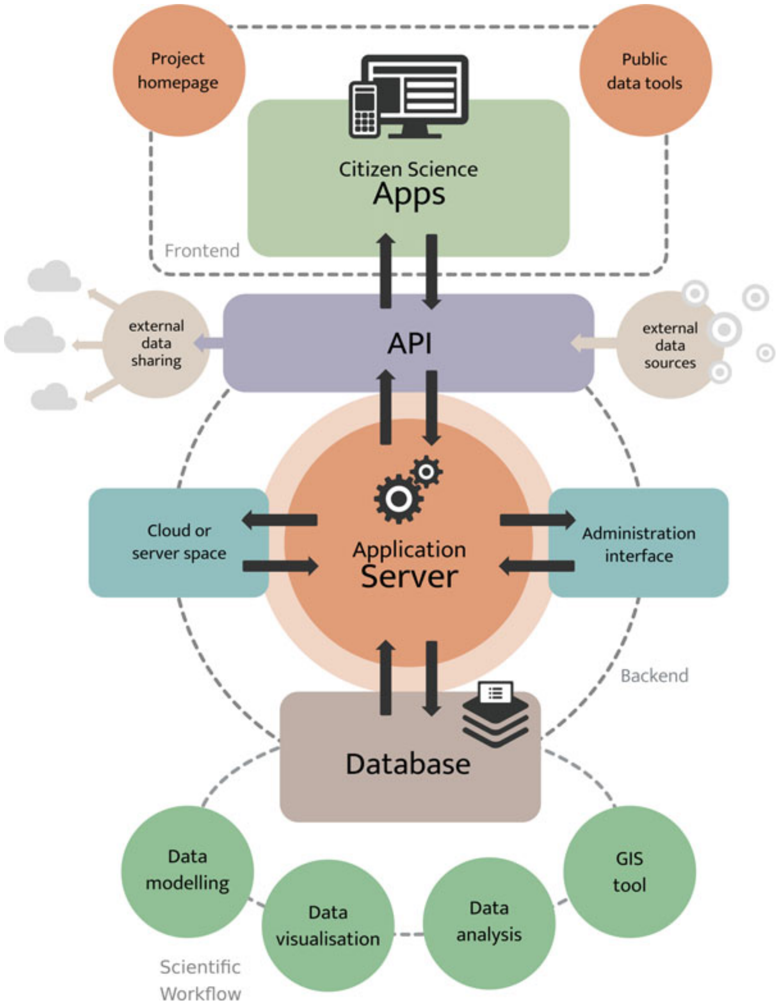

Fig. 23.1 An app/server system with a common online infrastructure

critical content and functionalities must be included in the app itself, and data contributions must be saved locally to be uploaded later. If an app is map based, an offline map download feature can sometimes also be required.

Due to the many different approaches, systems, and coding languages available to develop and run software, solutions can vary. This is underlined by the extensive inventory provided by Rieger and Majchrzak (2019) in which they compare mobile app tools, such as Cordova and PhoneGap, and languages such as AngularJS and HTML5/JS. Their comparison was based on the following criteria: infrastructure, development, hardware and software functionality, and usage. Despite the fact that it is hard to choose the best combination of tools for a specific application, the authors introduce *weight profiles*, which can be seen as common patterns of development and allow for a quick assessment of needs.

How to Create and Maintain Citizen Science Apps

The development of apps and digital tools can be a complex task. There are many aspects to consider, from technical development to design, from the server infrastructure to ongoing updates. The online technology environment changes rapidly, especially in the mobile sector. Rieger and Majchrzak (2019) refer to a 2-year period (2017–2019) in which mobile app development has shifted from a focus on smartphones and tablets to a wide range of devices, such as car-based technology and the *Internet of Things* (IoT). Personal data protection and security aspects must also be considered when planning to run citizen science apps.

Look and Feel Since citizen science is interactive by definition, the visual quality (look and feel) and the *project identity* (strong branding: a telling name with a quality logo, the wording, and the colours used) are essential elements when planning apps, websites, and dissemination activities (see Rüfenacht et al., this volume, Chap. 24). Since, in most citizen science projects, the aim is to include the public, having a strong project identity helps to communicate project objectives. While a high-quality look and feel can help to spark participant curiosity, app usability is also enhanced by definite forms of visual communication.

Re-use The best method of app development depends on the needs, goals, and target group/s of a project. If the required features are unique or highly specialised, the project will need to develop stand-alone apps. However, if the features required are relatively common in the field of citizen science, it is best not to reinvent the wheel. App platforms offer out-of-the-box functionalities and also provide app maintenance.

Co-creation Sometimes utilised by *hackathons*, co-creation can be used for prototyping, creating proof-of-concept versions of apps, and experimental approaches to developing specialised app functionalities. Hackathons are events where participants create software which can then be used more widely. Due to the limited time available when using a hackathon approach, it is vital to have a clear focus on functionality and also to plan for ongoing app updates. In the COST Action CA15212 *Citizen Science to Promote Creativity, Scientific Literacy, and Innovation throughout Europe*, ways have been explored to foster innovation in app development and learn from good practice. Therefore, it initiated a hackathon focused on citizen science app development (see Box 23.1). The main realisation that emerged from the preparation and execution of the hackathon is that while there are many apps relevant to citizen science, they are usually dedicated to a single purpose. Simultaneously, many apps have similar functionality, and there is a need for interoperability to let new developers build their apps by sharing software modules and data formats, so less time is spent reinventing the wheel.

Box 23.1: House of Apps: A COST Action Hackathon
During June–August 2018, the COST Action CA15212 organised a hackathon aimed at the creation, findability, and re-use of mobile apps for citizen scientists (Lemmens and Antoniou 2019). App developers were asked to create small software components that focused either on *interfacing mobile sensors* or *importing geodata* (e.g. satellite images, in situ sensor data). Prior to the actual software development, project partners were asked to formulate suggested challenges (see Table 23.2 for examples).

The hackathon was concluded with a COST workshop at the OGRS symposium in Lugano,[1] at which the winning app and the research undertaken were presented. This research led to the re-use of the app's components in the GEO-C Open City Toolkit (see also Pajarito and Gould 2018).

User Interface Design The design of a citizen science app is crucial for participation, motivation, and, also, data quality. Design connects function and form and defines how the various elements work together and how they are perceived when being used. Modern apps should have a clear and structured layout and well-interchained functionalities that are presented in the user interface only when necessary. In general, the more on point an interface is, the more effective it becomes for frequent use. Apps can still have complex functionalities, but their interfaces must be user-friendly. This principle is also essential for the *input dialog* used to add data to a citizen science project. The input dialog is established by app menus and user input (text, pictures, voice, etc.) and determines what a participant can and cannot contribute via the app. A hierarchical structure with visual representations for options and manageable selection lists facilitates straightforward participation and reduces data input errors.

Participant Motivation It is important to understand the target users and their needs and desires. These have a significant influence on participant motivation. For example, depending on the participants and task community, app features can help maintain long-term motivation. In order to achieve this, usability must also be maintained. Thus, apps need a plan to ensure constant maintenance and updates. This includes security updates and constant privacy protection. Equally important is the scientific perspective. Data and API standards can provide valuable guidelines on how data should be stored and made accessible.

Supporting Infrastructure The technical infrastructure needed to run citizen science apps must also be considered. Due to their interactivity, data security and performance of the servers are both essential infrastructure components. The protection of users' personal data is also affected: everything, from data hosting to map servers, should run on professionally hosted infrastructure (see also Hai-Ying Liu

[1]http://2018.ogrs-community.org/

Table 23.2 A selection of mobile app challenges for the COST hackathon. The app functionality needs set out the requirements for developing the app

Theme – Title	Objective	App functionality needs
The networking citizen – 'How unusual is it?'	An app that explores whether an observation is common or unusual (out of the normal range of measurement). Provides immediate feedback based on frequency of occurrence in social networks; this should reinforce participation	Intensity of the phenomenon (e.g. fish size, number of fish, rainfall measurements) Time stamp (date) Location Location attributes (e.g. land use)
Health – 'Promoting sustainable traffic'	An app that collects data about pedestrian and cyclist usage of roads, pavements, and trails, with an emphasis on understanding which elements disturb the flow of traffic. The aim of this app is to provide data for planners to help design and manage a sustainable transportation network for pedestrians and cyclists	Route used (GPS location, elevation) and time Number of stops Number of accidents for bikes and pedestrians (if known) Subjective feeling of security and route efficiency Active reporting of obstacles and hazards Measuring of light conditions Parking places Time of year and weather Uploading photos of obstacles, places, and vistas Measuring noise levels
Land use – Land use camera function	A software library that will handle smartphone cameras for land use and land cover apps	GPS awareness Show the line of the horizon accurately Zoom level awareness Calculate sky percentage Flash awareness Provide information and tips to the user before photo capturing Panorama mode Resolution awareness

https://cs-eu.net/news/house-apps-create-great-apps-citizens

et al., this volume, Chap. 22). If free services offered by commercial corporations are put to use in citizen science projects, significant conflict can arise. Free services such as online forms, maps, and even analytics tools are not paid for with money, but with users' personal data that is used for profiling and targeted advertising.

Testing After the app design and development processes, it is important to plan for extensive *testing* and *bug fixing* that can be in place when an app launches. Regular app updates are also essential. Mobile software development deals with a fast-changing environment, and software, like apps, must be able to adapt to that environment on an ongoing basis. Planning for ongoing maintenance is especially important when creating stand-alone apps. On citizen science app platforms, the system is usually already established and been proven to work successfully in other public citizen science apps.

Maintenance The life cycles of online software and, especially, mobile apps, are short, usually measured in weeks rather than months. To prevent citizen science apps from becoming outdated and unusable or losing functionality, ongoing development and regular updates are required. App updates can deliver bug fixes and improvements; they are essential for ongoing security, stability, and compatibility over a project's runtime. For stand-alone apps, the runtime costs can easily exceed the development costs; on citizen science app platforms, app updates are usually provided automatically.

Future of Apps in Citizen Science

In parallel with the use of current technologies, citizen science project stakeholders should maintain a forward-looking mindset regarding technological advances. With technology it is not uncommon to experience changes and disruptions in existing processes, which can considerably alter the way they are dealt with (such as how data is gathered or analysed). This, in combination with the fact that hardware is progressively improving and becoming more affordable, alongside advances in open-source software, points to a promising future for the use of new technologies in citizen science.

In this context, citizen science projects can aim to achieve two important goals. First, they should take advantage of existing technologies that are used in other domains. Migrating effective technologies and applications from other domains can enable citizen science projects to be more productive and simplify participant activities. For example, adoption of existing technologies can improve several aspects of citizen science projects, such as the ability to increase data collection through newly available sensors (Plageras et al. 2018); enhance user engagement and participation through gamification (Antoniou and Schlieder 2014); improve and manage data quality through *machine learning* (ML) and *artificial intelligence* (AI) algorithms (Zhang et al. 2018); and create more collaborative environments by using social networking approaches (Liao et al. 2015).

Adoption of existing technologies paves the way to achieve the second goal: enabling citizen science projects to be able to absorb new technological advances and developments and, thus, to ensure that citizen science will not be left behind in the technological race. There is real danger of creating a technological gap in future citizen science projects – which is tempting to excuse or disguise behind the 'citizen' element of a citizen science project. In other words, citizen science projects need to stay at the forefront of technological advances in order to be in a position to adopt future developments. If citizen science projects try to develop by relying only on volunteer strength, they will position themselves in a situation where emerging technologies and applications will be difficult, if not impossible, to adopt. Furthermore, citizen science project research should be on a par with research that take place purely in the academic arena. To achieve this parity, citizen science projects should aim for technological proficiency and excellence. Technologies and apps related to *cloud computing*, IoT, and AI need to become mainstream for citizen science projects, rather than being the reserve of flagship projects.

In this context, and despite the obvious challenge of predicting the future of apps in citizen science, the discussion will turn to what are deemed the most influential technological factors in citizen science: AI and ML (see also Franzen et al., this volume, Chap. 10). The hypothesis that AI and ML will lead future developments in citizen science is based on recent breakthroughs that have been achieved in several domains. Examples can be found in earth observation and remote sensing tasks (Ma et al. 2019) and in quality assurance (Li et al. 2017). In general, when the availability of huge volumes of data can threaten to overwhelm human efforts to meaningfully analyse or understand useful patterns and rules, AI and ML can provide considerable advantages.

Indeed, globally, citizen science projects are gathering large volumes of citizen-contributed data and observations (e.g. iNaturalist, which at the time of writing, has achieved almost 30 million observations in almost 250 thousand categories, contributed by more than a million citizens). Tasks such as *observation categorisation* (and, as a result, data quality) are primarily based on the unverified contributions of participants (especially of newcomers) or verified by groups of moderators that act as quality filters. While this approach has been successful in a number of citizen science projects, the addition of AI and ML can help significantly by 'learning' to recognise species to assign them to the correct category or to suggest the most plausible choice to participants.

This generic example can be applied with varying degrees to several other citizen science projects or tasks. These include the correction of *raster data* through noise removal (Wolterink et al. 2017), the completion of *missing data* (Turabieh et al. 2018), and spotting *outliers and anomalies in data sets* (Zhou and Paffenroth 2017).

The introduction of AI and ML in citizen science projects is not meant to replace humans. For various reasons (Gilmer et al. 2018), including the immaturity of the AI and ML fields (Heaven 2019), humans are still needed in the decision-making process to provide their intuition, imagination, and reasoning, which are not possible to mimic via AI or ML algorithms. However, as AI and ML are becoming increasingly accessible, the collaboration of AI and ML can provide benefits in time, resources, and effort needed for both simple and critical tasks (Antoniou and Potsiou 2020). Moreover, the intertwining of volunteerism with the power of AI and ML can boost citizen science projects' effectiveness in user engagement and project usability. User engagement can be enhanced and increased through AI and ML processes, which can facilitate certain tasks and make apps more responsive and contributions less error-prone. Project usability can be enhanced by improving overall data quality that, in turn, will encourage the use of citizen science data sets by multiple stakeholders while at the same time free manpower for other tasks that need human input.

The next big step in the development of the future citizen science apps will likely be the mainstream incorporation of AI and ML-trained models in mobile citizen science apps that will be able to infer or suggest options to participants with high accuracy levels. In such an AI and ML-enabled future, the possibilities for citizen science projects are countless and the combination of human effort and mobile apps will become the centre of gravity for every project.

Mobile apps rapidly adopt technology developments. Typically, maintenance cycles measured in weeks are not uncommon. Especially in citizen science, mobile apps play an important role as the *extended sensor* of the user. Practice has shown that key aspects should be considered for the successful development of apps in citizen science, such as usability, user interaction, and interoperability. Just as in any other aspect of a citizen science project, the development of apps should also focus on participants' requirements. The performance, usability, a high-quality look and feel, and interface design are main keys for success. As computing power is rapidly increasing in mobile devices, so are the possibilities to use high-end software functionality, implementing AI and ML-driven features. This may even change the role of citizens in citizen science, as certain tasks will be done automatically.

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Chapter 24
Communication and Dissemination in Citizen Science

Simone Rüfenacht, Tim Woods, Gaia Agnello, Margaret Gold, Philipp Hummer, Anne Land-Zandstra, and Andrea Sieber

Abstract Citizen science projects rely on public involvement, making a communication and dissemination strategy essential to their success and impact. This needs to include many aspects, such as identifying the audience, selecting the communication channel(s), and establishing the right language to use. Importantly, citizen science projects must expand beyond traditional top-down *monologue* interactions and embrace two-way *dialogue* approaches, especially when communicating with project participants. Further, to be effective, communication activities require good planning and dedicated resources. This chapter highlights the importance of communication and dissemination in citizen science; provides examples of successful strategies and identifies the factors that determine success; and describes some of the challenges that can arise and how to overcome these.

Keywords Community building · Face-to-face interaction · Online communication · Storytelling · Non-written communication

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Introduction

Communication and dissemination are fundamental to the success of projects in any field. This is especially true for citizen science, where projects rely on public involvement and often aim to reach policymakers. Effective communication and dissemination efforts reach and engage their target audience(s) and achieve the desired impact. They also increase a project's visibility and reach, keep participants actively engaged, and increase the likelihood of influencing policy. Ensuring that communication and dissemination are effective requires careful planning, the use of best practice, and sufficient resources.

Communication in citizen science may change during a project's life cycle. At different stages, it may be needed to recruit, motivate, and retain participants; to recognise and acknowledge their inputs (e.g. through reports and media coverage); to inform them of the project's aims and scientific processes; and for exchanging information about the project's results and outcomes (Fig. 24.1; Hecker et al. 2018; de Vries et al. 2019; Veeckman et al. 2019).

Communication activities also need to be suited to factors that differ between projects, such as audiences, geographical scales, timescales (e.g. 1-day events, multi-year projects, annual investigations), tools (e.g. mainstream media, live events, social media), and desired impacts and outcomes (e.g. new scientific knowledge and/or understanding, education, policy change). Defining target audiences is fundamental as it influences decisions on all other factors.

In this chapter, we discuss some key themes around communication and dissemination in citizen science (see Box 24.1). First, we debate *factors* that influence the success of communication and dissemination efforts. Then we describe different

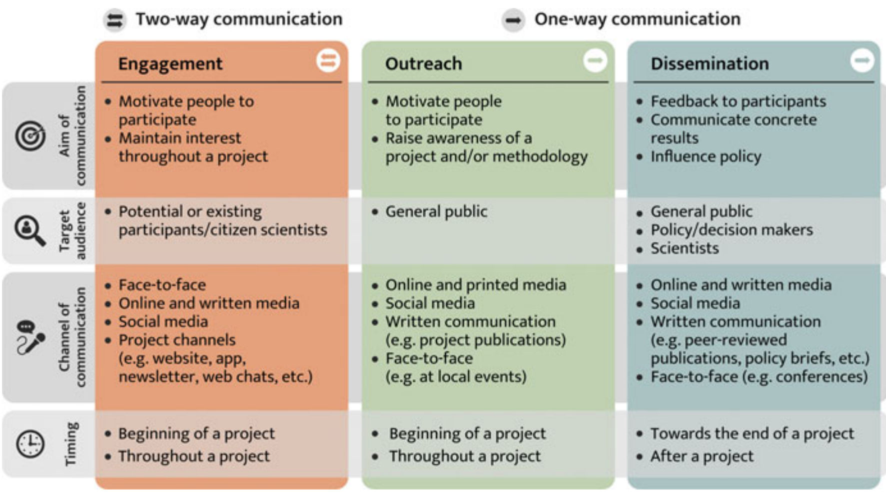

Fig. 24.1 Types of communication and their associated aims, target audiences, channels of communication, and most appropriate time point within a project

communication approaches and provide *examples* of what works in citizen science. Finally, we consider some of the *challenges* with communication, along with *tips* for developing an effective *communication and dissemination strategy*.

Box 24.1: What Is Dissemination?

Unlike communication – the continuous transfer of information and feedback between project organisers and other stakeholders – dissemination commonly happens towards the end of a project, for example, the distribution of project results (e.g. data analysis and results) and lessons (e.g. good practice guidelines). Dissemination in science, even citizen science, is often a one-way process, frequently through published research (e.g. in scientific journals), conference presentations, or policy briefs. The importance of both communication and dissemination is reflected in the European Citizen Science Association's *10 Principles of Citizen Science* (Robinson et al. 2018). They state that 'citizen scientists receive feedback from the project' (communication); 'citizen science data and metadata are made publicly available and, where possible, results are published in an open-access format'; and 'citizen scientists are acknowledged in project results and publications' (dissemination). This shows that, whilst distinct from communication, dissemination remains important in citizen science: participants value access to project data and being informed about scientific findings and outcomes throughout a project (de Vries et al. 2019).

What Is Good Communication?

Many factors affect the success of communication activities, and ensuring these are in place is an intricate, time-consuming task. The first questions for citizen science projects, and almost all communication efforts, are to consider who is your audience and how to address them (both outlined below).

Communication is a continuous process that maintains openness between all participants at each stage, from setting research questions to publishing the results (Veeckman et al. 2019) and informing as many people as possible of the project's outputs and lessons. Given this time frame, communications planning should be done right at the start of a project. This involves an assessment of the resources available and how much time and money to dedicate to reaching each target audience and at each stage of the project. A communication and dissemination plan is also important, for developing a schedule for each activity and later evaluating how successful activities have been (see Schäfer et al., this volume, Chap. 25).

Ultimately, good communication means that people have listened to, understood, and acted upon your messages – and, hopefully, become involved in your project.

Who Is Your Audience?

For any communication activity, in any field, the first step is to decide who your audience is, which should be done through a systematic process of determining the individuals, organisations, and groups that have an interest in a project or initiative and are impacted by its outcomes. It is typically broken down into four phases:

1. *Identifying:* listing relevant groups, organisations, and people
2. *Analysing:* understanding stakeholder perspectives and interests
3. *Mapping:* visualising relationships to objectives and other stakeholders
4. *Prioritising:* ranking stakeholder relevance and identifying issues

The audience(s) you identify for each communication initiative will determine its characteristics: where it is held, the frequency and duration, the medium used (face-to-face or online), the amount of resources invested (time and financial), and the language used. The message to be conveyed is also influenced by the audience and their motivation to participate in the project (Land-Zandstra et al., this volume, Chap. 13). Generally, stakeholders want different things: *citizens* want a sense of being part of the project and that their ideas are taken into account; *professional scientists* want their research to be seen and understood by a larger, more engaged audience; *project organisers* want more people to know about, and participate in, their projects; and *policymakers* want better information on which to base their decisions. The better you understand your target audience(s), the more personally – and effectively – you can tailor your communication (Veeckman et al. 2019).

Use of Language

Whether communicating online, through printed media, or face-to-face, the language you use – its terminology, tone, and complexity – matters. This is especially significant for citizen science projects, as these broadly aim to increase participation and inclusiveness in science (see Paleco et al., this volume, Chap. 14). Whilst certain terms can engage some audiences, getting the language 'wrong' can exclude people at the first step of the communication process (Eitzel et al. 2017). For instance, common words used in science need to be adapted to audiences from different cultural or literal backgrounds, and the tone should never be authoritative. In addition, texts should be easily understandable; we suggest using *readability formulas*, statistical tools to objectively measure the relative difficulty of texts.

It is also necessary to reflect on how inclusive the language used is (e.g. not describing citizen scientists as 'he' or 'she') and whether it reflects people's everyday lives: explaining why an issue is relevant to someone's location, culture, or community is likely to increase interest and, ultimately, participation. Even the term chosen to refer to participants is significant: are they 'volunteers', 'citizens', 'amateurs', 'hobbyists', or 'helpers'?[1] Two-way communication with project participants is important here, as it can lead to co-creating specific language for the project.

Monologue or Dialogue

Until a few decades ago, most science communication was based on the *deficit model* (Smallman 2018). Information was sent from a sender (scientist, science communicator) to the audience in the form of a monologue, a one-way message. Scientists and science communicators saw it as their duty to inform the general public about science, to instil a positive public attitude towards science. When controversies over science arose, a lack of scientific knowledge among the public was often seen as the culprit (Bubela et al. 2009; Smallman 2018). However, this deficit model does not always increase trust and support for science; it can even be counterproductive (Bubela et al. 2009).

Recently, thinking in science communication has shifted towards a more interactive approach, in which *dialogue*, or *two-way communication*, is preferred (Bubela et al. 2009; Smallman 2018). The idea is that in a democracy, citizens should be consulted in decisions about scientific research and policy. This new paradigm of dialogue recognises the role that trust, participation, and relationships play in effective communication, in addition to knowledge. Citizen science fits this new focus. When considered as an avenue for science communication, it can be a way for scientists and citizens to interact and collaborate. However, its impact depends on how a project is designed. For example, crowdsourcing projects, or projects where participants collect data without ever meeting or engaging with scientists, are less able to follow this interactive approach.

When organisers and participants truly want to become collaborators, it is essential that communication goes beyond the one-way diffusion of information. Ideally, all participants should have regular opportunities to communicate with each other, and with project leaders, to share their ideas and ask questions. Similarly, professional scientists need to communicate with participants, for example, to follow up on data quality issues. Target audiences (e.g. the media or policymakers) should also have opportunities to provide feedback or communicate what information they want or need from a project. Inclusion and participation are central to citizen science, and this field has been at the forefront of the shift from linear monologues to two-way dialogues, as a way to encourage engagement, interaction, feedback, shared knowledge, and mutual learning. In a similar vein, there has been a shift to expand beyond top-down projects, where initiatives are devised and led by professional scientists and research institutions, to a range of bottom-up and co-creational approaches, where the research question is determined in collaboration with a range of stakeholders, together with researchers, or entirely community-led (e.g. to

[1] Eitzel et al. (2017) consider potential pitfalls with each of these terms.

address a local concern). However, there may still be moments in a project when one-way communication is appropriate, for example, when raising awareness, sending around instructions or protocols, and updating participants about progress (Fig. 24.1).

Approaches to Communication

Technologies have been effective in engaging large numbers of people in citizen science. *Online projects* provide opportunities to support geographically dispersed groups of participants and can attract participants that want to contribute at a time and level convenient to them. However, *offline activities*, such as attending face-to-face meetings and events, remain important for social interaction and networking with other participants in person. Both channels of communication appeal to different types of participants and can be combined to overcome barriers and increase the inclusiveness of the project (Land-Zandstra et al., this volume, Chap. 13; Paleco et al., this volume, Chap. 14).

The type of project will influence the most appropriate mix. Van Noordwijk et al. (this volume, Chap. 19) define four types of citizen science projects, which have different target audiences and require various communication media. Successful citizen science projects rely on a careful choice about how to blend these channels, according to their type and target audiences.

- *Place-based actions* are targeted at audiences within a specific geographic range. Face-to-face communication can help to recruit more participants; attendees may motivate others to participate. Online communication can be useful to inform about events and milestones.
- *Interest group investigations* target existing communities and people with a shared specific interest. Face-to-face communication is important to bring like-minded people together and to grow existing communities. Online communication can maintain contact between communities and help to include participants/communities from other areas.
- *Educational research* targets educational facilities. Face-to-face communication can promote exchange between different groups. Online communication is crucial to motivate new groups to join the project and to include groups from other areas.
- *Mass census* projects target the general public. Online communication is often more appropriate, because face-to-face events exclude anyone from other areas or with time constraints. Face-to-face communication can be relevant to mass census projects if they are organised at numerous places across a large area – but this can be highly cost- and time-intensive.

Face-to-Face Interaction

Face-to-face interaction involves both verbal and non-verbal communication. Facial expressions and gestures help to build relationships as much as words, creating bonds between individuals and setting a foundation of trust and collaboration. Such interactions provide long-lasting memories and connections for people in a way that is more challenging with online participation.

Events and other 'live' outreach activities provide opportunities for face-to-face interactions between a project's scientists and participants and ideally other stakeholders (e.g. policymakers, media). They are key to engagement and bring a range of benefits that can influence the social and scientific outcomes of a project. For example, ongoing face-to-face communication between project staff and participants often helps to improve data quality and reliability. In addition, events provide opportunities to recruit new participants and reward existing ones for their contributions, thereby improving participant retention rates. Events also allow project organisers to observe participants' behaviours, which can help with efforts to monitor and evaluate project developments and impacts.

Informal settings for face-to-face communication enable participants to interact and socialise with their peers, thus enabling effective dialogue, facilitating mutual learning, and increasing knowledge uptake (Cappa et al. 2016). Including hands-on activities helps to encourage questions and critical thinking and therefore learning. For example, practical experiences outdoors, such as *BioBlitzes* (see Box 24.2), have been successful in achieving this. In addition, they have the potential to reconnect people with nature and develop a sense of ownership of their local environment, which motivates citizens to take action and get involved in scientific research.

Box 24.2: BioBlitzes as a Communication Tool

During a BioBlitz, members of the public, professional scientists, and voluntary naturalists come together to record species inventories and abundances at a specific geographical site and within a predefined time frame. A BioBlitz aims to capture a snapshot of biodiversity, but it is also commonly focused on creating a social experience. Such social events often prove an effective way to engage the public and recruit new participants. When planned effectively (i.e. informing the media beforehand), BioBlitzes have often also been covered by the local media, amplifying the impact on society and raising awareness for environmental issues. Acting not only as data collection initiatives but also communication tools, BioBlitzes have become very common worldwide, and practitioners have created several user guides to enable the sharing of good practice (e.g. Robinson et al. 2013).

When planning an event, it is important to consider the different motivations, needs, skills, and available time of participants. However, scientists and citizen science project organisers often receive little or no formal training in public outreach and communication. Fortunately, the DITOs project (discussed in detail in Vohland et al., this volume, Chaps. 1 and 3), which carried out a wide range of events – including travelling exhibitions, film nights, debates, hands-on workshops, and BioBlitzes (see Box 24.2) – provides invaluable experiences on how to enable people to participate at a level suitable for them. Some of these experiences and best practices (DITOs Consortium 2019) are summarised here.

- Regular meetings with people already active in the target area build trust and can increase participation in citizen science activities.
- It is important to be inclusive and ensure that meeting hours comply with the participants' schedule limitations.
- Events should include ice-breaking activities and playful check-ins to set a relaxed tone and encourage interaction.
- The public appreciates informal conversations with scientists. Effective and simple communication at events can help demystify science and academic research.
- In presentations, lengthy explanations and complicated methods should be balanced with photos and videos to explain results and (re)capture attention.
- The use of examples, analogies, and *storytelling* helps make information accessible to non-experts and to connect science to their interests, values, and everyday lives.
- Allowing everyone to access equipment (e.g. microscopes, projectors), and being authentic about the knowledge limits of the organisers, raises the self-confidence of participants.
- Citizen science is about teamwork. To create a supportive atmosphere at an event, it is important to be on time; ask participants for their feedback after the event; and give compliments in public, but criticism in a private and constructive way.
- Co-designing events can stimulate creativity: integrate ideas and suggestions from your team, participants, and other institutions.

Communication in a Digital World

Much of the growth in citizen science initiatives over the past two decades is due to the emergence of enabling technologies, such as the Internet and smartphones. In the digital world, we can be connected almost continuously with our spheres of interest. From a citizen science project's perspective, technology supports two key types of communication (Fig. 24.1): engagement (internal communication) with project participants and the building of communities (a form of outreach).

Online Communication with Participants

Communication with participants not only conveys information; it also acknowledges the time and effort they put into a project. Frequent exchanges also act as a motivation and prompt for regular contributions. Often, a project's *website* is the first (digital) port of call for newcomers to a project, but it should not be the only one.

Through modern approaches, such as *push messaging* features in the apps and digital tools of a project, the project team can reach out to participants directly and provide information in real time, ideally with an option to read more about the topic. For web-based projects, a newsletter function and postings via social media networks can also be effective.

Online communication should always have a distinct message and a clear writing style. The use of *emojis* can help reduce the danger of misinterpretation and can convey the tone of the conversation or a feeling about a message. They should not be seen as a gimmick, or unscientific, but rather a way to add nuance and be inclusive.

Building Online Communities

Citizen science projects often aim to create a community of participants around the core issue (see Box 24.3). Direct communication using online tools can facilitate the growth of and exchange within communities, during data collection phases and when projects are inactive.

Box 24.3: Naturkalender ZAMG*: An Active Digital Community*

This Austrian citizen science project achieved a very active community, with more than 5000 app downloads, through continuous press and media coverage. Participants contribute observations of plant and animal species throughout the year and record their changing phases (e.g. first appearance of a species, fruit ripening, leaf colouring).

The app, created by SPOTTERON, features an integrated community toolkit, which allows established users to welcome and support newcomers to the project and to help with the classification of observations via instant feedback loops in the comment sections of each contribution. To help with community management and data quality, regional project partners, such as national parks and meteorological stations, work as data moderators. For clear distinction between user types, these partners have unique profile pictures (*avatars*) with the visual design elements of the project.

The project research team also interacts directly with the community via comments and feedback on new contributions. Further functionalities to support ongoing community building include highlighting valuable contributions and being able to appreciate a spot by pressing a heart-shaped button. The project team also utilises a ‘push messages’ feature to report news back to citizen scientists or to communicate seasonal information about key species to observe.

Fig. 24.2 Communication flow in a modern citizen science community-based app based on the SPOTTERON platform model

Forms of communication between participants can have different levels. Even quick, straightforward forms of appreciation (e.g. giving 'likes' or 'hearts') to comments and discussion threads make people feel recognised and rewarded for their inputs. Through an online friendship or following model, users can build their own network within a citizen science app and interact with each other, forming an inclusive and immersive community of participants and scientists alike (Fig. 24.2).

However, not every user has the same level of digital competence; it is essential to have materials available for new users which answer basic questions about interactive concepts within an app or web application (e.g. a downloadable manual, Frequently Asked Questions on a website).

The management of online community activities is best done in a separate section of an administration interface, allowing the option for the project team to reply or intervene. For example, such an interface should have the option to unpublish comments in real time or block users if abuse of the tools occurs. In addition, report functions are helpful so that community members can report such abuse. As with the protection of users' personal data (see Tauginienė et al., this volume, Chap. 20), it is the project's responsibility to establish a healthy space for communication.

Reaching Out to the Public

Citizen science always requires 'getting the word out': a project has to actively communicate with potential target groups and spark interest for them to contribute to data collection and analysis. The first impression is a lasting one, as it conveys a project's image to potential participants and affects their decision to take part. General design and marketing principles, such as clear wording, high visual quality, *bite-size media outputs*, and a constant flow of information and activities, are crucial to this. As with all communications, it is vital to catch people's attention and have a clear, strong message.

A lot of early information is processed by people when they look at the website, app, materials, or even just the logo: known in the advertising world as *project identity*. The project identity needs strong individuality, a descriptive name, and a message that conveys what the project is about with few words and ideally connects with people and piques their interest. A distinct *visual identity* – logo and colour scheme – acts as a visual anchor that links the project to every image, media post, publication, and tool it produces (see Box 24.4). Overall, the project identity helps users build a relationship with the project.

Box 24.4: CrowdWater: An Effective Project Identity
CrowdWater is a global citizen science project which collects hydrological data. Initiated by the University of Zurich, Switzerland, its aim is to develop a cheap and easy data collection method that can be used to predict floods and low river flows.

CrowdWater has a strong visual identity which includes Droppy, a character who appears in all CrowdWater-related communication and activities.

(continued)

Box 24.4 (continued)
Having a character constantly represented creates a positive image: it can help to increase participation by appealing to a broad sector of the public, without making the project seem too serious. Droppy appears in various poses on the website, in videos, on printed material, in social media, and in presentations and acts as the mascot of the project.

In our digital and mobile world, reaching out to the public is fast and happens in real time, but attention spans are short. This makes it imperative to create a flow of information in the form of bite-size media outputs, in which project information is shared with the public in small parts. Each item can be posted on various platforms with a ‘Read more’ link to a news item when available. However, newspapers, radio, and television remain great *message multipliers*, even in an age dominated by social media and the Internet. When the traditional media reports about a project, this can not only be useful for reaching new audiences (i.e. those not using social media) but also give a project’s messages credibility that is sometimes lacking in online communication.

If citizen science is to truly contribute to the democratisation of science, it must strive to reach a wider range of audiences and participants (see Paleco et al., this volume, Chap. 14). When planning communication activities, it is important to consider how inclusive the chosen methods of reaching out to the public are. Rather than just considering who each format will reach, it is necessary to ask: who *won’t* it reach? And, as an essential follow-up question: how can I reach those overlooked groups and individuals? Ensuring a project is inclusive requires allocating resources, considering which communication approaches are most likely to reach excluded groups, the type of language used, and where and when these groups are already meeting (Veeckman et al. 2019).

Successful Communication Approaches

There are numerous examples of successful communication in the field of citizen science. Here, we consider in detail a specific method (storytelling) reaching a particular audience (policymakers)[2] and using non-written forms of communication.

[2]As an alternative, Veeckman et al. (2019) provide a good outline of how to engage with teachers in citizen science projects.

Storytelling to Generate and Transfer Knowledge

Storytelling is a proven way to generate and impart knowledge, one that is currently used in diverse contexts. It is regarded as an independent form of knowledge generation and knowledge transfer that can complement scientific knowledge in a meaningful way on cultural, social, and individual levels. In citizen science, storytelling focuses on communicating the ways in which citizens can get involved in projects. Stories can be personal, historical, or educational (Veeckman et al. 2019), and a narrative is created when they are linked together, which can provide people with a connection point for their own experiences. Stories can depict the immediate context, providing meaning to participants and reflecting their experiences, thereby providing a means to generate, analyse, and pass on actions, experiences, and biographical knowledge for citizen science projects in creative ways (Hecker et al. 2018; Richter et al. 2019). Good stories are memorable, often feature a ‘hero’ and describe a conflict, have a specific aim, and awaken emotions in your audience (Hecker et al. 2017). This ensures that the generated and shared knowledge is accessible to all, making it a particularly effective tool for hard-to-reach or neglected groups.

Narrative knowledge should not be regarded as less developed than scientific knowledge; it is of equal importance in the context of citizen science. Whilst scientific knowledge is directed towards the *general* (the objective), storytelling is about the *particular*: the concrete, the subjective, and the transitory. Storytelling also allows events to be interpreted from different perspectives, which encourages the discovery of new contexts and aspects. As Box 24.5 shows, storytelling can play an important role in citizen science projects, far beyond knowledge generation and communication.

Box 24.5: Storytelling as an Effective Communication Tool

In the citizen science project *BrotZeit*, people who cultivate and process grains in the Lesachtal region of the Austrian Alps report their experiences in moderated narrative cafes. Through interviews with young people, they tell stories about their former practices and the rituals around baking bread. Other residents donate photos and films on this subject. Together, these are secured (e.g. interviews transcribed, films archived), analysed, and transformed into media products such as animated films, documentary films, open-air exhibitions, and raps.

Storytelling in *BrotZeit* sets a public and collective dialogue in motion: about experiential knowledge, the landscape, the change from generation to generation, and the sustainable use of resources. It makes visible the customs and practices that have often existed in secret, leading to a new understanding of regional characteristics, functioning communities, and a sustainable use of local resources. The ongoing documentation of the 36-month project, which includes a blog, public presentations, radio features, and monthly newspaper reports, enables people to reflect on this joint work on collective memory and evaluate the project results.

Communicating with Policymakers

Policymakers are a key target audience for citizen science projects that want to contribute to evidence-based policy, but bridging the gap between research and policy is notoriously difficult. One major challenge is bridging the differing values, expectations, and needs of the research system and policymakers (Hecker et al. 2018). Policymakers deal in facts and look for a high degree of certainty (Durham et al. 2014), whilst scientists (usually) deal in terms of probability and uncertainty. Also, there is often a mismatch between the time frames of policymaking and project results (Schade et al., this volume, Chap. 18). Policymakers tend to work on far shorter timescales than researchers, requiring quick answers as policy develops, whilst research often takes place over years (Durham et al. 2014). Another issue is reaching the right policymaker; they can range from those who sign off on the final policy document (the decisionmaker) to those that advise, inform, and influence them throughout the process. Then there are the alternative – often competing – influences on policy formation (e.g. voter priorities, funding, personal views, media-led priorities, and agendas). In light of these many barriers, it is not surprising that many citizen science projects find communicating with policymakers to be a challenge.

Fortunately, communicating with policymakers is not impossible, and there are examples of citizen science projects that have done this successfully (see Box 24.6). One popular approach is to produce policy briefs which summarise the key project results and findings in a clear style. Policy briefs can also provide interim results and updates, which fill a timely gap, as final project findings can take years to be published (e.g. in academic journals). Another method is to invite policymakers to project events and discussions, such as round tables. Whilst this can be harder to achieve, it has the advantage of being a place to start a dialogue (e.g. answering queries they might have or gaining feedback on future research they would like to see). Face-to-face contact can also establish personal connections, making future engagement with policymakers easier to plan and realise.

Box 24.6: Case Study on Policy Engagement for Citizen Science

The DITOs project's policy engagement strategy included producing 13 policy briefs[3] to provide inputs and recommendations on key topics in policy discussions. These were disseminated online via DITOs and partner communication channels and were also printed and distributed at events. The dissemination was amplified through the inclusion of experts not directly involved in the project.

A second strand involved organising events such as local and European stakeholder round tables, delegation visits, and the final conference

(continued)

[3]All available at: https://discovery.ucl.ac.uk

Box 24.6 (continued)
Pan-European Policy Forum. These were organised with the aim of mobilising communities of practitioners, sharing of good practice, and strengthening the science-policy interface by opening up dialogue with decisionmakers. This successful strategy enabled the DITOs project to establish networks and influence national science policy; provide information for policy improvement; promote citizen science as an approach to research and science communication; demonstrate that citizen science can be an instrument to advance political agendas; and use citizen science as a direct governance instrument via non-policy actors (Göbel et al. 2019).

In some projects, policy engagement is planned from the outset, but too often it is an afterthought. Whilst not all projects should – or want to – link to policy, those that do should consider the expectations of policymakers from the beginning (Durham et al. 2014). Policymakers are more likely to engage with a project and use its results if it can provide what they need and expect. Further, collaborations with similar projects can increase the chance of reaching policymakers and provide a stronger evidence base for the policy advocated. Furthermore, projects that explicitly include efforts to communicate with the general public, especially through media channels, are often better received and taken more seriously by policymakers (Hecker et al. 2018).

Non-written Communication

Alongside considering how language can be inclusive, it is important to recognise that for some, language will always present a barrier: people who are visually impaired or illiterate (for written communication), deaf or hard of hearing (for face-to-face interaction), or not fluent in the language used. To reduce this barrier to participation, it is necessary to think beyond words and consider how pictures, graphics, charts, and video or audio clips can play a part in your communication activities.

Non-written communication should be used regularly throughout a project. Two effective approaches are *video blogs* (vlogs) and *podcasts*. These non-written forms of communication require equipment and software skills, and the production is often time-intensive. However, they will increase engagement and thus a project's impact. They are easily shared via social media, which can capture the attention of people that might otherwise not stumble across your project. There are a few general rules for both of these (adapted from Welbourne and Grant 2015; Gray 2020):

1. *Decide on a frequency:* Will you produce vlogs and podcasts on a regular basis or after specific milestones in your project? Bear in mind that these can be relatively resource-intensive.
2. *Identify your reporter:* Consistency is important – if vlogs and podcasts always feature the same reporter, your audience will get familiar with this person and be much more likely to join or follow your project.
3. *Find a style:* Will you appear in your vlogs, or will it feature only your voice? Will your podcasts be a monologue or feature interview guest(s)?
4. *Keep it short:* Both vlogs and podcasts should get to the point quickly. Front-load them with interesting information to catch people's attention.
5. *Make it inclusive:* Vlogs and podcasts should be presented in an inclusive way, for example, featuring participants (whether citizens or others) that represent a wide range of genders, ages, races, and living environments (e.g. inner cities as well as the countryside).

Challenges

Communication can be one of the main challenges for citizen science projects. Despite outreach gaining importance in the scientific community, many scientists still receive little or no formal training in public communication. Those organising citizen science projects are often surprised by the amount of time and effort it takes to communicate well with participants and other stakeholders.

The first, and most essential, step to overcoming this is a communication and dissemination strategy. The effectiveness of this should be monitored and evaluated as soon as the project begins, using the principles for project evaluation (see Schäfer et al., this volume, Chap. 25). Following well-established practices from a range of fields, including science communication, can also increase the effectiveness of communication and dissemination across a project's life cycle. Even better, appoint a communication expert as part of the team, if there is sufficient budget to devote to this.

In citizen science projects, there is sometimes an initial burst of awareness-raising activity, after which attention on communication peters out until the project is nearing its end. Although this may in part be due to insufficient resources (or inadequate planning), it can also be an indication of changing circumstances. To catch such changes and address them effectively, it is important to build *health checks* into the project to account for changes, such as a shift in the research question being pursued and new stakeholders becoming involved, or simply to see if one communication medium is working more effectively than another. This should include a review of the project goals, a reassessment of the key stakeholders and their needs, a review of the effectiveness of communication activities and channels to date, and an update on the resources left (or that have become available). The outcome of this health check should be a renewed action plan for the remainder of the project.

Dissemination towards the end of the project, such as publishing in peer-reviewed journals and presenting papers at conferences, is much more within the comfort zone of academics and researchers – albeit outside those of many citizen scientists. However, two unique challenges are common within the field of citizen science.

The first is the importance of giving credit to all participants who contributed, directly or indirectly, to the generation of new knowledge or new discoveries. This requires some creative thinking. Examples of how to address this are the inclusion of schoolteacher Hanny van Arkel in the list of authors for the publication of the discovery of a new celestial object (Lintott et al. 2009) and the listing of all contributing participants in the Radio Galaxy Zoo project, which ensured they were directly acknowledged in the resulting publication (Alger et al. 2018).

The second challenge is how to make published outcomes, which are often written in academic language, accessible to all participants. Apart from publishing as open access and sharing the full academic publication or conference paper with all stakeholders – without presumption as to their ability to understand it – it is good practice to write up or visualise the outcomes in simpler terms and with a clear connection back to the original stated goal of the project.

Conclusions

There is not one perfect solution to effective communication in citizen science, as there are many factors in each project that must be taken into account. Furthermore, no communication and dissemination strategy should be static: it must be monitored, adjusted, and updated throughout the life cycle of a project (and possibly beyond). Many citizen science projects – including those highlighted in this chapter – have developed successful communication and dissemination strategies and have shared their best practice for others to learn from and adapt to. To conclude, we list some key communication tips (see Box 24.7).

Box 24.7: Tips for Communicating in Citizen Science

1. Create a communication and dissemination strategy for your project by asking the following:

   - Who are the main participants? Who else do you want/need to reach?
   - Who has the skills and resources to communicate effectively from the pre-project phase through to the post-project phase?[4]

(continued)

[4]Veeckman et al. (2019) suggest this is split into three roles: community manager, science communicator, and science trainer. This breakdown provides a useful way of mapping the different communication skills needed to reach different audiences/achieve a range of aims.

Box 24.7 (continued)

- What information do you need to communicate, and how often?
- How will this communication take place?
- How will you invite feedback, and how will you respond to it?
- Are there guides, resources, and networks already out there that can help you to communicate your aims to your target audience(s)?

2. Communicate clearly: use simple language, strong messages, and different approaches to ensure you reach a wide and diverse audience.
3. Actively communicate your project outside the scientific community, to increase visibility, raise awareness, and stimulate participation.
4. Use online tools (e.g. blogs, social media, newsletters, vlogs, podcasts) and supplement them with offline tools (e.g. newspapers, radio, television) to reach people who do not have access to online media.
5. Use non-written tools and approaches such as storytelling to increase people's understanding.
6. Evaluate the success and impact of communication strategies to understand which are effective and which mistakes can be avoided in future projects.

Adapted from Pettibone et al. 2016*; Hecker* et al. 2018*; Veeckman* et al. 2019

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Chapter 25
Evaluation in Citizen Science: The Art of Tracing a Moving Target

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Abstract Evaluation is a core management instrument and part of many scientific projects. Evaluation can be approached from several different angles, with distinct objectives in mind. In any project, we can evaluate the project process and the scientific outcomes, but with citizen science this does not go far enough. We need to additionally evaluate the effects of projects on the participants themselves and on society at large. While citizen science itself is still in evolution, we should aim to capture and understand the multiple traces it leaves in its direct and broader environment. Considering that projects often have limited resources for evaluation, we need to bundle existing knowledge and experiences on how to best assess citizen science initiatives and continually learn from this assessment. What should we concentrate on when we evaluate citizen science projects and programmes? What are current practices and what are we lacking? Are we really targeting the most relevant aspects of citizen science with our current evaluation approaches?

Keywords Impact assessment · Scientific literacy · Logic model · Latent class analysis · Experience sampling method

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Introduction

Evaluation comprises a systematic assessment of the operation and/or the outcomes of an activity or programme, against a set of explicit or implicit standards and criteria (Weiss 1998). Generally, we distinguish between *formative* and *summative* evaluation, where the former is considered process-based evaluation, while the latter is more outcome-oriented. Whereas outcome-based evaluation is concerned with assessing the overall goals of the activities or programmes and the benefits to the participants, process-based evaluation identifies the activities' or programmes' strengths and weaknesses. For some academics, evaluation refers foremost to assuring quality during the scientific process; for others the term is closely related to impact assessment, providing evidence for change triggered by the intervention.

A widely accepted model for defining project success is the *logic model of evaluation* (Örtengren 2004). Although coming mainly from developmental programme design and evaluation, the logic model has been widely adopted and used for evaluating scientific programmes and technology deployment programmes. However, it can also be applied to systematic analysis, implementation, monitoring, and evaluation of development and intervention projects of various kinds; and it has already been applied to citizen science projects.

The logic model provides a structured approach for project design and evaluation as it systematically relates project inputs, activities, outputs, outcomes, and impacts (Fig. 25.1). A variety of definitions and interpretations of these terms are in use. For the purposes of this chapter, we refer to inputs as the resources available to a project and the activities as what is done with those resources. Activities, in turn, deliver products or services – the outputs (e.g. data points collected, workshops conducted). Outcomes are the effects of the outputs on the target group. Impacts are long-term changes brought about on a societal level; they constitute the progress made towards high-level goals.

In the evaluation of citizen science projects, inputs, activities, and outputs are usually easy to measure with quantitative indicators that show the success, or not, of project management. In contrast, recording outcomes requires dedicated effort, and, even then, it may be difficult to causally attribute measured changes as an effect of the project; this is the focus of our chapter. When the intended outcome is a change in people's lives, it is therefore important to include the perceptions and experiences of the intended beneficiaries. For example, if a citizen scientist changes their behaviour and converts to a more sustainable lifestyle, this could be due to

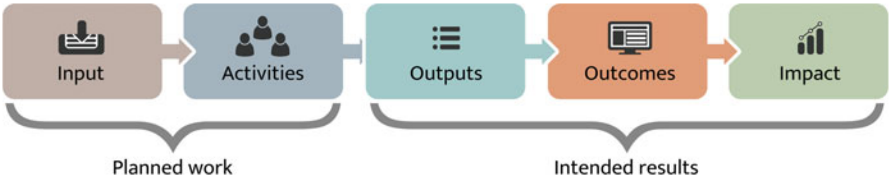

Fig. 25.1 The logic model of evaluation

knowledge and attitudes acquired through participation in a project, but it could also be because their new partner is an environmental activist. Since impact describes a much broader effect than outcome, measuring impacts is even more of a challenge. Broader impacts include primary and secondary long-term effects and aspects of sustainability, both of which have a long-term horizon. Due to its methodological complexity, *impact assessment* requires large amounts of resources, and, even if change is detected on a societal level, causal attribution of this change to one specific citizen science project may often be impossible. This applies to both directions of causal attribution: a project may cause multiple effects, and an observed effect (such as a societal change) usually has not one but many different causes. Due to these difficulties in causal attribution, outcome and impact assessments often include qualitative assessments and case studies (Goertz and Mahoney 2012).

In this chapter we discuss approaches towards outcome and impact-oriented evaluation in citizen science, showcased by concrete examples that depict the variety of practice, and reflect on current challenges as well as new developments in the field.

Historical Development of Evaluation

Evaluation in research projects and programmes has historically been associated with the research output itself, e.g. the validity of the collected data and the resulting scientific evidence. In some scientific disciplines, such as the natural sciences, this is still the prevailing approach, mostly validated via a disciplinary peer review system. However, research policy has also started to value the economic and social importance of research, defined by its mission orientation, alongside scientific quality. The use of scientific indicators in research evaluation can be traced back to the 1960s and 1970s (Leydesdorff 2005). Today's research policy tends to refer to output assessment, measuring not only research quality but also its broader impact or use. Interest in research impact started in the early 1990s, in the UK, which is often considered a leader in research evaluation (Williams and Grant 2018).

This shift towards societal impact assessment of research falls in line with the general historical development of redefining the relationship between science and society, which is observable on many levels, including the increasing institutionalisation of public engagement, the development of practices of technology assessments, and the wide support for the concept of responsible research and innovation (RRI) (Wickson and Carew 2014). Citizen science falls within the principles of RRI and, at the same time, has strong resonance with the characteristics of transdisciplinary research. When dealing with evaluation of citizen science, we have to consider its socioecological relevance, its multi-stakeholder engagement, and its societal embeddedness (also core elements of RRI evaluation).

Contemporary Evaluation of Citizen Science

Evaluation in citizen science today refers to the assessment of the value of its different outcomes and of its processes. It should be understood as a learning process that supports self-reflection and adaptive management, while also helping to understand which effects citizen science initiatives have on science, involved citizens, and socioecological systems. In the following paragraphs, we will reflect on the applied indicators for evaluation, as well as the methods used for evaluating citizen science initiatives. We will also show how different project goals and contexts influence the applied evaluation strategy via a number of case studies.

What Is Currently Evaluated in Citizen Science Projects?

A comprehensive collection of indicators for the evaluation of citizen science initiatives can be found in the *citizen science evaluation framework* (Kieslinger et al. 2018, see Fig. 25.2). This framework suggests indicators for three dimensions of participatory scientific processes: (1) scientific aspects, (2) participants, and (3) socioecological/economic systems.

For each of these dimensions, the framework suggests process-based and outcome-based evaluation: *process and feasibility* collects formative input for an adaptive project design and management; *outcome and impact* brings evidence of a project's benefits to its participants and their surrounding contexts and shows how much an intervention's impact contributes to the project's expected and possibly unintended goals.

The authors of this framework suggest that both types of evaluation, process-based and outcome-based, are crucial for evaluating citizen science projects. Taking a critical look at the project design and continuous progress contributes to the successful implementation of citizen science missions. Impact assessment is

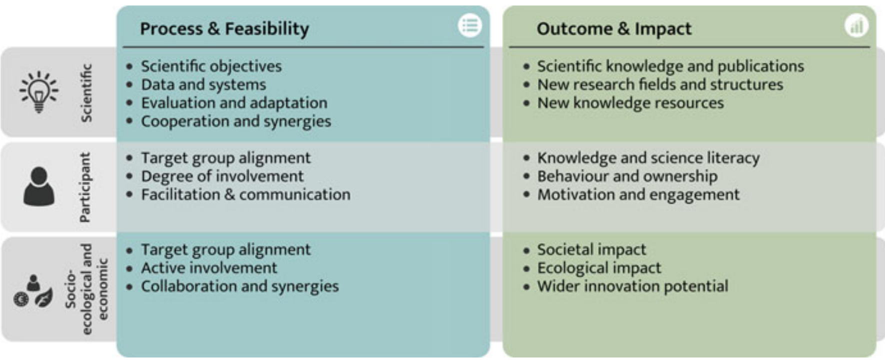

Fig. 25.2 Citizen science evaluation framework, by Kieslinger et al. 2018

increasingly being requested by science policymakers and their funding agencies and enriches our understanding of the value of citizen science.

Within the three dimensions, the citizen science evaluation framework suggests a prioritisation of indicators, adapted to the project context and specific objectives. Projects are not expected to cover all aspects of the framework equally. For example, a co-constructed project, which collaborates with citizens from the onset of the scientific process, might have a clearly defined objective of solving a pressing societal issue. Thus, the scientific outcome in terms of academic publications might be less of a concern. On the other hand, a contributory project, which has been designed with the intention of increasing science knowledge and literacy amongst the participants, should focus its evaluation on the measurable effects of the engagement on the participants.

In the following sections, we will show that evaluation can address all three dimensions suggested by Kieslinger et al. (2018).

Scientific Dimension

Scientific outputs are by far the most important outcome of those citizen science projects that understand citizen science as a research method for new knowledge. These projects also generate the highest number of scientific publications (Kasperowski et al. 2017). In quantitative terms, the largest scientific outputs can be found in the fields of ornithology, astronomy, meteorology, and microbiology, especially in citizen science projects that have developed digital platforms for volunteer contributions, such as Galaxy Zoo, Foldit, etc. (Kullenberg and Kasperowski 2016). On the other side of the spectrum, there are a number of citizen science projects, which do not yet have any output in the form of scientific publications, but it remains unclear how many of these there are (Kullenberg and Kasperowski 2016; Follett and Strezov 2015).

Academic publishing is, however, only one possible metric amongst others. The lack of peer-reviewed publications, especially in the humanities, might simply reflect the fact that many citizen science projects have objectives other than scientific publications. There are projects that prefer to publish their outcomes in societal publications, such as newspaper articles, television, or social media, reaching out to a wider audience and influencing local policies. Others have the transfer of knowledge and the raising of awareness on specific topics as their main goal, which will be examined more closely in the following two dimensions.

What we can also observe is a rising interest in citizen science as a study object and an increasing number of articles that specifically focus on methodological issues in citizen science (Follett and Strezov 2015). Other outcomes in the scientific dimension are more trustful relationships between members of society and the scientific community (e.g. Suomela 2014) and an enhanced capacity for the joint analysis of scientific findings (Bonn et al. 2016).

Participants

A large proportion of citizen science projects still do not evaluate the outcomes for individual participants (Phillips et al. 2018). Amongst those who investigate their projects' impact on individual citizens, the most common outcome documented so far is the one of learning new content knowledge.

Gaining knowledge on scientific subjects was by far the most reported type of learning in citizen science projects (Stepenuck and Green 2015). This ranges from research in climate change (Groulx et al. 2017) to public data collection projects in the field of biodiversity (Bonney et al. 2016) to a number of cyberscience projects, e.g. in the Zooniverse, where even in the absence of a direct educational motivation in the project design, participants learned about specific scientific topics (Masters et al. 2016).

Alongside these proven effects of increased content knowledge in citizen science engagement are much broader learning outcomes as well (Phillips et al. 2018). Citizen science has contributed to learning about the processes of scientific inquiry and to gaining a deeper understanding of scientific outcomes (Bonney et al. 2016), although some studies have questioned this learning outcome (Crall et al. 2012). Recently, citizen science is also being discussed in respect to its potential impact on science capital (Edwards et al. 2018).

Learning in this context is often informal or incidental; picking things up, rather than planning to learn or perceiving an activity as learning. Repeating tasks trains volunteers in specific project skills, so they gain confidence in their contribution and start to take more responsibility, for example, in supporting other learners. The community as a place to develop and exchange is a key aspect in this process, where individuals acquire skills to accomplish project tasks, scientific literacy, and on-topic extra learning through external resources (Jennett et al. 2016).

Overall, simple and visible learning outcomes that are easy to assess (i.e. content learning) are reviewed most frequently in the literature, whereas the more complex and multifaceted aspects of individual and collective learning are rarely evaluated in a systematic way (Bela et al. 2016). We also find a call for intentional learning designs, such as inquiry-based learning, in order for real learning effects to take place (Trautmann et al. 2012).

In contrast, the assessments of transformative effects of learning, such as changes in behaviour, awareness, and stewardship, are often based on assumptions and are rarely evaluated in a transparent way by projects (Bela et al. 2016; Phillips et al. 2018). Relatively few studies refer to outcomes such as a sense of empowerment, a feeling of contributing to science, or insight into one's values and interests (Groulx et al. 2017). In one example on gas drilling, Zerbe and Wilderman (2010) show that many citizens seem to care more about their residential environment than before and are also more responsive as they learn how to measure the contamination around them. Participants' involvement in citizen science proved to influence their ecological perceptions and sense of place, as it increased their understanding of the connections existing between science, place, ecosystem, and the impacts of one's actions on the environment (Ballard et al. 2017). Also, changing attitudes towards more environmentally sustainable resource management could be observed amongst environmental citizen scientists. In one of the case studies below we exemplify how a citizen science project on air quality contributed to stewardship and citizen activism (Schaefer et al. 2020).

A good overview of learning outcomes from participation in citizen science has recently been published by Phillips et al. (2018), including a framework for evaluation that includes six types of learning outcomes, ranging from content knowledge to self-efficacy and behavioural change.

Socioecological and Economic Systems

Next to the scientific and the participants' perspective, the citizen science evaluation framework (Kieslinger et al. 2018) suggests evaluation should look at the wider social, ecological, economic, and political contexts in which projects are embedded. Considering the socioecological and economic systems is especially relevant for citizen science projects that are initiated by local communities, originating outside of academia. They involve scientists and experts in order to provide evidence in support of campaigns and political decisions regarding issues like pollution, health hazards, and species conservation. These projects do not necessarily strive for purely scientific outcomes but rather aim for transformative change and an impact on the dominate socioecological systems.

Only a few scholars address the evaluation of impacts on socioecological and economic systems, and the need for a more strategic assessment of complex science–society relations in the context of citizen science has been expressed (Bonney et al. 2016). What we currently find are studies that show how the benefits on the level of individual participants help to cascade the outcomes to whole regions and communities. Johnson et al. (2014) report that individuals diffuse their acquired skills and knowledge to peers through social networks. Individual citizen scientists feel more confident expressing their ideas to natural resource managers and figures of authority (Cornwell and Campbell 2012); thus citizen science increases their political participation.

When engaging with an ecological system and its associated social institutions (e.g. policies, management practices) through citizen science, individuals may collectively gain knowledge that increases the capacity of the contextually embedded socioecological community to reorganise and adapt to changes. In this way, learning through citizen science projects is not only an outcome to be measured on an individual level but may also be an influence or driving force for meeting project goals for a whole community or region. Phillips et al. (2018) conclude that their focus on individuals' learning can contribute to civic action and policy forming and bring supportive evidence for the democratisation of science via citizen science engagement.

A good illustration of the socioecological impact of citizen science can be found in the community-based air quality monitoring projects that use low-cost measuring devices. These projects demonstrate a higher sense of community as an outcome, stimulate discussions with policymakers, and influence political decisions in the involved regions (Van Brussel and Huyse 2019). There is also evidence from evaluation that citizen engagement in air quality monitoring may trigger the development of measures to avoid exposure to air pollutants or to an active political involvement in seeking solutions to the problem (Schaefer et al. 2020). Another impressive example comes from Japan, where Safecast, an international, volunteer-based organisation devoted to monitoring and openly sharing information on environmental radiation and other pollutants, emerged as a response to the lack of publicly available information about radiation levels after the Fukushima Daiichi Nuclear Power Plant disaster in 2011. The organisation provided tools and community resources to help people understand the complexities of radiation measurement and to make their own informed decisions. In addition to the measurement and easily accessible provision of radiation data, the group identified relevant information sources, summarised their contents, characterised any differences of opinion and interpretation that existed, and guided people to relevant resources. This spontaneous citizen science engagement helped to close 'crucial gaps, ultimately the timely provision of data that citizens need to make informed decisions about their livelihoods and well-being is the government's responsibility' (Brown et al. 2016, p. 98). In their publication, the authors state that 'this vigorous emergence suggests that a shift in social expectations and in the balance of information is already happening, from one which favors government and large institutions, to a more egalitarian and democratic relationship driven by citizen access to objective, independent information of high quality which has been generated by the citizens themselves' (Brown et al. 2016, p. 98).

When looking at evaluation to indicate change in social practices, we should also not forget the work being done in related areas, such as *community-based participatory research*. Especially in the social sciences, participatory action research paved the way for our contemporary understanding of participation in citizen science, even though these approaches are still often neglected (Mayer et al. 2020). Evaluation frameworks have been established for participatory research that suggests questions, indicators, and measures that provide evidence for the effectiveness of certain programmes (e.g. Nash 2015). Similar to what we know from citizen science evaluation, these concepts look at aspects such as personal knowledge development, personal research skill development, organisational/group access to and use of information, and community and organisational development.

Tools and Methods in Evaluating Citizen Science

The tools and methods used for evaluation in citizen science mostly tend to follow standard social science practice, ranging from questionnaires, interviews, focus groups, participant observations, and documented self-reflections from the involved scientists and volunteers. In their overview of citizen science projects in biodiversity, for example, Peter et al. (2019) report on a great diversity of study designs and methods for evaluation, with many projects relying on *self-reported data*.

Surveys are amongst the most frequent instruments to be applied for self-reported data, aiming mainly at collecting evidence for learning outcomes for the participants. Citizen science practitioners can nowadays turn to a number of shared resources online that help to collect insights into participants' motivations, satisfaction, benefits, self-efficacy, etc. (Phillips et al. 2018).

Interviews are another instrument frequently used for evaluation. These range from structured or semi-structured sets of questions to very open and exploratory formats. Scholars have published their interview guidelines to gather insights into their participants' motivations, engagement activities, and benefits, amongst others (Schaefer et al. 2020). But we also find narratives and forms of *storytelling* approaches as part of the evaluation spectrum. For example, Constant and Roberts (2017) combine narrative interviews with instruments like photo essays, research diaries, and storyboards to reveal the context-based, tacit, and intangible factors involved in personal outcomes.

Other evaluation approaches are built into the interaction process or are simply applied on the data available without an a priori evaluation design. An example of the former is the *embedded assessment* approach, where a series of games or quizzes are part of the citizen science activity and help to collect insights on participants' increased skills and knowledge in playful ways without people being aware that their knowledge is tested (Becker-Klein et al. 2016). The nonintrusive, non-design specific, approach can be exemplified by Luczak-Rösch et al. (2014) who analysed the comments shared by and amongst their online citizen scientists and measured how far citizen scientists adopted technical terms in their language as a sign of new knowledge gains.

For self-reflection and self-assessment of projects, Kieslinger et al. (2018) defined a set of key questions covering the three dimensions of the citizen science evaluation framework that have been implemented in an online questionnaire, which is part of the resources available on the European platform EU-Citizen.Science. The self-assessment tool aims to support the detection of strengths and weaknesses for an adaptive management of citizen science initiatives.

Case Studies That Show the Diversity of Citizen Science Evaluation Approaches

The diversity and continuous emergence of new practices in citizen science requires special caution when trying to draw comparisons across different projects outcomes. Nor can we speak of one exemplary approach or proxy to be followed by all when dealing with such a diverse population. The type of scientific work, societal challenge, and geographic scale of participation strongly shapes the strategies that a project uses to meet its goals. Likewise, evaluation and impact assessment depend strongly on the project goals, as well as on contextual conditions that support or impede evaluation activities (such as the availability of respondents, the resources of the project, knowledge of evaluation techniques, etc.). The following section presents different case studies that illustrate the large leeway for citizen science projects to design their own evaluation objectives and activities.

CAPTOR: Applying Classical Evaluation Instruments for Impact Assessment at Individual and Socio-economic Levels

The CAPTOR project was funded by the European Commission's H2020 programme during the years 2016–2018. It combined citizen science activities with grassroots activism to create awareness for the ozone pollution problem in three regions in Austria, Italy, and Spain. In total, 46 low-cost sensors were distributed to volunteering households and public spaces to measure the ozone pollution during the summer. The defined core project objectives were individual learning outcomes amongst the participants involved in the measurement of ozone, behavioural change, and civic activism. However, the project not only wanted to affect participants at the individual level; it also aimed to benefit whole regions and drive political change to improve air quality. This was a highly complex endeavour compared to other pollutants, because tropospheric ozone is formed in *urban* areas through chemical reactions from precursor gases but emitted mainly in *rural* environments.

With these goals in mind and given that there were only a limited number of volunteers involved, the main evaluation instrument was guided interviews – backed up by pre- and post-questionnaires about the participants' knowledge and observations in the field. In total, 53 guided interviews were conducted at the end of each measurement period. This qualitative method helped to gain deep insights into the motivations of participants and their activities as volunteering hosts of ozone measurement devices (such as promoting the project to friends and neighbours). It also revealed in how far the hosts' involvement in the project impacted them as individuals and their neighbourhoods, in terms of knowledge, changed behaviour, and more political involvement in the area of air quality protection. The comparison of the detailed insights across the three different test bed regions allowed the project leaders to learn how far different contexts influenced outcomes at both individual and community levels, and details can be found in Schaefer et al. (2020).

The analysis of data showed that at an individual level the benefits of involvement in CAPTOR were mostly an increased knowledge about and awareness of ozone pollution amongst all private participants. They became promoters for the topic in their private network, and some even took more responsibility and raised the topic with environmental organisations and local municipalities, showing some engagement in political action taking. In experimental maker workshops, where people were invited to build their own measuring devices, evaluation data confirmed that building devices provides users with a feeling of empowerment and independence. In addition, the Spanish test bed revealed considerable regional impacts, beyond individual benefits. After 3 years of citizen science activities, ozone values are now communicated on local television, and one municipality made the CAPTOR data and data from a reference station visible in a public place as well as on the municipality website to increase transparency and awareness. In order to fight the origins of ozone, alliances with other environmental organisations were established and pressure put on politicians in Barcelona. As a result of the collective efforts, a judgement was rendered by the Spanish court, committing Spanish regions to actively fight air pollution if their air quality data exceeds EU limit values.

Reflecting on the evaluation approach revealed that participants volunteered willingly in the interviews, talking openly to researchers. While this is certainly a good method for getting very rich feedback, it requires time and effort and cannot be applied to a larger group of participants. Also, one of the main constraints for impact assessment is the limited time and resources for longer-term data collection to measure the persistence of the perceived change over time. Thus, additional impact at regional policy level might become visible only at a later stage and not be captured by the project evaluation.

Plastic Pirates: An Experimental Study Design to Assess the Impact of Citizen Science Activities on School Children

The citizen science campaign Plastic Pirates was started in 2016 as part of the research focus Plastics in the Environment, which is funded by the German Federal Ministry of Education and Research (BMBF). The scientific analysis of the data collected by the Plastic Pirates is carried out in the ocean: laboratory of the Kieler Forschungswerkstatt. The goal of this nationwide programme is to develop and establish scientific procedures, methods, instruments, and concepts for investigating plastics in the environment. Plastic Pirates invites schools and youth organisations across Germany to investigate litter contamination at a riverside of their choice. The collected data is uploaded to a database and subsequently analysed by the experts at Kieler Forschungswerkstatt. At the moment of writing, little research has been carried out on the prevalence, distribution, and range of plastic waste in German waterways; therefore these young people are making an important contribution to researching the spread of macro- and microplastics.

Evaluation in the Plastic Pirates project was specifically concerned with the influence that a conscious participation in citizen science activities may have on the interest and motivation of students. The hypothesis was that students, who know they are part of a citizen science approach, are more interested and motivated than students who participate in the project in a classic educational approach. An experimental design setup was used to compare the interest and motivation of students in different conditions. Subjects nested in classes were randomly assigned to one of two groups. One group received the intervention (information about Plastic Pirates and participation in this citizen science approach), while the control group received no information about the citizen science approach in this project. The evaluation process studied what happened to subjects in each group via questionnaires, in order to link differences in the outcomes to the intervention. This enabled the evaluation of the impact of the citizen science approach, and it was shown that the citizen science approach had a positive impact on students' interests (van den Bogaert et al. 2018).

In order to define the most effective study design for the specific question and hypothesis, this project approached the evaluation process from a widely accepted hierarchy of evidence, which claims that the most reliable evidence comes from systematic reviews, followed by evidence from randomised controlled trials, cohort studies, and case control studies. Since empirical evidence to answer the specific question was still poor, the evaluation team used an experimental field study design, introduced an intervention, and studied the effects. As common for experimental studies, the selection was randomised, meaning the subjects (in this case subjects nested in classes) were grouped by chance. Before starting interventions in the field, experimental studies need a lot of preparation time. During the preparation, different challenges have to be faced, for example, assigning school classes to different conditions when the teachers believe that students in a control group might miss essential content. Also, whole-day interventions require a challenging coordination of arrangements with teachers and school leaders, because lessons have to be cancelled. But the prospect for schools to work on current scientific topics is an attractive one that is unique to citizen science projects.

WTimpact: Assessing Citizen Science as a Tool for Knowledge Transfer

The interdisciplinary research project WTimpact, funded by the BMBF from 2017 to 2020, aimed to assess the effects of citizen science on the participants. This research project comprised three citizen science studies. The Leibniz Institute for Troposphere Research conducted a study in which volunteers measured air quality in Leipzig. In two studies run by the Leibniz Institute for Zoo and Wildlife Research, participants recorded the biodiversity of terrestrial mammals and bats in Berlin. In all three studies, citizen scientists were provided with devices for collecting data and afterwards uploaded their data to an Internet platform. On this platform, they could also find information on the specific content and the scientific process, analyse their own data as well as the aggregated data set, and discuss their experiences, questions, and results in the forum. Education researchers and psychologists from the IPN – Leibniz Institute for Science and Mathematics Education and the Leibniz Institut für Wissensmedien evaluated the outcomes at the individual level of participants with regard to content knowledge, scientific reasoning, ownership, and attitudes towards science and citizen science.

Participants were asked to fill in detailed questionnaires including tests of their content knowledge and scientific reasoning skills before and after the project. In addition, all activities of the participants on the Internet platform were tracked in order to correlate individual learning outcomes derived from the questionnaires with participation in scientific activities on the Internet platform.

This setup proved valuable for evaluation purposes. One very clear result was that offering background materials and tools for data analysis does not necessarily lead to citizen scientists actually using these opportunities for participation in scientific activities. Thus, if evaluation results are interpreted based on the scientific activities theoretically available to participants, rather than the ones they actually engage in, this may lead to misleading results.

The questionnaire was refined in different rounds of the project, taking into account the participants' feedback. One of the challenges was to balance the aim of adhering to scientific standards in social and educational sciences (e.g. ensuring internal consistency by a certain degree of redundancy) with the amount of time and effort participants could be expected to invest in answering the questionnaires. Restricting the length of the questionnaires, in turn, meant that not all potentially relevant outcomes could be covered. Regarding the knowledge and scientific reasoning tests in the questionnaires, another challenge was that some participants expressed that they felt like they were taking an IQ test, leading them to wonder about the 'true purpose' of the study. This improved when the scientists explained to the citizen scientists in more detail what the questionnaire entailed and what they were aiming to achieve with it (albeit without providing the research hypotheses to avoid prompting participants to provide socially desirable answers).

Initial results from the evaluation showed that participants gained content knowledge in the project, and this was influenced by their scientific reasoning skills and their motivation. Also, their attitudes towards citizen science and towards science in general improved, which, amongst other things, depended on their attitudes towards the topic and their participation in scientific activities on the Internet platform.

Future Trends in the Evaluation of Citizen Science

We see future trends in the evaluation of citizen science on three levels. First, new approaches will put the evaluation of citizen and community benefits in perspective. Second, new methods will allow us to enrich the way evaluation is done. Finally, new topic areas, such as human health and food, will influence the demands on the evaluation of citizen science initiatives.

New Approaches

New approaches to evaluation will focus strongly on the dimensions of individual and socioecological benefits, by involving all actors more intensively in defining, collecting, and analysing evaluation data.

In a recent paper, Mayer et al. (2020) propose a participatory approach to evaluation, which they label *co-evaluation*. It is defined as a process that involves all relevant actors in a project in an iterative evaluation practice and combines methods of participatory action research for evaluation purposes. It is inspired by community-based participatory research as well as science and technology studies' perspective on the evaluation of public participation exercises in research. Project goals and objectives and understanding of success, challenges, and unintended aspects are collectively discussed and documented at the beginning of a project and regularly revisited during the research design and execution, ideally even beyond the project's end. Assessment and intended impacts hence become transparent entities in the project design and important elements of the research tools inventory. With this participatory approach towards evaluation, the authors argue that citizen and community benefits, as well as the wider sociopolitical and ecological impact, can be equally assessed, alongside scientific goals, and form an integral part of the evaluation scheme.

The presented approach does not focus on individual learning outcomes but has a more social focus. During the co-evaluation process, which is conducted as a team effort that includes relevant stakeholder representatives, the assessment procedures may vary greatly in their manifestation, from surveys to storytelling to improvisational theatre, depending on the context. Another important aspect of this approach relates to the dimension of *open science*. In the process of co-evaluation, informed consent procedures and open data strategies are determined collectively by the participants.

New Methods

New evaluation methods will help to collect evaluation data and deepen the understanding of citizen science outcomes. In the past few years, a rising number of articles reflecting on the usage of specific methods for evaluation have appeared. One may assume that this increased interest in applied methods will also result in an uptake of new methods and instruments. One example is the *experience sampling method* (ESM) (Larson and Csikszentmihalyi 2014). This approach might help to better answer questions like: What is the typical citizen scientist like, and how much do citizen scientists differ from each other? What motivates citizen scientists? and What do they learn, and how do they change their behaviour? So far, it is common in evaluation research to ask participants to reflect back over weeks and months and provide a summary account of their experiences. Therefore, new approaches like ESM, which have not yet been applied in citizen science, might provide a valid instrument for systematic self-reporting, allowing the creation of an archival file of daily experiences. In ESM, upon receipt of random signals, participants respond to questions about their objective situation and their subjective state at that moment, such as their cognitive, emotional, and motivational state (Larson and Csikszentmihalyi 2014). Such data can be used to generate summary accounts without the biases introduced by retrospection over relatively long periods and allow observing changes in participants over time, as well as individual differences in such change.

Another method that can be considered in citizen science evaluation requires a shift in perspective, towards a person-centred approach. *Latent class analysis* (LCA) is a method frequently applied in social science data analysis (Collins and Lanza 2010) and is used to trace the heterogeneity in a group to a number of underlying homogeneous subgroups, at specific measurement points, allowing for their longitudinal extensions. LCA also allows empirically representing not directly measureable aspects, like social class, lifestyle, and recreational behaviour, via directly measurable variables in the form of typologies.

If applied in a citizen science context, this may allow a better understanding of the subpopulations engaged in scientific tasks and their specific characteristics that might change over time.

New Topics of Research

And finally, citizen science is finding its way into new fields of research, bringing new challenges from an evaluation perspective. One growing area of opportunity for citizen science methods is in the fields of health and biomedical research. If we take health research as an example, we come across online communities such as PatientsLikeMe, where patients share their health data for research on various conditions, generate hypotheses based on common experiences and conduct their own experiments. Such citizen science activities are certainly prime opportunities with regard to health literacy, empowerment, and active participation in public health governance (Den Broeder et al. 2018), which deserve proper project evaluation in order to show those impacts.

However, this type of citizen science raises complex ethical issues that may be of less relevance for other disciplines. Ethical aspects have to be given special attention, especially when assessing the impacts of such citizen-driven initiatives, and we need to look very carefully at potential negative and unwanted effects, like the spreading of misinformation. The peer review process of scientific publishing combined with the slow pace and high cost of clinical studies has limited broader participation in health and biomedical research so far but has the virtue of preventing the spread of misinformation (Wiggins and Wilbanks 2019) – an aspect which should be carefully considered in future evaluation activities by involving a wide range of stakeholders in evaluation and applying a diversified set of evaluation instruments that allow critically examining the citizen science outcomes and impacts from various angles.

Lessons Learned and Recommendations in Evaluating Citizen Science

For many citizen science projects, outcome evaluation, beyond the purely scientific results, is not a priority. Having to deal with the active involvement of citizens and the continuous bidirectional communication with all target groups, while driving the research process and answering the research questions, constitutes a considerably higher workload compared to traditional research practice. Many initiatives have limited resources and lack specific expertise in evaluation. However, as pressure from funding agencies, universities, ministries, etc. increases, there is a rising need to provide evidence of the outcomes and impacts of citizen science projects beyond the science itself.

Thus, evaluation of citizen science is in a continuously developing state, not unlike the field of citizen science itself. In recent years, the number of scientific articles, discussions, and demands for evaluating citizen science initiatives has been growing steadily. Examples are now emerging of citizen science projects that provide evidence for concrete outcomes and impacts, and some also share their lessons on the applied tools and methods for evaluation.

The majority of scientist-led citizen science initiatives measure their outcomes in the scientific dimension, using broadly accepted and standardised indicators, such as the number of scientific publications or presentations at scientific conferences. A smaller number of these initiatives investigate their impact on the individual citizens involved in the research. We find evidence in the literature of how the involvement of volunteer citizens in the research process in different thematic fields impacts participants' content knowledge, skills, attitudes, and behaviour concerning the topic of research. Evaluation methods that focus on the investigation of changes on individual participants have been developed and made available to the citizen science community for reuse, enabling comparisons across an increasing number of projects. Looking beyond the effects on individuals, the evaluation of outcomes that affect whole regions, communities, and socioecological systems is an even more complex task. But, here we also find a number of interesting studies that show the benefits of citizen science approaches in this regard.

Still, there is a call for the further development, sharing, and uptake of standardised, easy-to-use, and proven evaluation instruments that go beyond impacts on individuals. Such instruments could benefit both project owners and the citizen science community overall and would allow for a deeper understanding of different contexts that influence the changes in individuals, communities, and regions.

Alongside the calls for more standardisation, it is also necessary to keep discussions about evaluation open and self-reflective, not only to continually improve, but also to stay flexible and adaptable to the continuous evolution of citizen science itself. There are, for instance, standardised metrics for scientific outcomes of citizen science; but in grassroots initiatives, which prioritise the impact on socioecological systems and are not led by academics, scientific outcomes are less likely to be published in research journals. These projects require additional metrics to provide evidence of their scientific impact. Also, experimenting with new evaluation approaches and methods, as introduced above, would be highly enriching: going beyond self-reporting to involve citizens from the very beginning in a co-evaluation process, or taking an inclusive look at unintended outcomes.

To date, there is little analysis of targets which were not achieved or of unintended results. Reporting on these is crucial for the whole field to learn from others' mistakes and improve future projects. But assessing unintended results is difficult, because evaluation instruments are geared towards the intended project goals, and unintended side effects may only come to light as anecdotal evidence.

At the very least, we need better access to information on the validated evaluation practices that are already in use. Existing knowledge and experiences are currently dispersed across countries, spread in disciplinary-focused journals, and published on institutions' websites, requiring much effort to find and extract the relevant content to be reused in different project contexts. A better overview is required of outcomes that have already been documented, applied instruments that have been shown to be successful, resulting in a knowledge base that is easily accessible and can continually grow, with new insights, instruments, and processes, via an active discussion by those involved. Complementary to such a comprehensive and accessible knowledge base, we would also recommend more workshops and training dedicated to evaluation, fostering the mutual exchange of knowledge and experiences between the members of the citizen science community and other disciplines, as well as involving political decision makers in the discussion. Such a process of consolidation needs to be nurtured continually, assuring that higher-level organisations (such as government authorities, research funders, and citizen science associations) are involved in shaping a broader societal assessment of citizen science initiatives and take up the results in their own programmes and agendas.

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Part IV
Conclusions/Lessons Learnt

Chapter 26
The Recent Past and Possible Futures of Citizen Science: Final Remarks

Josep Perelló, Andrzej Klimczuk, Anne Land-Zandstra, Katrin Vohland, Katherin Wagenknecht, Claire Narraway, Rob Lemmens, and Marisa Ponti

The COST Action: The Recent Past

This book is the culmination of the COST Action[1] CA15212 *Citizen Science to Promote Creativity, Scientific Literacy, and Innovation throughout Europe*. It represents the final stage of a shared journey taken over the last 4 years. During this relatively short period, our citizen science practices and perspectives have rapidly evolved.

[1]COST Actions help to connect research initiatives across Europe and beyond and enable researchers and innovators to grow their ideas in any science and technology field by sharing them with their peers. COST Actions are bottom-up networks with a duration of 4 years that boost research, innovation, and careers.

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The COST Action started in 2016, when citizen science was gaining momentum in Europe and worldwide. The first international citizen science conference took place in San José, California, in 2012. This period also saw the foundation of citizen science organisations, such as the European Citizen Science Association (ECSA) at the Museum für Naturkunde Berlin, in 2014. These milestones were not isolated events in the evolution of citizen science. There was a confluence of factors on multiple levels: globally, nationally, and locally. There was a sense of urgency to find common spaces to discuss the widespread flourishing of citizen science practices. These factors led to the formation of the citizen science COST Action.

The impetus for citizen science in Europe over the last few years is partially indebted to the activities and interactions of this COST Action. This has offered a panoramic view of new initiatives, recently built digital platforms, and ongoing hot topic debates in the citizen science community of practitioners. It also helped spark several European-funded projects. The most relevant example is EU-Citizen. Science, a coordination and support platform launched in 2019. Its goal is to become the European reference point for citizen science, through cross-network knowledge sharing on a multi-language repository website with access to projects and resources for all stakeholders.

Since 2016, the COST Action has expanded the network of people involved in citizen science practices in Europe. Even in its embryonic stage, the COST Action was a large-scale networking exercise, with the proposal writing being led by Claudia Göbel, Marisa Ponti, and Katrin Vohland. When the COST Action was launched, the initial community expanded rapidly to 500 participating individuals in 39 member countries. The success in terms of number of participants, however, meant that COST Action management and governance became more challenging than initially anticipated by the COST co-chairs, Katrin Vohland, Marisa Ponti, and Anne Land-Zandstra (who replaced Marisa Ponti when she started a new position at the EC Joint Research Centre). Reaching consensus was not always easy. Sometimes it was hard to get everyone on the same page or to engage them in the multiple issues that COST Actions face. For everyone, the COST Action activities involved a commitment beyond their organisational roles. The COST Action refunds travel costs to members, but it does not provide support with regard to, for instance, personal costs. It was therefore challenging for many of the stakeholders to invest

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time and energy in the COST Action. Co-chairs worked hard to balance the diverse interests of a large group of people and ensure all their efforts could be best aligned. As a COST Action citizen science community, we acknowledge the co-chairs for their dedicated time commitment.

The COST Action has been an arena for connecting with citizen science initiatives across Europe, from Greece to Ireland, from Norway to Spain. COST meetings have included many people from various countries, with diverse backgrounds, experiences, and expertise. It has broadened understanding of what citizen science looks like in different parts of Europe and across the world. The case of Central and Eastern Europe has been particularly interesting, since citizen science is in its infancy. It was somewhat hidden and generally initiated from different sociopolitical contexts, compared to other European countries. The COST Action has also strengthened the links between us, which will no doubt lead to continued collaboration in the future.

The COST Action has also offered workshops, short-term scientific missions, and training schools to share and exchange ideas. These have brought together a wide variety of viewpoints on citizen science and provided support to develop them. The COST Action also allowed us to learn about different aspects of citizen science from our peers in relation to terminologies, conceptualisations, and theoretical frameworks and also practical issues such as data management and interoperability. However, above all, it is always great to sit alongside others who are excited about the same things. This proximity has increased our self-confidence, self-esteem, and enthusiasm for citizen science practices.

The COST Action has enabled an academic forum to emerge for connecting disciplines and consolidating citizen science as a scientific practice. The COST Action has been a shared space, bypassing disciplinary differences, to enable the discussion of common transversal issues. For example, an economist and a public policy expert have found in the COST Action a space to work together with scholars from environmental science and the computational sciences. Computational sciences practitioners have indeed increased their presence as they are interested in shifting from a users' paradigm to a participants' paradigm, when referring to crowdsourcing and collective intelligence digital platforms. The computational sciences are expected to further increase their presence in the citizen science world in order to build better infrastructures to increase active citizenship, driving citizen science initiatives and embracing ethical and legal issues.

Many scholars from the natural sciences have also learnt from social scientists. Social scientists are increasingly needed to improve citizen science practices in terms of fair citizen participation and project research goals. Social scientists can contribute to improved reflection on these issues, by considering the social dimension of citizen science projects and guaranteeing diversity and fairness in projects among different stakeholders. On another level, the COST Action has bridged the divide between practitioners and those with a more theoretical approach. It has created spaces for listening to each other, thus increasing reflection on the practice while influencing theory based on existing experiences. Lastly, COST Action activities have allowed participants to find spontaneous ways to contribute to citizen science.

For early career researchers, the COST Action has been a great opportunity to become fully immersed in the citizen science universe facilitating horizontal-level discussions. This is often difficult to achieve coming from institutions or countries where citizen science is not well established and can be viewed with some scepticism. Additionally, working on tasks such as the current book, a lesson in collective writing and editing, has been challenging for early career researchers but allowed them to develop new skills.

Furthermore, most of the COST Action meetings included representatives from non-governmental organisations (NGOs) and civil society organisations working in the field of citizen science. This has allowed the COST Action to have a holistic perspective of citizen science practices which extends far beyond academia. This is crucial as it lies at the heart of what citizen science is. Citizen science is not only about scholars from academia in disciplinary fields; it is also about transdisciplinary cooperation across various scientific disciplines and across the boundaries of various sectors of society (private entities, public entities, NGOs, and non-formal entities). Such a *mixed economy of citizen science* – cooperation, collaboration, and exchange across stakeholders and sectors – is always a challenge (cf. Irwin 1995; Powell 2007).

The COST Action has stimulated the development of the science of citizen science from the perspectives of the *quadruple* (science, policy, civil society, economy) and *quintuple innovation* (plus environment) *helix framework* (see Carayannis and Campbell 2010; Carayannis and Rakhmatullin 2014) and *open innovation 2.0* which entails integrated collaboration and co-created shared value (see Curley 2016; Curley and Salmelin 2018). Due to the high level of heterogeneity, every occasion to meet and discuss increased innovation and creativity.

The Book

The book was planned from the inception of the COST Action. More than a year before writing the book, the co-chairs started brainstorming with a small group of COST Action members about the possible contents and the target audiences. Together, we also discussed how to include the COST Action's achievements. From this discussion, the structure naturally emerged, with three main parts: Citizen Science as Science, Citizen Science and Society, and Citizen Science in Practice. Based on the list of COST Action activities being organised, a tentative list of chapters along with an initial list of related authors was relatively easy to establish. The final configuration of the list of authors was left open, and anyone in the citizen science community was invited to join in the writing of any of the planned chapters.

Given the emerging dynamics, writing or acting as editor for the book meant being part of a European citizen science community. The final list of chapters includes more than 100 authors from 23 countries. Collaboration with the editorial team has also been very productive. We divided tasks so that two editors closely supervised each part of the book. The evolution of each part was shared with the whole editorial team periodically to discuss the content as whole.

We also involved all the authors in the editorial process. They were asked to peer review other chapters as part of the quality control process. During a meeting halfway through the writing process, authors and editors discussed the chapters and the final shape of the book. We aimed to make the authors feel like part of the publication team, and they were able to follow the overall editorial process in an integrative and transparent way. The majority of the chapters are co-written by a group of authors that had not previously written together. The diversity of authors in each chapter is another important factor. In this way, the book has organically developed a high degree of interdisciplinarity and inclusiveness in its contents, which is an important characteristic of the citizen science spirit in Europe. With collective and diverse knowledge, we have covered important issues that a person who is new to the field of citizen science would need to know.

Therefore, the book functions as a handbook rather than as an encyclopaedia or an exhaustive collection of citizen science examples. The book aims to represent the current state of the art of the field. However, this does not avoid the fact that chapters may need to be updated due to the rapid evolution of citizen science practices. We also believe that the book succeeds in combining both theoretical and methodological chapters, reflecting the practice of citizen science. There is a swift transition from the focus on theoretical descriptions and analysis to the practical specifications, tools, and guidelines that can be of substantial value, not only for academic communities but also for citizen groups, civil society organisations, and policymakers wanting to embrace citizen science practices.

Academics who are new to the field of citizen science will find the book interesting since it can provide a solid basis for discovering insights and discourses. The term citizen science itself may at first seem quite straightforward, but behind its participatory spirit lie different interpretations of the active presence of citizens in scientific research. The ambiguities and differences in its definition may seem counterproductive to the consolidation of the citizen science field. However, the fluidity and dynamism of the concept not only strengthens citizen science but also describes the heterogeneity and diversity of the community. The newcomer is also able to become acquainted with the theoretical perspectives of citizen science, including research topics where citizen science can be implemented and different aspects of citizen science practice. Illustrated with case studies, the book provides guidance on how to organise a new citizen science project while stressing the key multidisciplinary nature of citizen science practices.

In fact, the last part of the book, Citizen Science in Practice, is targeted at project managers. The chapters cover the practical aspects that need to be considered and lead the practitioner through guidelines for establishing a new project and outline key aspects, such as ethics and data management. Project managers will appreciate advice on standardised ways to disseminate citizen science projects and will learn strategies to make projects more sustainable and interoperable with other projects. The advice also includes discussion of the design of apps and platforms to support citizen science project goals. Key insights on the effort required to develop and maintain apps and platforms are balanced with the ability to use off-the-shelf solutions.

We also aimed to make this book relevant for policymakers, policy officers, and public managers who work in various institutional environments at all levels: local, regional, national, European, and international. They can further reflect on what is needed to move forwards by transforming citizen science knowledge into dedicated and focused policy actions. In the book, entities supporting science can find practical tips for government employees responsible for collaboration with academia and the public, including the dissemination of results of scientific activities. The book can also help experts working at the regional and local levels who are responsible for direct cooperation with civil society organisations, by illustrating key aspects needed to organise and implement citizen science activities.

Ideas and recommendations provided can also be easily adapted to the specific needs and conditions of public programmes and funding schemes, as well as legislation and associated regulations related to the participatory spirit of citizen science practices. From the perspective of developing such programmes, the book analyses cross-cutting issues in citizen science practices, such as ethics, gender dimensions, and the management of intellectual property, as well as digital platforms and data management. Local, regional, national, and international policymakers can find guidance to support citizen science and to ensure project quality. From a broader perspective, practitioners will also find the evaluation framework invaluable. The evaluation covers scientific, participant, socioecological, and economic dimensions.

Civil society organisations will also find the book insightful. Their role in citizen science is examined in the Citizen Science and Society part. There is much work to be done to connect their mission to scientific activity. The roles of each of the actors and their rationale for engaging in citizen science are discussed. Civil society can appreciate and reflect upon key agents of transformative research, which in some cases might be framed within *citizen social science*. Citizen social science includes concerned persons or groups who are typically excluded from research processes. Prominent examples are AIDS treatment activists and movements; patients' associations introducing social dimensions in mental health care; and environmental justice movement organisations, which focus on the vulnerability of specific social groups. Organisations hoping to identify the problems affecting our environment and our societies might find this particularly informative. The different audience attributes and project types being presented could inform the design of their own projects.

Possible Futures of Citizen Science

The writer Mark Twain once said: 'The future interests me – I'm going to spend the rest of my life there'. We want to close this book by delivering some thoughts about the possible futures of citizen science and the challenges that citizen science will face

(Bonney et al. 2014). Despite the risk of getting it completely wrong, and thus being discredited when the future becomes present, this is a necessary exercise to further reflect on the nature of citizen science practices.

Funding In the short term, the most important challenge might be funding. With a few exceptions – such as in Austria, Germany, the Netherlands, and the United Kingdom – citizen science is not consolidated in national research programmes. It is true that in other countries, such as Spain, citizen science projects receive funding, but it is constrained to public awareness and science communication funding programmes. These programmes are generally modest and tend to omit the quality of research outputs when evaluating proposals. Unfortunately, on a more strategic level, there will be austerity measures related to the economic and political consequences of the COVID-19 pandemic for several years. In general, but especially in peripheral countries where citizen science is still young, it could be challenging to secure public funding, and this may limit the advancement of citizen science practices. The lack of funding can hamper the quality assurance of citizen science projects and can have knock-on consequences for the multidisciplinary nature of citizen science.

The short-term evolution of citizen science in Europe is strongly shaped by the EU funding programmes managed by the Research Executive Agency of the European Commission. This research funding organisation has invested more money in citizen science projects over the last 3 years. Its funding scheme asks for consortia composed of at least three European countries so that the project unites and aligns efforts at the European level. Horizon Europe will be the ninth European Framework Programme (2021–2027). The scope of the funding calls will have a key role in shaping citizen science in the future, but this programme is still in progress at the time of writing (European Commission 2019, 2020). However, national contacts are anticipating that citizen science and participatory research practices might eventually be included in a transversal manner across the different calls of the work programme instead of having specific calls for citizen science. The citizen science community does not have a consensus view on whether this would be the best strategy to promote the adoption of citizen science principles in a large number of EU research funding calls. The transversal approach has a positive aspect because it recognises citizen science practices within the scientific research world, and this could be a path to becoming mainstream. However, there is a risk of downgrading the ambitions of citizen science if they are instrumentalised and trivialised by the current research establishment. The alternative would be to preserve citizen science in a limited but protected space with topic specific calls.

Project Management and Organisation The current COVID-19 pandemic will also affect management and organisational issues in citizen science projects and may have contradictory effects. We face the challenge of organising most participatory activities differently, due to social distancing measures. Trust and social ties around citizen science activities are currently built mostly through direct and physical contact. Therefore, the call for social distancing also means testing new, alternative ways of communication and interaction. Some citizen science projects may provide opportunities to escape feelings of powerlessness. Citizen scientists may contribute to the search for proteins (for instance, Foldit), but also report personal and societal shifts. The situation could be an opportunity to awaken more global citizen science projects, enhance worldwide distributed activities, or show how citizen science can participate in and enrich socially relevant discourses. In any case, the current dynamics and strategies in citizen science will need to be revised and adapted while trying not to exclude specific communities or groups that are not as comfortable in digital or physically distant spaces. The situation could also disincentivise disparate initiatives. This could limit the duplication of citizen science efforts and make them more efficient, coordinated, and distributed across countries and disciplines. The crisis could also be an opportunity for the development and further dissemination of innovative citizen science methods and tools.

The next few years could be a testing time to prove the usefulness and effectiveness of new ways of organising scientific processes and scientific organisations. The academic community could be driven by the socio-economic situation to be more open and receptive to exchanges and collaboration with citizens, public entities, and civil society organisations which want a more adaptive, responsive, and agile science to respond to societal challenges. The next few years could lead to a 'new enlightenment' (cf. the Enlightenment 2.0 programme of the European Commission's Joint Research Centre[2]; Mair et al. 2019). New hybridised research methods and tools will emerge from the collaborative efforts that might be facilitated at the local and regional levels. The need to find cost-effective solutions to gathering data and achieving novel scientific results could favour citizen science practices.

Over the next 20 years, citizen science will have to deal with societal factors that are liable to drastic and unexpected change. For example, labour conditions will be modified, and it is unclear how, and if, volunteering, spare time, and employment will overlap. Also, science in general, and research infrastructures and universities in particular, is rapidly moving towards a more flexible and permeable environment.

Another important aspect is the need to further advance the consolidation of mutual learning spaces for the community of practitioners. ECSA and EU-Citizen.Science are helping with this challenge across Europe. EU-Citizen.Science offers a meeting place for researchers, policymakers, civil society organisations, and individuals. However, there are still many metalevel issues that will need to be deeper considered. The most important challenge might be to deepen the exchange of experiences between countries and cultures. Some other common challenges exist around how to engage with those who are not initially interested in science and how to embrace diversity. These latter efforts are related to a better understanding of the impact of participation on scientific literacy. This in turn is related to the power of citizen contributions in successful scientific projects and the potential of bottom-up approaches and co-creation strategies to develop innovative science.

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[2] https://ec.europa.eu/jrc/en/enlightenment-research-programme

Impact In Germany, for instance, there is a demand for proof of impact in citizen science practices, and we expect to see this expanding to other countries. Once citizen science has matured, there will be a greater need to show how citizen science is improving standard research practices, how citizen science can result in better and more representative data, how participation promotes democratic values and collective decision-making for new policies, and how schools can provide motivation in *science, technology, engineering, and mathematics* (STEM) subjects. These are signs that citizen science is maturing, but this open framework will also require the citizen science community to increase their quality standards in an extremely wide set of aspects, much wider than those demanded in standard scientific research projects.

We, as authors, also take a longer-term perspective of 5 years. We expect a stronger citizen science presence inside the scientific system, but also with a more transformative spirit. Citizen science practices reveal the ongoing challenges of citizen engagement and inclusivity. It will become even more important to address these due to the expected increase in inequalities and socio-economic divides. Citizen science will continue to prove its value by providing appropriate arguments to engage and communicate with each of the different stakeholders. We envision that success will also be linked to better representations of the different strata in our societies. This will be a key challenge for citizen science engagement, and a vital one, if citizen science is to uphold its shared values. For many policymakers and scholars, citizen science methods are still not seen as comparable to traditional statistical sampling methods, such as randomised controlled trials and representative surveys. Citizen science will have to find ways to further show the robustness and, by extension, the validity of their scientific results.

Technology Given the recent progress in *data science*, data sharing among participants could become easier and safer due to better digital tools. Also, with the rapid advancement of artificial intelligence, some tasks done today by citizens could also be, at least partially, replaced by algorithms – the concept of participation will in turn need to be reconsidered, especially in contributory projects using *crowd science* strategies. This effect could, in fact, increase the pre-eminence of the co-creation component in citizen science projects, thus providing citizens more opportunities to be engaged in all aspects of the research process. We still do not know what the technological factors will be and which emerging technologies will be implemented in the upcoming years. However, we can already anticipate that mobile phones and their evolved forms will be bundled with a myriad of low-cost sensors relevant for citizen science observations. Mobile phones will become powerful enough to process sensor data on the spot, with the help of artificial intelligence and machine learning computational efficiency. The Internet of Things, distributed computing, cloud computing, and cognitive computing will surely transform the concept of participation when dealing with data interpretation in a citizen science project. A good part of the data analysis could be done in the field in near real time, and citizens could benefit from in situ information provision. In combination with social media, individuals and their backgrounds will also personalise data generation and conversations with volunteers. This effort needs to be carefully balanced with privacy issues and any exacerbation of inequalities and social exclusion. In relation to some contentious topics, such as environmental pollution, the ability to preserve participants' privacy could become a serious issue in countries where freedoms of speech and of information are not fully respected. Citizen scientists could be prosecuted and even receive death threats if they report sensitive observations.

Participation Due to the current trend to intensify hands-on and inquiry-based learning strategies, educational resources linked to citizen science will be even more present. Participatory citizen science tasks will have a stronger learning focus, both within formal and curricular education and informal lifelong learning contexts. We also expect that citizen social science will increase its relevance, with a stronger role for civil society organisations, embracing participatory strategies to strengthen their mission. This could position citizen science as more closely aligned to social and environmental actions. Citizen science would in all likelihood develop more hybrid forms that are less subordinate to academic rules and structure.

The COVID-19 crisis might also affect participants' willingness to collaborate since citizen priorities could change rapidly during the socio-economic crisis that experts are anticipating. For many people, participation in citizen science projects may no longer be attractive. They may now lack the necessary spare time to undertake the planned tasks. More dedicated analysis about benefits and advantages will be necessary in terms of social, human, cultural, and creative capital. While the natural sciences may still hold a dominant place in the citizen science world, an increase of citizen science projects related to social and health issues might also be anticipated. This will be encompassed by citizens' growing need to empower themselves in these issues due to the likely increase in socio-economic inequalities, alongside a decrease in public funding for health-care services. Also, based on the strong debates on the use of apps for tracing contacts during the COVID-19 crisis, public opinion may have a higher sensitivity to data privacy and ethics (Council of Europe 2020). These will now need to be considered with even more rigour in citizen science digital platforms.

Research The overall quality of citizen science projects will still be pursued, but challenges may no longer be primarily linked to increasing the presence of citizen science practices in academia. Citizen science could then have more opportunities to engage with diverse stakeholders. Scientific research would be less exclusive. Anyone in society could have access to the necessary tools and resources to undertake research. The publication of scientific results will change, seeking transparency, accessibility, flexibility, and even more impact. An educator with his or her own classroom could eventually take leadership of a global project. In relation to specific topics, the first-hand experience of concerned groups or communities will gain relevance. For instance, the involvement of older people in the co-creation processes of scientific research will be fundamental to informing better understanding of population ageing. At a lower level of intensity, further development of remote work and new employment formats will shape more strongly what we understand as citizens' contributions to citizen science projects.

Environmental issues and the climate change emergency are key global issues and will be aligned to a sense of urgency and need for immediate action, with implications for citizen science projects. *Fake news* and bubbles of information will also be widespread digital phenomena and will deeply influence our societies; citizen science practices could confront them and the polarisation of society by creating a productive dialogue through jointly gathered evidence and data (see Mair et al. 2019). Digital platforms, which today are looking for new ways to understand democracy, could also find in citizen science a perfect partner to enhance empowerment and consensus building. These driving forces will surely modify the current ways of designing citizen science projects, which perhaps will be more related to individual well-being, lifelong learning, and social ties.

Conclusion

The challenge of transferring and exchanging good practices, as this book aims to do, will always exist in the citizen science community. The transparency and honesty of scientific results is something to be valued. Improving the replicability and scalability of projects will require investment of time. There will always be space to improve the participation of the public and other stakeholders in our diverse societies. If science is about knowledge and satisfying our endless curiosity as humans, citizen science will always represent the desire to make this journey together as a global and diverse society.

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