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.

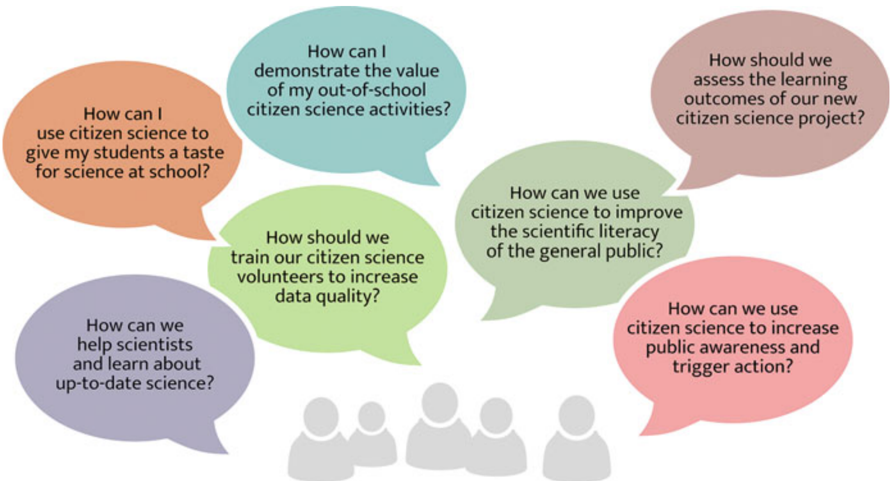

Fig. 15.1 Frequent questions regarding learning in citizen science

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

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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.

[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

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[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).

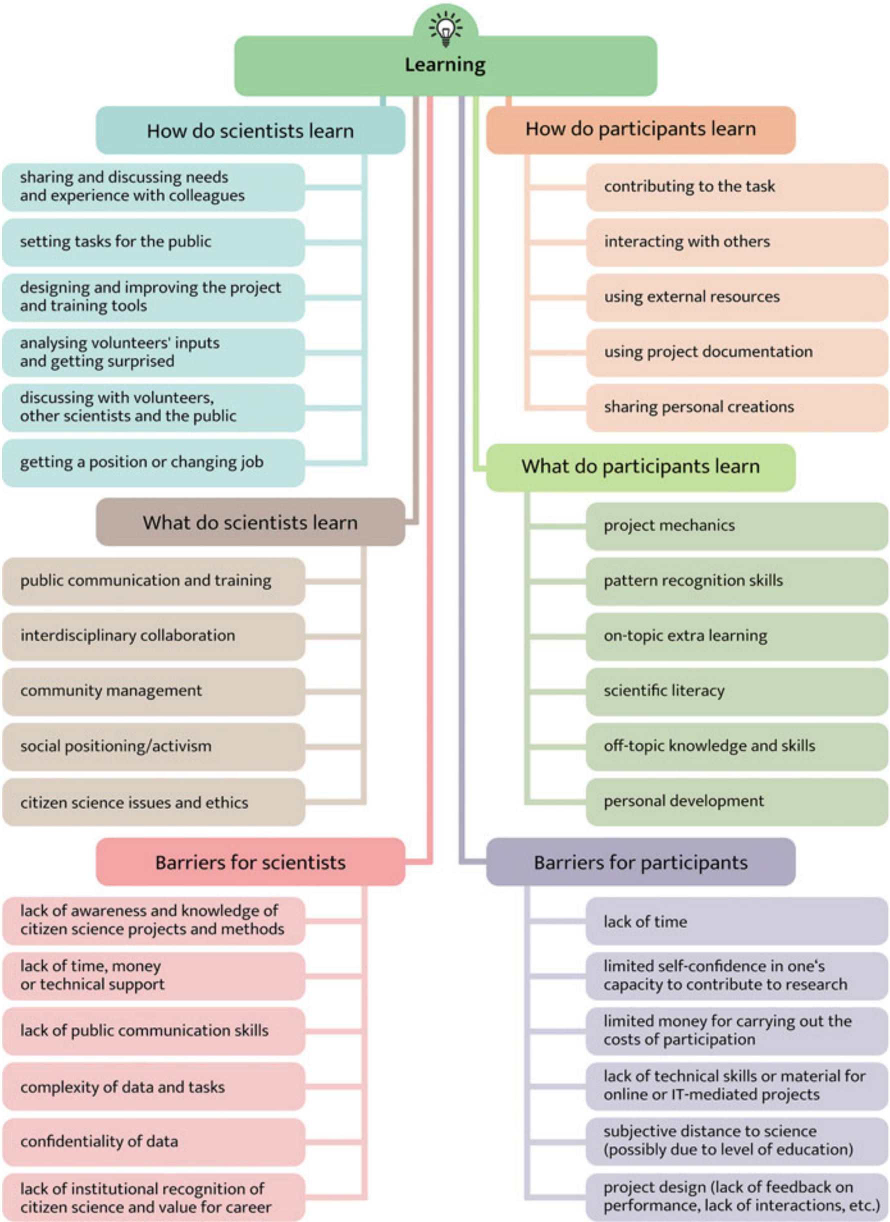

Fig. 15.4 Extended thematic map of volunteers' learning

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

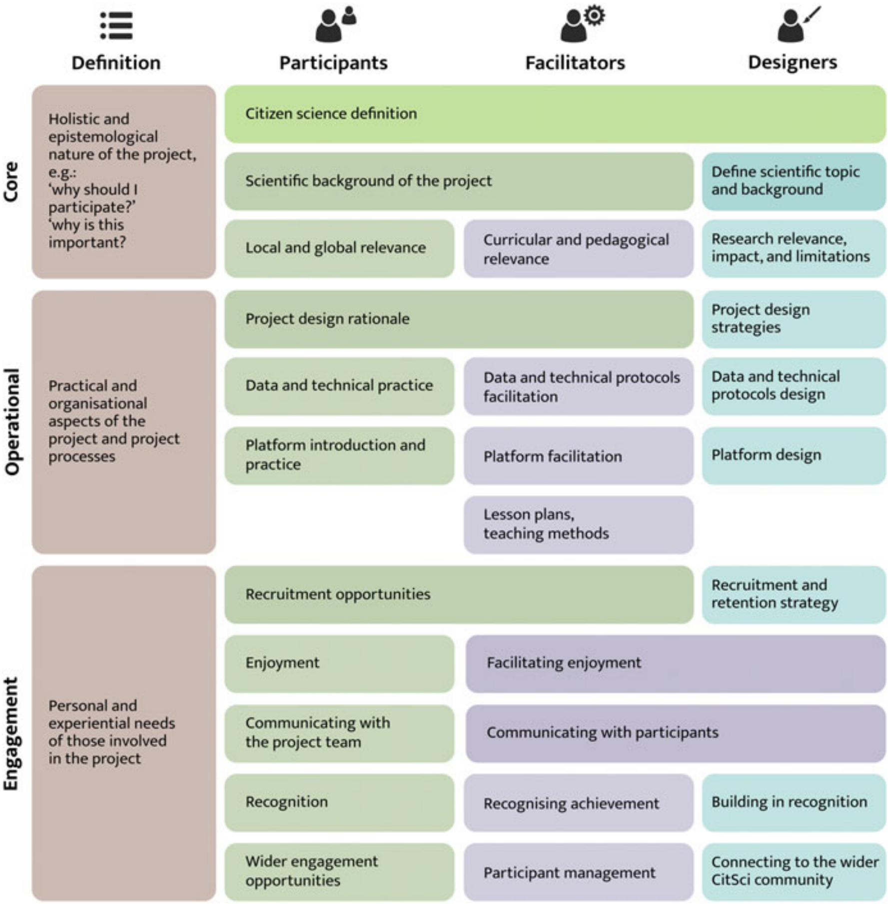

Fig. 15.5 Summary of training needs in citizen science. (Lorke et al. 2019)

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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