26
Learning and developing science capital through citizen science

Richard Edwards[1], Sarah Kirn[2], Thomas Hillman[3], Laure Kloetzer[4], Katherine Mathieson[5], Diarmuid McDonnell[6] and Tina Phillips[7]

[1] *University of Stirling, UK*
[2] *Gulf of Maine Research Institute, Portland, US*
[3] *University of Gothenburg, Sweden*
[4] *University of Neuchatel, Switzerland*
[5] *British Science Association, London, UK*
[6] *University of Stirling, UK*
[7] *Cornell Lab of Ornithology, Ithaca, NY, US*

corresponding author email: r.g.edwards@stir.ac.uk

In: Hecker, S., Haklay, M., Bowser, A., Makuch, Z., Vogel, J. & Bonn, A. 2018. *Citizen Science: Innovation in Open Science, Society and Policy*. UCL Press, London. https://doi.org/10.14324/111.9781787352339

Highlights

- Increased attention is focused on how to support and evaluate participation and learning through citizen science.
- The dimensions of science capital provide a new framework through which to consider participation and learning.
- The links between volunteers' prior level of educational qualifications and disciplines studied, and the learning they report from contributing to citizen science are not uniform across projects.
- The levels and dimensions of volunteers' engagement and learning do not always reflect the intentions of citizen science project designers.

Introduction

Inclusiveness and learning are two concepts underpinning the principles of citizen science put forward by the European Citizen Science Association (ECSA). The learning of volunteers in citizen science and its educative potential have been much discussed in recent years, as have the educational backgrounds and qualifications of those contributing to such projects (e.g., Bonney et al., 'Citizen Science', 2009; Garibay Group 2015; Haklay in this volume). There has also been growing exploration of how project design can affect the educational profiles of volunteers, the learning potential of projects (e.g., Phillips et al. 2014) and how projects may be designed to widen participation in citizen science (Novak et al. and Mazumdar et al., both in this volume). Overall, however, the educational impact of participating in citizen science has remained under-researched (see also Peltola & Arpin in this volume). Evidence is often anecdotal or based on evaluations rather than up-to-date learning theory and systematic research (Falk et al. 2012).

This is beginning to change and this chapter offers research evidence on learning through citizen science based on work that has been developed in the United States and Europe. This is ongoing, so broad conclusions would be premature. Research on learning through citizen science is in its infancy and, while it can draw on wider research traditions in informal science learning (e.g., Falk et al. 2012) and informal and experiential learning more generally, this is not yet fully the case. The chapter also seeks to make the case for considering learning through citizen science within a broader conceptual framework, that of science capital (Archer et al. 2015). The developing concept of science capital points to the iterative relationship between people's dispositions towards science, participation in science-related activities and science-related outcomes, including learning (DeWitt, Archer & Mau 2016). Basically, the more one is part of a culture of participation in science-related activities, the more one is likely to develop science learning outcomes and the disposition to participate further in science-related activities. In other words, developing science capital means developing a culture of participation in, and learning from, science-related activities, including citizen science.

The concept of science capital is relatively new within research on science learning in general and at the periphery of research and practice in citizen science (Edwards et al. 2015). It provides a broader framework to consider issues of participation and learning in citizen science. It contrasts with many preliminary explorations of learning through citizen science, which focus primarily on what people learn and how best to evaluate learning outcomes while trying to draw connections to peoples' motivation to participate. These outcomes can be identified narrowly or broadly. Narrow science learning outcomes may embrace areas such as domain knowledge, for instance in relation to specific fauna or flora, or specific scientific methods. Broader learning outcomes may embrace areas such as environmental stewardship and the development of science identities.

While there has been a widening of ideas about what volunteers may learn from participation in citizen science, less attention has been given to how they learn; that is, the practices in which they participate that enable learning when contributing to citizen science projects. Exploring how people learn focuses on the people and resources with which volunteers interact and how they engage with them to learn, if indeed they do learn. Better understanding how people learn can enable practitioners to better design projects or develop curriculum, training materials or professional development materials for teachers to enhance the educative potential of citizen science projects. Learning is not simply cognitive, but also social and cultural (Fenwick, Edwards & Sawchuk 2011), hence the interactions among volunteers or between volunteers and project coordinators, and facilitation thereof, should be carefully considered.

If it is important to develop broad science-related outcomes, including learning, then exploring the social and cultural aspects of volunteer participation – the nature and extent of their science capital – and how these can be developed becomes important. Some citizen science practitioners are becoming interested, therefore, in how citizen science might enhance the building of science capital among volunteers – developing a wider culture of engagement in science-related activities – as well as their specific science learning through individual projects (e.g., Bailey 2016; Kirn 2016).

This chapter suggests that an approach to developing citizen science projects that seeks to develop science capital could have positive benefits on the educational profiles of those who participate and enhance the educative potential of citizen science.

Science capital

The concept of science capital has been developed from the work of the French sociologist Pierre Bourdieu. Science capital refers to the educational qualifications, social networks, dispositions and behaviours among those working in, or engaged with, sciences (Archer et al. 2015). It is a subset of the social and cultural capital that accrues to individuals unequally in society and results in the reproduction of those inequalities. In other words, inequality is not only economic, but is also social and cultural.

The existence of individuals and families with higher or lower levels of science capital, therefore, can be utilised to explain inequalities in participation in science-related activities and the unequal learning of science. It can also help to shape practitioner responses to this situation. Science capital can be seen as a resource to support the development of science learning and identities as part of a culture of engagement with science-related activities. Individuals and families may develop more or less science capital and the children of those families with most science capital are more likely to consider science education and a scientific career as options for their futures (Archer et al. 2015). Science capital helps explain the ways some people engage with and learn sciences, while others do not, and can also be considered an outcome of participation in science-related activities. In other words, the more one develops science capital, the more one is likely to participate in science-related activities, thus further enhancing one's capital.

Archer et al. (2015) identify eight dimensions of science capital:

- scientific literacy;
- scientific-related values;
- knowledge about transferability of science in the labour market;
- consumption of science-related media;
- participation in out-of-school science learning contexts;
- knowing someone who works in a science-related job;
- parental science qualification; and
- talking to others about science outside the classroom.

Some of these dimensions may be used to design citizen science projects and develop pedagogical and other interventions that can build science capital and change current patterns of participation. Science capital also suggests that broadening participation in citizen science and enhancing its educative potential is not simply an educational issue, but also social and cultural. Citizen science projects may become a means to enhance volunteers' science capital, but, at present, they seem to draw largely from populations with higher pre-existing levels of science capital. Refocusing attention on potential volunteers with lower science capital means addressing the wider cultural factors that influence what and how people participate in science-related activities in society.

Little research has yet been done to investigate how citizen science participation may increase science capital and the concept itself is still in development. More rigorous research drawing on the notion of science capital is required before stronger claims can be made. This might involve new studies or the re-analysis of existing datasets. Some existing studies are discussed in the next section.

Science capital and volunteer demographics

Understanding who currently contributes to citizen science and their educational and wider backgrounds is an area of concern. While there are significant attempts to widen participation and encourage diversity among volunteers contributing to citizen science projects, to date most surveys show that it is those that are older, more highly qualified and from higher socio-economic backgrounds who are most likely to participate (e.g., Garibay Group 2015). In addition to these factors, gender and race are also significant in who volunteers in what types of citizen science project. In general, it is the already advantaged – those with the greatest social and cultural capital – who are most likely to volunteer. This is a pattern to be found in volunteering more broadly (European Foundation for the Improvement of Living and Working Conditions 2011). Determining the extent to which this is also related to higher levels of science capital, however, means examining the specific scientific disciplines previously studied by volunteers and the nature and level of their engagement in wider science-related activities.

In two ornithology citizen science projects in the UK studied by Edwards, McDonnell and Simpson (2016), 83 per cent of respondents were male, 98 per cent were white and the largest proportion was in the 61–70 age range. As a proxy of their higher socio-economic status, 67 per cent of respondents had a university-level qualification. In other words, the majority of volunteers might be argued to have high social and cultural capital. Exploring further, the study found that large numbers of volunteers had gained either school and/or university-level qualifications in the sciences. Therefore, a majority of volunteers could further be argued to have higher levels of science capital as the basis of their participation in these citizen science projects than the wider population. To explore the impact of citizen science participation on the development of science capital, the study also explored volunteers' enjoyment of participation in a wider range of science-related activities, such as scientific hobbies or watching science television programmes as a result of participation in the projects. Little overall affect was found. The building of science capital was not an explicit goal of the two projects studied, nor does it appear to be a significant implicit outcome.

Working with schoolchildren offers an opportunity to engage a population with more diverse levels of science capital than would be the case through volunteer-based projects (see Makuch & Aczel; Harlin et al., both in this volume). In these cases, the student citizen science participants are not volunteering out of interest, but rather participating in a compulsory curriculum. Increasingly, citizen science programmes are designing experiences and curriculum that engage students in both practising the skills of science and interacting with the broader community of volunteers and scientists also participating in the project. For instance, the Gulf of Maine Research Institute's Vital Signs programme (Kirn 2016) has developed novice-friendly protocols, standards-aligned curriculum, and professional development support and coaching for schools and teachers to facilitate the successful engagement of children in scientific investigations and provide an opportunity for increasing science capital. Through Vital Signs, students practice scientific skills to explore their environments, collect rigorous observational data, conduct peer review of one another's work, share data online, and engage in public discussion through the programme website with the scientists and natural resource managers using their data. Kirn notes how resources and protocols designed explicitly for novice volunteers, as well as interaction with experts, helps to encourage and sustain engagement and learning, contributing to an increase in science literacy. Additionally, these interactions between experts and novices give science novices the opportunity to get to know scientists and/or science enthusiasts with high science capital.

Other providers of science-related activities, such as urban ecology centres and museums, link with citizen science projects to promote wider engagement and learning. Some citizen science projects, such as eBird at the Cornell Lab of Ornithology, have developed curriculum and professional development materials for teachers to support engagement and learning. While valuable initiatives, the extent to which they continue to engage those with pre-existing higher levels of science capital rather than provide bridges for those with lower science capital remains unknown.

How and what volunteers learn

In addition to increasing knowledge in science content areas, some citizen science projects aim to increase science learning in the broader sense and include cognitive, affective, practical and behavioural outcomes (Bonney et al. 2016). Here, learning is not simply focused on the knowledge and skills relevant to the scientific goals of the specific project, but extends to a wider engagement with science as a whole. For instance, learning outcomes intertwined with environmental science knowledge include interest in science and the environment; efficacy to do and learn about science and engage in environmental activities; motivation to participate in science and environmental learning; understanding of the nature of science; acquisition of science enquiry skills such as data collection, analysis and interpretation; and involvement in environmental stewardship practices outside of project activities (Phillips et al. 2014). It is in developing these broader learning outcomes and how they are enhanced that citizen science might be said to contribute to the building of science capital and a culture of engagement with science-related activities in society more generally.

However, although many citizen science projects have successfully demonstrated an increase in participants' understanding of science content and processes, fewer studies have examined wider outcomes. For instance, in their study of ornithology citizen science projects, Edwards, McDonnell & Simpson (2016) found that large percentages of volunteers identified themselves as learning something across a range of science-related outcomes. However, it was only in relation to 'learning about the topic' and 'learning about data collection' that volunteers identified themselves as learning a lot. Prior level of educational qualification, one marker of science capital, was significant here, as there were statistically significant differences between volunteers with or without a degree. Overall, the less qualified the volunteers, the more they evaluated themselves as learning across most of the outcomes. This suggests that those with a higher level of qualification are not being extended or are not extending themselves in contributing to projects – they are simply drawing on their existing levels of science capital. There are indications from this study that citizen science participation can enhance the learning of those with less science capital.

However, existing research is not entirely consistent on this point. For instance, Kloetzer, Schneider & Jennett (2016) researched learning and creativity in nine online citizen science projects. Unlike Edwards, McDonnell & Simpson (2016), they found a very low correlation between level of education and self-reported learning. However, as with other studies, they found also different degrees of participation among volunteers with a minority being more active than the majority. The degree of active participation was linked to the level of learning outcomes reported. The extent to which that participation was linked to prior levels of science capital remains unknown. However, there are some indications that high engagement enhanced science capital as higher-order learning was related to active and social learning, and 37.5 per cent of the participants claimed that participation in a citizen science project helped them discover a new field of interest. This shows the importance of examining not only who is participating in citizen science but also how they are participating and examining the impact of citizen science on volunteers within the framework of a wider culture of participation in science-related activities.

Kloetzer, Schneider & Jennett (2016) identified a number of ways in which people learn through participation in citizen science: contributing to the project; using external resources; using project documentation; interacting with others and personal creations. These point to the relational and material ways in which people learn, and the heterogeneity of learning outcomes and processes: people learn different things in different ways within the same project. In other words, how learning is designed into citizen science projects does not guarantee that volunteers will learn what is intended or in the ways planned. The mismatches between planned and actual outcomes is found elsewhere. Drawing on a study of six citizen science projects across a spectrum of contributory to co-created (see also Ballard, Phillips & Robinson; Novak et al., both in this volume, on these different types of participation), Phillips (2016) identified four different dimensions of engagement – behavioural, affective, effort and social – and various indicators of each. Significantly, levels of engagement were not directly related to the type of project as more co-created projects did not necessarily have a larger proportion of participants identifying themselves as having higher levels of engagement. This suggests that what is planned and designed as learning does not necessarily result in the anticipated outcomes; volunteers engage with and make use of projects in unplanned ways and, as a result, learn different things.

Evidencing participants' existing expertise and how peer support occurs is another important element of citizen science practice. For instance, Hillman and Mäkitalo (2016) studied the learning of contributors to Galaxy Zoo, an online international project to classify images of galaxies (see also Haklay in this volume). They argue that online citizen science projects that focus on classification tasks tend to deliberately require relatively low skill levels since their goal is often to enrol as many volunteers as possible and render all their contributions equal in relation to the scientific protocol. Communities of volunteers were identified as developing around classification tasks and it was activities in these communities that provided a rich source for learning. It was also in online discussion among these communities that the resources volunteers drew on became visible through, for instance, moving from using URLs to newspaper articles or popular science websites to referring to more research-focused resources such as astronomical databases. Drawing on a sociocultural conception of learning as the appropriation of cultural tools or resources, Hillman and Mäkitalo (2016) used changes in resource use in online forums as an indicator of learning and scientific literacy. In the discussion forums, those with less scientific literacy moved from the use of popular to more scientific resources, from curating content to formulating arguments, and from soliciting advice to providing guidance as contributors developed more familiarity and expertise. In particular, the authors argue that the appropriation of scientific resources is a strong indicator of scientific literacy and that progression along learning trajectories is visible for new members of citizen science communities as they successively appropriate these resources. While such shifts are difficult to track in the more ephemeral interactions of face-to-face citizen science projects, the technologies of the internet often render them readily chartable in relation to online citizen science projects. Tracing the activities of citizen science volunteers as they discuss online means that data produced can be argued to reflect trajectories in the building of science capital and reveal some of the means through which it can be built.

Issues for the future

It is clear from both the research and practice worlds that learning is occurring among volunteers in citizen science. Yet exploring how that occurs as well as what is learnt remains in its the early stages, and the picture emerging is complex, full of tensions and highly influenced by context. Prior qualifications, volunteer demographics, project design, participation and engagement are all significant. Examining these issues through a social and cultural framework and drawing on the dimensions of science capital could enable a better understanding of the dynamic interrelationship of these and other issues.

At a broad strategic level, building a stronger international research base on learning in citizen science; relating it more clearly to wider educational research; and engendering stronger relationships between research and practice are clear priorities for the future. More specifically, questions remain about the correlation between project design and learning outcomes; variations in the prior science capital of participants; and what and how resources are used in citizen science projects. Much research and evaluation in citizen science to date relies on self-reported learning processes through surveys and less often interviews (see Kieslinger et al. in this volume). There is a need for more refined, ethnographically informed studies to examine more closely how volunteers learn (see, for example, Peltola &

Arpin in this volume). Exploring the extent to which patterns emerge in relation to prior science capital, project design, participant recruitment, engagement and learning would be helpful for practitioners. The forms of project support for learning, and the possibilities for peer learning within the context of projects, are also of interest. The possible contribution of citizen science to enhancing science capital has also yet to be addressed fully, as has how best to support those contributing to projects with different levels of science capital. These are only a few of the issues emerging for research and practice as the field of citizen science expands.

Conclusions

At a policy level, the potential of citizen science to engage citizens in more informed debates on science and scientific issues as they relate to broader social, economic, environmental and cultural questions is becoming clear. In relation to education policy specifically, the continued growth of the links between citizen science projects and formal educational institutions is to be encouraged (see also Wyler & Haklay in this volume). Here citizen science can be rethought of as itself a form of pedagogy, and one with the capacity to increase learners' science capital. The extent to which citizen science can build science capital and enable wider engagement with science-related issues, such as the impact of climate change, deserves further experimentation and investigation.

In relation to the management of citizen science projects, a more explicit engagement with the issues of learning and science capital would be welcome when designing and resourcing projects. This entails more and greater systematising of relevant research, and developing more and better models of research-practice interactions. As the field of citizen science grows, there will no doubt be a related growth in the diversity of projects and scientists seeking to engage participants or understand the dynamics of participation. Supporting that growth while enhancing the diversity of participants in citizen science and their learning remains a challenge, but one for which there is a growing evidence base.

Acknowledgements

Funding for the research projects reported in this chapter is gratefully acknowledged from the British Academy, European Union, National Science Foundation and Wellcome Trust.