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Book Section

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Citizen science and crowd sourcing are often used interchangeably to denote the participation of the general public in social activities or projects. The "crowd" becomes a source of information when it contributes ideas, content, or services to solve a problem, generate content, raise funds, and vote best solutions. Wikipedia (https://en.wikipedia.org/wiki/Main_Page) is a crowd sourcing example where a large number of people adds or curates information online resulting in the collective creation of a considerably large encyclopaedia. Kickstarter (www.kickstarter.com) is an online crowd sourcing website where people share their project ideas and request funds from the general public to implement these ideas. The term citizen science is more specific; it is used to denote the participation of the public in scientific or research projects. Members of the public volunteer to support the work of scientists by contributing data to projects initiated by professionals and research institutions. The Oxford English Dictionary (OED, 2016) defines citizen scientists as amateurs who engage in scientific work in collaboration or under the supervision of professional scientists with the aim to serve the community.

There is a diversity of citizen science projects available ranging from exclusively online projects to offline field-based research activities. One example of online citizen science is the iSpot platform (www.ispotnature.org/) developed and run by The Open University, UK. Members of the public identify species such as birds, reptiles, and insects, by taking and posting pictures of them on iSpot, recognise species others have posted, and comment about their contributions in forums. To recognise people's contributions and demonstrate their level of expertise, iSpot activities are rewarded with points through a system of reputation. This system can help people distinguish expert users from novices. One example of offline field-based citizen science is BioBlitz. Instead of recognizing species individually and uploading pictures of them online in platforms such as iSpot, groups of people (e.g., schools, families) gather together in a specific area (e.g., park) and work together to get an overall account of the species identified in an area often in a limited time (e.g., National Geography Society Bioblitz events, http://nationalgeographic.org/projects/bioblitz/). Environmental and ecological issues and the engagement of the public in field work have been the main focus of most citizen science projects (Edwards, 2015). The power of citizen science has yet to be harnessed in fields such as medicine and humanities. The crowd sourcing game Fold-it is an example that shows the potential of citizen science for medicine. Through engaging with protein-folding puzzles, members of the public managed to identify the structure of an enzyme involved in the reproduction of HIV, helping scientists to devise drugs to fight it (Cooper et al., 2010).

For scientists who initiate citizen science projects, the contributions of the public to research projects entail certain benefits including the accomplishment of time-consuming and expensive projects that could not be easily or at all implemented without the support of the public. For the general public taking part in citizen science, benefits are often connected to learning about science and the scientific method, appreciating nature, and supporting conservation initiatives including ensuring that species are secured and recovered (Freitag & Pfeffer, 2013). To understand how participation in citizen science projects might be a source of informal learning for the general public we first need to detail the forms this participation may take. The classification of citizen science projects by Shirk et al. (2012) sheds light in this respect. Five types of projects are proposed indicating the type of people's involvement in scientific activities: a) Contractual projects: projects are initiated by scientists due to requests by communities to conduct scientific research and report outcomes, b) Contributory projects: projects are designed by scientists and the role of the public is to collect data, c) Collaborative projects: apart from contributing data, the public contributes to refining the design of the project, analyse, and disseminate findings, d) Co-created projects: projects are designed in collaboration with the public. Members of the public are engaged in all the aspects of the research project from defining the research questions to collecting, analysing and reporting data. e) Collegial contributions: Non-professional members of the public conduct research independently.

With the exception of contractual projects, the last four types of projects indicate how the public may engage with citizen science. The criterion that differentiates types of participation is the level of involvement in scientific research. Participation in all the stages of scientific research has been coined as "extreme science" (Haklay, 2012) and "citizen inquiry" (Sharples, Aristeidou, Villasclaras-Fernández, Herodotou, & Scanlon, 2015). The latter raises the need for citizen science projects that will provide opportunities to the public to initiate and conduct their own personally meaningful research and will explicitly target informal science learning. According to Edwards' (2015) concluding remarks in a recent review of the field, it is questionable whether learning is a structured part of the design of citizen science projects. There is still the need to investigate the educational impact of citizen science projects on the public and provide opportunities for participation in all the range of scientific activities. Towards this direction, online platforms such as nQuire-it (www.nquire-it.org) have been designed to provide to the public the technology to initiate and implement citizen science projects and the tools to scaffold the process of data collection and analysis including the use of mobile sensing apps (Herodotou, Villasclaras-Fernández, & Sharples, 2014). Yet, having the public to devise their own research agendas is not without challenges such as the creation of scientifically robust investigations, the validity of the collected data, the need for moderation and advice from experts, and long-term engagement in citizen science projects to develop skills to conduct reliable research.

The type of participation a citizen science project affords affects the learning outcomes emerging from it. Bonney, Phillips, Ballard, and Enck (2016) reviewed the learning outcomes of four different citizen science projects as defined by the way participants are engaged with the scientific activities and commented on the learning potential of citizen science. In particular, a) Data Collection projects: Evidence suggest improvements in the knowledge of the general public about scientific content such as knowledge about bird biology and invasive species, and awareness of the effects of invasive species on the environment. Improvements in their understanding of the scientific process were also identified yet these were limited. No changes in attitudes about science were recorded, an outcome that might be explained by people already possessing positive attitudes when volunteering to participate in citizen science projects. b) Data Processing projects have the potential to contribute to the understanding of science as they engage people in activities such as transcription and interpretation of the collected data. Evaluation of these projects is limited yet promising. Bonney et al. (2016) make reference to the evaluation of the "Citizen Sky" project and the reporting of improvement in participants' attitudes about science and their epistemological beliefs about the nature of science after taking part in the project. c) Curriculum-based projects yielded very promising outcomes in terms of youth engagement and learning from citizen science, especially when facilitated by teachers. In particular, improvements were measured in students' content knowledge, communication, knowledge of the scientific method (including sampling, measurement, data interpretation) and science-based inferences about the natural world. Yet, as authors note, the fact that these projects take place in schools restricts their impact on community-development and personal empowerment that can lead to social change. d) Community Science projects: These projects may hold the greatest potential for learning improvements as they involve the public in all the stages of the scientific research from the shaping of research questions, to the development of protocols for data collection, data analysis and interpretation. Evidence suggest that community science projects gave a voice to people to document environmental problems that could not have done otherwise and gained insights about the scientific method when working along with scientists.

This review reveals that our understanding of what the public gains from its participation in citizen science projects is still in its infancy. More and systematic work is needed to detail the learning impact of those projects on participants. Such knowledge could inform the design of citizen science projects by documenting the design elements and mechanisms that better support learning and engagement. Quoting Bonney et al. (2016, p. 11), "practitioners who design and implement citizen science projects without specific learning objectives or lesson plans must realize that learning does not just “happen” via project participation. Citizen science participants are unlikely to change their perspectives about science unless their participation includes reflection about their role and how it relates to the processes of science".

Participation in citizen science projects might be an effective way to engage young people with Science, Technology, Engineering, and Maths (STEM), areas where youth is found to be disinterested, with rather negative attitudes and aspirations for future careers (Tapscott, 2012). Evidence suggest that there is a connection between participation in informal (out-of-the school) science activities (e.g., in the form of family initiatives) and positive attitudes towards science (OECD, 2012). Participation in existing citizen science projects or initiation of personally meaningful projects might raise youth's interest in STEM domains and bridge this gap. For the general public, citizen science might be a teaching experience that can educate on how to think critically through awareness of the scientific method and general reflection on the learning processes involved in citizen science projects.

In a society abundant with information, it becomes sine-qua-non to educate citizens in how to access and evaluate information in order to make informed decisions that consider and balance both the pros and cons of a given situation. To put this into practice, a scientifically educated public could engage critically in debates such as the provision of certain vaccination to young children (see debates around MMR) and decisions such as whether a country should remain or leave the European Union (see UK EU Referendum). An educated public would have the skills to access original sources of information around the arguments made by mass media, compare and contrast resources in terms of their reliability and validity, weigh the pros and cons of each approach, and make informed decisions considering for their impact on generations to come.

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