LifeWatch ITALY CITIZEN SCIENCE

The story of citizen science and crowdsourcing

The story of citizen science

Citizen science has many benefits over other research methods and should be seen as a powerful enabler and augmenter for the scientific process. Also, when humans are involved, there is the possibility of achieving significant positive social outcomes through civic education and participation. Individual contributors benefit from enhanced topical knowledge, or knowledge of the scientific research process. Social networks expand; and communities become more resilient, with enhanced capacity to influence research agendas and contribute to public policy dialogues (Haklay, 2015; Bonney et al., 2009; Irwin, 1995). Citizen science can also provide a form of "workplace experience" which can provide pathways to new or even first employment opportunities. In 2008, Stuart Harris, a vineyard worker in Canberra, Australia, discovered a new species of peacock spider. This experience created opportunities for him to work closely with practising scientists and set him on a path towards a new career in which he has developed many new skills and found a new personal sense of purpose and contribution to society (Vyver, 2014).

Today, "citizen science" is often just a convenient label for certain types of projects. There is no single, agreed-upon definition and typology by all parties involved, despite efforts from numerous researchers over the past 20 or so years.

Existing classifications of citizen-science projects

Here select classification efforts of citizen-science projects to date are presented. These are offered with the caveat that we are living at the dawn of dramatic changes in science, enabled by the internet, which are greatly accelerating scientific research, and empowering civic educators and citizens in transforming the nature of science.

Perhaps the most elusive problem—and also the most important—in describing citizen science originates from the multiple meanings of the concept itself. On a qualitative level, this is evident by observing how two distinct meanings have developed in the social and natural sciences respectively since the mid-1990s (Kullenberg, & Kasperowski, 2016; Cooper, & Lewenstein, 2016). Researchers often distinguish between:

1. Citizen science primarily conducted with goals including **democratization, public engagement, equity, and justice in the discourse of science and in setting the research agenda** (e.g., Irwin, 1995; Irwin, & Horst, 2015);
2. Citizen science that is focused on something else, usually on **public involvement in scientific research**, with members of the public partnering with professional scientists to **collectively gather, submit, or analyse large quantities of data** (e.g., Bonney, 1996; Dickinson, Zuckerberg, & Bonter, 2010).

While the second approach has often dominated scholarly dialogues over the past 20 years, the dramatic changes in technology that we are experiencing and the maturation of citizen-science communities could favour an increase in the significance of the first one, at least if citizen science's stakeholders recognise values in the discipline which extend beyond the value of "pigeon science" (Ceccaroni et al., 2019). Fully appreciating this trend of balancing of purpose within citizen-science communities, as they evolve and mature, requires exploring existing classifications in more detail, to better understand the history of the field and the ongoing discussion.

The examples provided in this chapter are mainly meant to facilitate the comparison among typologies. Most of these classifications are not mutually exclusive; for example, a project could be classified in terms of: governance model; goals and tasks; or intellectual property concern. Additionally, in some cases, the same

project may be classified according to a number of classes within a single typology. For example, a project may involve, at the same time and with equal priority, data collection and data processing as the nature of the activities participants engage in. Other times, classifications are designed as exhaustive and mutually exclusive. While project governance models may change over time, no single project will employ two distinct governance models simultaneously (e.g., Shirk et al., 2012).

Citizen-science projects are often classified by **the nature of the activities participants engage in** (Bonney et al., 2015):

- *data-collection* projects (the National Audubon Society's Christmas Bird Count, numerous projects hosted by the Atlas of Living Australia, scientist-lead ecological projects, etc.), for which contributors who may or may not have any formal training as scientists collect data that can be used in organized scientific research;
- *data-processing* projects (those hosted by the Zooniverse suite, Australia's DigiVol digitization project (Ellwood et al., 2015), etc.), focused on categorization, transcription and interpretation, enabled by the Internet, and sometimes referred to as "crowdsourcing" or "crowd science";
- *curriculum-based* projects (BirdSleuth, the Basin Champions program in Australia, etc.), which take place in schools or in "informal" youth-development settings, collecting and submitting data to a larger, "parent" citizen-science project;
- *community-science* projects (the West Oakland Environmental Indicators project (California Energy Commission, 2012), the highly successful Waterwatch program in south-eastern Australia (Chalkley, Brendan, & Gowland, 1999), etc.), which place local or regional issues at the heart of the research, and typically seek to affect policy or local decision-making for public health, environmental health, or conservation.

Citizen-science projects can also be classified by **governance model**, or **the extent to which the public participates in different parts of the scientific process** (Shirk et al., 2012):

- *contractual* projects (exemplified by European Science Shops (Jorgensen et al., 2004)), where communities ask professional researchers to conduct a specific scientific investigation and report on the results;
- *contributory* projects (the Christmas Bird Count, Western Australia's MicroBlitz project (Gruber, 2015), Australia's Waterwatch program, etc.), which are generally designed by scientists and for which members of the public primarily contribute data;
- *collaborative* projects (e.g., community-based monitoring of wetlands in Madagascar (Andrianandrasana, Randriamahefasoa, Durbin, Lewis, & Ratsimbazafy, 2005), which are generally designed by scientists and for which members of the public contribute data, but also help to refine project design, analyse data or disseminate findings;
- *co-created* projects (e.g., the West Oakland Environmental Indicators project), which are designed by scientists and members of the public working together and for which at least some of the public participants are actively involved in most or all steps of the scientific process;
- *collegial* contributions (as exemplified by amateur astronomers, archaeologists, and taxonomists, who often work on their own (Hopkins, & Freckleton, 2002)), where non-credentialed individuals conduct research independently with varying degrees of expected recognition by institutionalized science and/or professionals.

Another classification of citizen science according to **governance models, framed as the level of participation and collaboration between professional and non-professional scientists,** is offered by Haklay (2013):

- *crowdsourcing* projects (the Christmas Bird Count, the Australian DigiVol project, etc.), in which participation is limited to the provision of resources, and the cognitive engagement is minimal;
- *distributed-intelligence* projects (e.g., Galaxy Zoo), in which the cognitive ability of the participants is the resource that is being used;
- *community-science* or *participatory-science* projects (e.g., the West Oakland Environmental Indicators project), in which the problem definition is set by the participants, and in consultation with scientists and experts, a data collection method is devised;
- *collaborative-science* or *extreme citizen-science* projects, which are completely integrated activities, where professional and non-professional scientists are involved in deciding on which scientific problems to work and the nature of the data collection, so it answers the needs of scientific protocols while matching the motivations and interests of the participants.

Other definitions are specific to public participation in certain domains. For example, citizen-science projects have been defined by **the degree of local participation in the domain of natural resource monitoring** (Danielsen et al., 2009):

- *externally-driven, professionally executed monitoring* projects, which do not involve local stakeholders;
- *externally-driven monitoring* projects *with local data collectors* (e.g., the Citclops project on natural-water monitoring (Ceccaroni et al., 2020)), which involve local stakeholders mainly in data collection;
- *collaborative monitoring* projects *with external data interpretation* (e.g., community-based monitoring of wetlands in Madagascar), which involve local people in data collection and management-oriented decision making, but in which the design of the scheme and the data analysis are undertaken by external scientists;
- *collaborative monitoring* projects *with local data interpretation* (e.g., ranger and community-based monitoring of resource use and wildlife in China (Van Rijsoort & Jinfeng, 2005)), which involve local stakeholders in data collection, interpretation or analysis, and management decision making, although external scientists may provide advice and training;
- *autonomous local monitoring* projects (e.g., the West Oakland Environmental Indicators project), in which the whole monitoring process -from design to data collection, to analysis, and finally to use of data for management decisions- is carried out autonomously by local stakeholders; there is no direct involvement of external agencies.

In addition, numerous typologies extend beyond examining citizen science through the degree of public participation. For example, citizen science projects may be defined in terms of **project goals and tasks** (Wiggins, & Crowston, 2011):

- *Action-oriented* projects (e.g., the West Oakland Environmental Indicators project), which encourage participant intervention in local concerns, using scientific research as a tool to support civic agendas;
- *Conservation* projects (e.g., the Missouri Stream Team program on river conservation), which support stewardship and natural resource management goals, primarily in the area of ecology; they engage citizens as a matter of practicality and outreach;

- *Investigation* projects (e.g., Citclops), which are focused on scientific research goals requiring data collection from the physical environment;
- *Science-oriented virtual* projects (e.g., Galaxy Zoo), in which all project activities are ICT-mediated with no physical elements whatsoever, differentiating them from the investigation projects in which the physical places of contributor participation was also important;
- *Education* projects (e.g., BirdSleuth), which make education and outreach primary goals, all of which include relevant aspects of place.

Citizen-science projects are also defined by **the different ways that scientific inquiry can permeate the management of natural resources and collaboration between professional and non-professional scientists** (Cooper, Dickinson, Phillips, & Bonney, 2007):

- *scientific consulting research* projects (e.g., ranger and community-based monitoring of resource use and wildlife in China), in which knowledge-producing institutions (e.g., universities) function as consultants to community groups to answer questions raised by the community groups;
- *citizen science research* projects (e.g., Citclops), which engage a dispersed network of contributors to assist in professional research using methodologies that have been developed by or in collaboration with professional researchers;
- *adaptive citizen science research* projects, which involve providing a centralized organizational infrastructure that is specifically designed to promote individual, community, and regional science-based management via an interactive feedback loop;
- *adaptive co-management research* projects, where community groups, individuals, and professional land-managers and urban planners work together so that management objectives are carried out and evaluated as "experiments" tailored to specific locations;
- *participatory action research* projects (e.g., community-based monitoring of wetlands in Madagascar), which begin with the interests of participants, who work collaboratively with professional researchers through all steps of the scientific process to find solutions to problems of community relevance.

Citizen science may also be classified in terms of issues including *intellectual property* (IP) concerns (Scassa, & Chung, 2015), and many more topics. The existence and use of different classifications suggest that researchers take alternative views regarding what is and is not important to pay attention to in the field of citizen science, and how to structure their vocabularies in accordance with different values.

Existing Definitions of Citizen Science

By highlighting important aspects of the citizen science experience, these typologies lead to the related question of "What is *citizen science*?" Various definitions have been proposed, including:

- "The participation of non-scientists in the process of gathering data according to specific scientific protocols and in the process of using and interpreting that data; the engagement of non-scientists in true decision-making about policy issues that have technical or scientific components; and the engagement of research scientists in the democratic and policy process" (Lewenstein, 2004).
- "The systematic collection and analysis of data; development of technology; testing of natural phenomena; and the dissemination of these activities by researchers on a primarily avocational basis" (i.e., done regularly for enjoyment rather than as a job; OpenScientist, 2011).
- "The scientific activities in which non-professional scientists volunteer to participate in data collection, analysis and dissemination of a scientific project" (Haklay, 2013; based on Cohn (2008) and Silvertown (2009))

- "A contribution by the public to research, actively undertaken and requiring thoughtful action" (Simpson, 2013)
- "Scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions" (Oxford English Dictionary, 2014)
- "The collection and analysis of data relating to the natural world by members of the general public, typically as part of a collaborative project with professional scientists" (Oxford Dictionaries, 2014).
- A paradigm where "people who are not professional scientists take part in one or more aspects of science—systematic collection and analysis of data, development of technology, testing of natural phenomena and dissemination of the results of activities. They mainly participate on a voluntary basis." (Park, 2014)
- "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." (Serrano Sanz, Holocher-Ertl, Kieslinger, Sanz García, & Silva, 2014)
- "The public involvement in inquiry and discovery of new scientific knowledge. A citizen science project can involve one person or millions of people collaborating towards a common goal. Typically, public involvement is in data collection, analysis, or reporting." (SciStarter, 2016)

In seeking to understand who contributes to citizen science, it is also important to consider that neither civic educators nor **citizen scientists** are homogeneous groups. Social scientists made the important argument that "the public" as a single entity does not exist. Instead, we have to acknowledge the presence of a plurality of "publics" (Irwin, & Horst, 2015). In this sense, citizen scientists can be characterized as members of "communities." Such communities are thought to be at the opposite end of the spectrum of the larger "crowd" that is referred to in discussions on crowdsourcing. These communities are subsets of the public with specific and shared interests, whereas the crowd usually refers to a broader citizenry. Citizen-science community members may have some training and expertise; thus, they can be considered "expert amateurs" and not representative of the full suite of potential participants in citizen-science projects (Lukyanenko, Parsons, & Wiersma, 2016).

While existing conceptualizations of citizen science and citizen scientists are helpful points of departure, many of these major understandings and definitions do not exhaust all forms of citizen science that are of relevance for researchers interested in this phenomenon. Some leave out activities not related to the "natural world", such as activities conducted in the domain areas of health, medical science, and social science. Most of them focus on data and information, and leave knowledge and competence out of the equation. And there are still questions related to citizen science with no easy answer:

- Must citizen science generate data used in science, policymaking, or management planning? Or can experiential learning activities conducted without an impact on science, management or policy also be citizen science?
- Does participation need to be opt-in, meaning that a project mining citizen Twitter feeds about water and flooding would be out of scope?
- What degree of community participation is required? Is a project involving the use of camera traps out of scope if members of the general public participate only in the deployment of the instruments? And what about if they just change the batteries of the cameras once a year? And by the way, who owns the data collected: those who built the (possibly do-it-yourself) camera trap, those who deployed it, those who changed the batteries and retrieved the data, those who reviewed and interpreted the images, or the researchers who designed the experiment?

In addition to the above, there is the question of whether "citizen science" is even the best or most accurate term to use. *Citizenship* is the status of a person recognized under the custom or law as being a member of a country and this status plays no role in "citizen science". Perhaps "community science", "public science" or "participatory science" are better expressions. This is precisely the point made by a group of researchers in the *United States* (USA) who re-branded "citizen science" as "*public participation in scientific research* (PPSR)" in the early 2000s (Bonney et al., 2009). Notably, in the USA some organizations, including the *National Science Foundation* (NSF), still use the expressions PPSR to mean *citizen science* and also *public participation in science, technology, engineering, and mathematic research*. However other leading organizations, like the recently formed *US Citizen Science Association*, the *European Citizen Science Association* (ECSA) and the *Australian Citizen Science Association* (ACSA), use the now *de facto* standard term "citizen science," even while recognizing this nomenclature as problematic.

Finally, there is the issue of defining the relationships between citizen science and related types of open innovation activities such as: participatory mapping; *volunteered geographic information* (VGI); participatory health monitoring; social studies; and bio-medical studies, just to name some of the research and activity areas included in this book.

An Updated Distinction of Meaning

Achieving a practical working definition of *citizen science* is less important than communicating and understanding the general characteristics of citizen-science projects. Perhaps it would be more constructive to consider the *role* of these projects, in terms of supporting research, education, and/or public policy.

By synthesizing a number of the above definitions in a context of civic education, citizen science, and *public engagement in science* (PES), scientific projects in which citizens are engaged in matters of public interest, or in driving social learning, scientific endeavour or policy development, can be categorized into one of two forms:

1. "*Instrumental*" - Projects which involve the public in specific and limited parts of a process, for example, data collection. These projects usually take place in a traditional social and political structure with discrete and fixed actors who "engage" with one another in a specific context for a particular period of time, and then resume their separate, business-as-usual existences; and

2. "*Capacity building*" - Projects of a scientific nature undertaken by groups of citizens with a common goal or interest, either independently or in collaboration with professional scientists. These projects are not necessarily established exclusively to answer specific scientific questions, but rather are conducted to reach a range of social, scientific, learning, and/or environmental outcomes.

This new distinction of meaning expands and builds upon the approaches presented earlier, which framed the goal of citizen science as encouraging a more informed and active citizenry (developed in the social sciences) **or** for scaling data collection (developed in the natural sciences) (Kullenberg, & Kasperowski, 2016). Through this new categorization and slight re-framing, it is recognised that citizen-science projects can be conducted in any domain of interest to society. This categorisation also expands the previous distinction of meaning by acknowledging additional benefits of citizen science, including knowledge gains, which were not at the forefront of scholarly discourse when the previous approaches emerged in 1995. Finally, citizen-science projects of the capacity-building type are generally initiated by civic educators and involve the public as active participants (as opposed to passive data-collectors) in one or more aspects of the project activities.

While this re-framing is similar to the presentation of goals and tasks advanced by other researchers (Wiggins & Crowston, 2011), in this case, how the paradigm of citizen science itself is framed is explored. In other words, the ultimate and overarching value of public participation in scientific research is explained as:

Citizen science *is work undertaken by civic educators together with citizen communities to advance science, foster a broad scientific mentality, and/or encourage democratic engagement, which allows society to deal rationally with complex modern problems.*

This definition shifts the focus from the action-oriented, data-centred point of view of *collect*, *participate* and *contribute* (i.e., the instrumentalist point of view) towards a re-framing, based on civic education, of how science and society should respond to a call for *openness*, *inclusiveness*, *responsiveness, democratic engagement, consultation, dialogue* and *commons* (i.e., the capacity-building point of view). The definition reflects the values civic educators see in citizen science, which usually include some of the following: supporting and advancing scientific research; public engagement in scientific discourse; public engagement in informing policy at various levels, from local to international; desire to achieve a particular environmental, social or policy outcome; increased capacity to respond to community needs, such as concerns about water quality or access to scientific information; and enhancing lifelong learning/education about the scientific process, and the world around us.

By explaining the rationale behind this definition, awareness is raised of the role that semantics, or the meaning of words and phrases, plays in understanding and supporting citizen science and civic education. Semantics is important in human conversations, when diverse speakers and listeners must rely on shared or interoperable vocabularies to get their points across. Semantics is even more important in conversations between humans and machines, or between machines.

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