Citizen Science

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Definition

The term *citizen science* originates from Anglo-American contexts and generally describes the procedure of involving citizens who are not institutionally anchored in academia as active participants in a scientific research process. The use of the term "citizen" (etymologically derived from the Anglo-French word *citisein* "inhabitant of a city or community", approx. 13th century), indicates a specific understanding of the persons involved, who, in the sense of the term *citoyen* coined in the French Enlightenment, actively and autonomously participate in the community and help to shape it. The tasks of citizens in this context range from collecting data to co-designing the entire research process, applying scientific quality standards, and producing scientifically usable results (Haklay et al. 2021; Pettibone et al. 2017). Citizen science as a designation for a specific form of knowledge production is mainly used in the European and North American context, where a differentiated research and funding landscape has evolved since the beginning of this century (Haklay et al. 2021). Similar approaches can be found in other parts of the world, but are framed under alternative terms such as *community science* (Conrad and Hilchey 2011) and *community-based research* (Amauchi et al. 2022). Citizen science brings together a multiplicity of approaches ranging from mass data collection events for citizens to forms of independent or self-determined research by non-academic groups or communities, calling the term itself into question (Eitzel et al. 2017).

Background

Long before the term citizen science was coined in 1989 (Kerson 1989), citizen engagement in science shaped the history of science in North America and Europe and was vital to its formalization and institutionalization (Mahr and Dickel 2019; Vetter 2011). For example, amateur experts like bishops, farmers, hunters, and so-called gentleman engaged in the collection and processing of data and information

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and pushed the evolution of humanities and natural science up to the 18th century (Brenna 2011; Chuine et al. 2004; Porter 1978). However, during the course of the institutionalization of science in North America and Europe in the 19th and early 20th centuries, voluntary scientific work by citizens was marginalized (Miller-Rushing et al. 2020). As disciplines differentiated, the pressure increased to legitimize and standardize scientific methods and procedures. Scientists started to claim a certain status as professionals which led to citizen science being more and more displaced as an (equal) actor from the scientific community. Nonetheless, data collection enabled by citizen engagement has retained a certain prominence in the natural sciences (Bonney et al. 2016; Resnik et al. 2015), with sometimes thousands of citizens participating in the observation of birds or insects, collecting and classifying data.

It is only since the end of the 20th century that citizen science has been increasingly associated with a programmatic call for opening up science in the European and North American context. This can be seen as an after-effect of the *Mode 2* science debate coined in the 1980s (Gibbons et al. 1994), which describes a change in the organization and epistemology of scientific knowledge production. The protagonists of the Mode 2 debate call for the participation of social groups outside science in knowledge-producing processes, in addition to a stronger reference to application. The Mode 2 debate has primarily shaped the emergence of transdisciplinary sustainability research, but is often used to justify the relevance of citizen science (Pettibone et al. 2017). Another related but different term is *Science 2.0*, which highlights new possibilities of communication and knowledge production due to the emergence and diffusion of digital tools and media (Bücheler and Sieg 2011). Science 2.0 emphasizes not only the expanded possibilities for science communication, for example through open access, but also the opportunity for increasing interactivity between research and society. This relates to initiatives in the context of *Open Knowledge* and *Open Education* which advocate for open data and open source infrastructures, not only to increase the level of transparency and reproducibility of science, but also to build the foundation for civic engagement with technologies and facilitate bottom-up technology development (Voigt 2021).

Beyond this particular development of citizen science in European and North American science systems, a separate line of participatory procedures which broadly fall into the category of citizen science has developed among others in postcolonial countries and regions. The focus here is often on the exploration and visualization of indigenous knowledge, which not only facilitates the collection of a type of data that is more closely oriented to the lifeworld of local populations (e.g. Eicken 2010; Snively and Corsiglia 2001), but also follows emancipatory objectives. These attempts can be associated with the plea for a *decolonization* of science that goes beyond (colonial) hierarchies in knowledge production and ownership (Bhawra 2022; Mistry and Berardi 2016).

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The background is thus complex and citizen science is a colorful and broad landscape of phenomena rather than a clearly definable methodological practice. A variety of typologies describe different intensities of participation along the research process (see Haklay 2013; Riesch and Potter 2013; Wiggins and Crowsten 2011). Haklay (2013), for example, distinguishes between *Crowdsourcing* (mainly virtual participation and data collection), *Distributed Intelligence* (cooperation in different phases of the research process), *Participatory Science* (cooperation in all phases of research), and *Extreme Citizen Science* (research mainly led by citizens or non-academics). Wiggins and Crowston (2011) describe education as a particular form of citizen science which represents a vast variety of different types of projects, where citizen science tools are used in courses at schools, universities, museums, and other educational institutions to enhance learning and science communication. But even though most typologies try to be as exhaustive as possible, they do not cover all cases of citizen science, particularly hybrid forms, like the integration of art projects and participatory action beyond disciplinary, sectoral or national borders (see Filgueira Risso and Greco 2020).

Debate and criticism

The increased attention towards citizen science can be connected to different transitions and innovation impulses in science systems. Since the beginning of the 21st century, the debate about the social relevance of science has gained momentum and traditional hegemonies of knowledge production are questioned (Böschen 2019). In this context, citizen science is supposed to overcome looming crises of legitimacy, such as declining trust in scientific evidence (Saltelli and Funtowicz 2017) and the call for citizen-oriented or citizen-involving research becomes part of a plea for greater engagement of science in societal transformation (Schneidewind et al. 2016). Modern science can also see citizen science as an opportunity to improve science communication, where citizens are more than an audience consuming research results (Bonney et al. 2016).

While citizen science has gained some popularity in science and science policy, a main challenge to a systematic overview of the debate is the increasing confusion of formats, goals, and actors in the growing field (see Strasser et al. 2019). Authors from different disciplines have repeatedly questioned the trend to gather many different approaches under the umbrella of citizen science (Eitzel et al. 2017; Haklay et al. 2021), since it obscures not only the differences but also the problems that can be associated with citizen science. Three critical issues in the rise of citizen science can be discerned.

The first issue relates to the *quality and credibility* of citizen science practices. On the one hand, the increasing availability of funding and the inclusion of cit-

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izen science in political strategies such as the European Green Deal (European Commission 2020) are revitalizing the field and giving it necessary attention. On the other hand, these measures can also lead to citizen science degenerating more and more into a label that is used primarily because the term is currently in vogue and not because it is scientifically or socially necessary. There is a certain risk that citizen science serves as a legitimacy provider instead of an "honest" attempt at co-creating socially relevant knowledge. This is particularly delicate in the context of funded citizen science research between the so-called Global North and Global South. Since citizen science originates from a Western European–North American context, terminologies and procedures are used that reproduce a Western image of science and implicitly reproduce hierarchies and power relations between those who offer participation and those who participate. It might lead to situations where the wrong questions are posed (Vela et al. 2021) or stereotypes arise about what "indigenous" means (Eitzel et al. 2017). Particularly in projects that aim for "eye-level" research beyond hierarchies of power in knowledge production, academic scientists might still superimpose their terminologies – and with them their paradigms and values – onto the research process and reproduce the (colonial) hegemonies they intend to overcome (Vela et al. 2017).

This related to a second critical issue which considers the claim of the *promotion of democratization and participation*. Even if citizen science has the potential to break down stereotypes about "science in the ivory tower", it seems questionable whether the projects, which are mostly tied to short-term funding and whose funding is also decided by scientific and political elites, can at all overcome current hegemonies of knowledge production and injustices in the education and science system (Strasser et al. 2019). The inclusion of citizens in scientific knowledge production is not just a matter of establishing channels of communication. Citizen science requires conflict management and, for academic researchers, always means relinquishing some responsibility and control over the research process (Weng 2015). The role of expert is not reserved for academic partners. Rather, different forms of expertise need to be defined (Mistry and Berardi 2016). Engaging in citizen science requires training of representatives from society in scientific methods which transforms them into some sort of experts. The crucial question then is: Is this expertise accepted by the "professionals" or not? Furthermore, questions of intellectual property and possible conflicts of interest need to be clarified (Resnik et al. 2015). Since citizens are often expected to volunteer for research, the question of potential exploitation arises (Riesch and Potter 2013). At the same time, there is the risk of delegitimizing professional academic work and an "Uberizing" of research (Strasser et al. 2019, 67).

The third critical issue relates to the *work and roles of academic scientists* and the contexts in which they are working. Notwithstanding the mentioned opportunities, motivating citizens to engage in research collaboration is a double-edged

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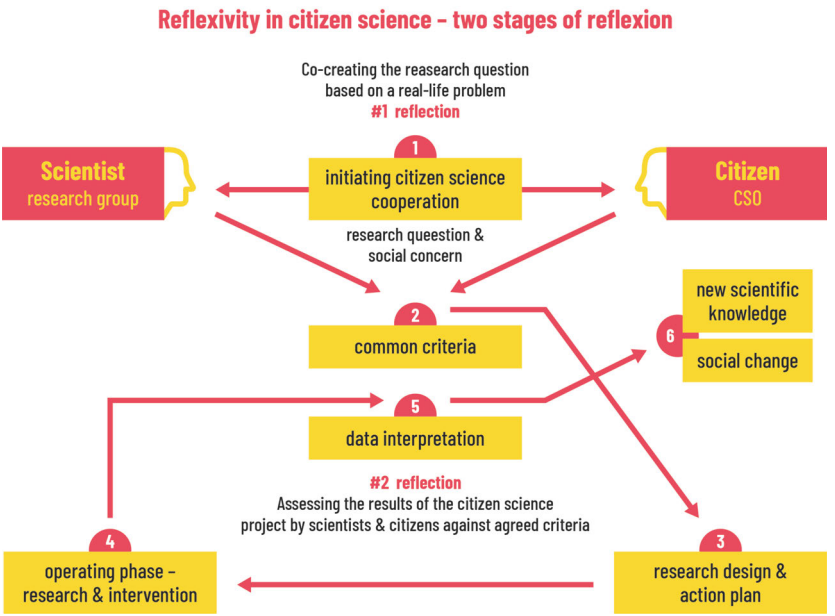
sword. Generating and sustaining interest and motivation over an extended period of time requires target-group or even person-specific approaches which consume much time in a situation where time is rare (Aristeidou et al. 2017). Co-designing research projects requires a high degree of reflexivity and the freedom (and time or resources) to adjust methods, strategies, and forms of communication (see Figure 1). Conducting citizen science is also a risk for academic research, because it is by no means clear whether the hoped-for effects will occur at all, despite greater effort, and whether the results will meet scientific standards (Riesch and Potter 2013). Furthermore, doing citizen science is not only a question of forms and methods, but also of developing relationships. Institutionally integrated, professional scientists need to apply communication skills and to develop forms of interaction – mostly without relevant training – in order to address, activate, and continuously interact with citizens. Intense forms of collaboration and co-design require high reflexivity from each person involved, particularly when developing research questions and interpreting data (see Figure 1).

Citizen science – if designed as an action- and transformation-oriented process – is an invitation to academic scientists to leave self-referential communication contexts, make their knowledge more accessible and debatable, and increase the chance that this knowledge becomes socially relevant (Stilgoe 2009; Wildschut

Figure 1. The two-stage reflection process in a citizen science collaboration (illustration: Frank Becker)



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2017). This openness also entails taking the notion of the citizen (*citoyen*) in citizen science seriously, and recognizing their interest in participating in societal development and shaping their lifeworld contexts (see the Irish Citizens' Assembly as an example for framing this notion of citizen in science: The Citizens Assembly 2022).

Current forms of implementation in higher education

The (often confusingly large) variety of citizen science approaches has some advantages since it offers many opportunities of implementation in higher education. A considerable challenge for a discussion of current forms of implementation is that published literature on empirical examples is rare. A recent review of by Vance-Chalcraft et al. (2022) revealed that most published literature stems from the United States, which could only represent part of the picture. The review shows that the majority of applications of citizen science reported in the literature is on topics like ecology and environment, followed by health and medicine. At lower levels of education (introductory courses), the participation was mainly concentrated on collecting data, whereas in higher levels of education it also stretched to the analysis of data and the development and test of hypotheses. The learning objectives for using citizen science in higher education were manifold, but mostly teachers wanted to foster the students' excitement about science, bring them into contact with authentic research, and demonstrate the relevance of science to society.

Citizen science is often applied in such a way that students act as citizen scientists (e.g. Esmaeilian et al. 2018; Heigl and Zaller 2014; Oberhauser and LeBuhn 2012), but there are also examples where students applied citizen science to co-produce knowledge about their study topic (Britton and Tippins 2015). Some universities try to strengthen their profile in applied sustainability research by integrating citizen science and transdisciplinary methods like living labs explicitly in their program (e.g. MSc program on Ecology and Citizen Science at University College London). While the courses follow a disciplinary focus, they often integrate different disciplinary perspectives. The advantages of citizen science in teaching can be summarized as follows: (1) By learning and applying citizen science methods, students' motivation as well as their interest in socially relevant research can be strengthened. (2) Skills for self-reflection as a researcher and for reflecting on the role of science in society are increased. (3) Students practice communicating research to society. (4) Students learn how to engage themselves and communities affected by their research in action research. In the following we present three examples which illustrate different approaches and objectives.

An example of the role of students as citizen scientists is the paper by Esmaeilian et al. (2018). In the course described, engineering students were motivated to systematically collect examples of product designs in their own everyday lives that

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wear out quickly, are not very functional, or are unwieldy, and to describe them via text and images. The collections were jointly evaluated and categorized. The goal was for students to use their own observations to learn principles of sustainable design as well as sustainable production methods.

A participatory approach in applying citizen science in higher education in the Philippines was reported by Mendoza et al. (2022). The transdisciplinary endeavor, bringing together local fisherman with teachers, students, and the Bureau of Fisheries and Aquatic Resources, aimed at a better understanding of changes in the fish habitats and environmental quality at the Laguna lakes of the Philippines. Given the cooperative attitude of local collaborators, the study shows that local resource users, including teacher and students along with fishers, can be research guides in exploring further ecosystems that experience major environmental changes.

An action-oriented approach (Haklay 2013) is the UNICATA university with and for waste pickers (Gutberlet et al. 2021), which was created based on citizen science research in São Paulo, Brazil. In January 2022, a small group of academics and citizen scientists (waste pickers, NGO members) in São Paulo, Brazil resumed the idea of creating a university with and for waste pickers (UNICATA), inspired by Paulo Freire's theoretical and praxis of popular education pedagogy and peer learning (Freire 2009). The approach underlines the crucial importance for a learner-experience to influence the design of the teaching, and address a whole system of change, thinking relationally about the social, economic, and environmental aspects regarding the work of waste pickers and their livelihoods.

A form of extreme citizen science can be found in participatory ethnobotany, which can in particular be employed in teaching and education in the context of conservation. Two exemplary projects were conducted by a Brazilian team composed of members of academia and the community, acting as ethnobotanical researchers in the Atlantic Rain Forest. In such projects, members of the community are trained from both botanical and anthropological perspectives, so that they can conduct the ethnobotanical survey themselves, with technical support from the academics. One of them started in 2015 and has been carried out in two Quilombola communities (Rodrigues et al. 2020).

Nevertheless, citizen science in academic teaching encounters similar challenges as citizen science in general: contrasting conceptions of science, conflicts over different ideas of the goals of research, and the ever-present question of responsibility for the process and product of collaborative research. To facilitate experimentation with such formats at universities (or even schools), the corresponding courses should not be subject to the pressures of time, publication, and success that are common in research. Rather, they should be recognized as learning experiments that require time for negotiation and adjustment of design, and in which mistakes reveal opportunities for learning and need not be avoided at all costs through excessive standardization.

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