The Valuable Plurality of the Citizen Sciences

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Abstract

Citizen science is a multilayered concept. Although it is generally understood as a form of public engagement with science and technology, it can take various forms, with widely different roles for citizens. Despite this vastness, a contributory strand of citizen science dominates the field, which formally limits citizens' roles to those of data gatherers for professional scientists or experts. This has led critics to argue that citizen science is not as inclusive, socially transformative, or democratizing as its advocates claim, and to appeals by scholars, practitioners, and policymakers for more dialogue and deliberation in all stages of citizen science processes. In this piece, we share our reflections on these questions drawing on our experiences as participant observers in contributory citizen science projects in various parts of the world. Responding to the above critiques, we illustrate how such projects can have emancipatory potential in terms of impacting policy agendas, inciting behavioral change, and engaging hard-to-reach societal groups. We argue that the future of citizen science lies in pluralizing the citizen sciences by experimenting with various modes of democratic representation, participation, and deliberation.

Keywords: Citizen Science, Contribution, Deliberation, Empowerment, Participation, Pluralism.

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Introduction

Sighting birds, scanning photographs of galaxies taken by space telescopes, monitoring waterways, exploring molecular patterns in cells. These are but a few of the many activities citizen scientists partake in across the globe. In the vast majority of these projects, citizens' roles are circumscribed to those of data gatherers or contributors; that is, citizens are mobilized to collect data for scientific experts without being given opportunities to set the agenda for research or science policy. This has led critics to argue that citizen science is not as inclusive, socially transformative, or democratizing as its advocates claim (Mirowski, 2017); and that citizen science processes serve the interests of science or industry, as citizens generate data for professionals through routinized labor using the latest crowdsourcing technologies and digital platforms (Mahr and Dickel, 2019). Others contend that citizen science can come at the expense of genuine collaboration, for instance when citizens' experiential knowledge about a problem is overlooked or dismissed (Gabrys, 2017), or that knowledge generated from citizen science projects too often excludes communities of color and vulnerable socio-economic groups (Mahmoudi et al., 2022). As Cooper et al. (2021) point out, in the United States participants in citizen science projects are overwhelmingly white adults, above median income, with a college degree, which effectively means that citizen science is not open to all members of society.

These criticisms are noteworthy. Not only do they signal significant limitations of citizen science, they urge us to explore the conceptions of science and citizenship at work, and to develop modes of public engagement that engage a wider array of stakeholders and communities, while facilitating reciprocal relationships between participants.

Yet, despite such shortcomings, there is also much to be said in favor of citizen science approaches in which citizens gather data for scientists or experts. Drawing on our experiences as researchers and practitioners in public engagement with science and technology, we illustrate how such approaches can be emancipatory in terms of impacting policy agendas, inciting behavioral change, and engaging hard-to-reach societal groups. Against claims that contributory citizen science is less meaningful than co-created citizen science or that it is "only about the data," we argue that contributory formats can be enabling of articulations of citizenship, social justice and democratization, particularly when they are responsive to shared problems of concern, such as ecosystem pollution, public health issues, etc. Adding to current debates about the roles of participants in citizen science (Bruckermann et al., 2022; Eckhardt et al., 2021; Haklay, 2018; Phillips et al., 2019), and combining Science and Technology Studies (STS) perspectives (Kasperowski and Kullenberg, 2019) with theories of democracy (Mutz, 2006), we propose that the future of citizen science lies in experimenting with, and combining, various modes of democratic representation, participation, and deliberation – and thus, in valuing the rich plurality of the citizen sciences.

From data collection to dialogue

Discussions about the meaning and purpose of citizen science rely on a common distinction within the citizen science literature, which differentiates between a citizen science based on contributions made by citizen-volunteers (which for the sake of simplicity, we will refer to as *contributory citizen science*), and citizen science as a form of science enacted by citizens themselves (commonly referred to as *participatory science, community-based citizen science,* or *extreme citizen science,* although other designations abound) (Eitzel et al., 2017; Haklay, 2013). Since the term citizen science came into vogue in the mid-nineties, the first conception has gained traction in the life sciences and in the media, aligning with a tradition of involving amateur scientists and lay people in scientific activities such as data collection (Bonney, 1996: 7-15). The second conception, which is often attributed to the sociologist of science Alan Irwin (1995), foregrounds the necessity of opening up science and science policy to wider publics. In recent years, it has made inroads into the life sciences, potentially expanding citizen science practices, for instance through the inclusion of citizens in the formulation of research questions and the interpretation of scientific data. As Cooper and Lewenstein (2016: 58) observe, life scientists

and practitioners increasingly frame their citizen science initiatives as "democratic," thus creating overlaps between previously distinct meanings of citizen science. This has led to the development of a third term, *co-creative* citizen science, where citizens participate in all levels of a project, from designing the research question to analyzing data (Shirk et al., 2012).

Social scientists and STS scholars have been influential in shaping this language of co-creation and broad public engagement, with the aim of advancing science and technology democratization, inclusion, and social justice (Kasperowski and Kullenberg, 2019). Building on traditions of participatory action research, cooperative research, and transdisciplinary knowledge, many social studies of citizen science conclude with calls for more civic engagement, more two-way dialogue between experts and lay persons, and more co-creation generally (Senabre et al., 2021).

Herzog and Lepenies (2022: 499) provide a helpful overview of such appeals to co-creation in the social sciences and humanities literature, arguing that a deliberative approach to citizen science can help to fulfill epistemic, ethical, and political goals, whereby citizens "do not only deliver data points, but also participate in discussions about the goals and implications of research." As noted elsewhere (Van Oudheusden, 2014), such calls typically rest on a deliberative view of innovation (increasingly framed as 'co-creative') that emphasizes the active involvement of citizens in research and in processes of joint discovery and invention.

We return to the notion of deliberation (and related terms) below. For now, suffice it to point to a rhetorical shift in how citizen science is portrayed and presented: from processes of data collection and crowdsourcing (whereby organizations solicit contributions, such as data, from a large group of individuals) to citizen science along the lines of deliberation and dialogue. This shift is manifest in the way research is funded and valorized. For more than a decade now, the European Commission has structured its research funding envelopes around the principles of citizen engagement in science, echoing a strong normative commitment to co-creation and deliberation, e.g., by involving citizens "at all stages of research and innovation, from developing agendas and methods, to collecting and analysing data, through to monitoring and evaluating activities" (EC, 2022a: 2). Researchers seeking grant funding must adhere to open science principles, integrating into their research proposals procedures that involve "all relevant knowledge actors including citizens, civil society and end users in the cocreation of R&I [Research and Innovation] agendas and contents (such as citizen science)" (EC, 2022b: 37-38).

With the EU-wide move to open science, many national research and funding institutes, think tanks, and others are adopting similar policies. For instance, in its report "Moving forward together with open science," the Rathenau Institute, which is supported by the Dutch government, maintains that "public engagement is *meaningful when it contributes to the democratisation of knowledge development*" (emphasis added) (Schölvinck et al., 2021: 4). The authors of the report argue that people should "get a say in the goal of the research, its execution and their own role in it" (Schölvinck et al., 2021: 6-7). Similarly, the Organisation for Economic Cooperation and Development (OECD) contends that citizen science is "a way to *democratise* a scientific process, opening it up to everyday people, and *tapping into their motivation and curiosity to co-create and further research goals*" (emphasis added) (OECD, 2022: 42).

The language of co-creation also emerges in the (science) policies of countries that have adopted other terms than citizen science, such as participatory science or community science (so as not to exclude people who do not officially hold formal membership as citizens of a nation state). In New Zealand, the Participatory Science Platform (PSP, n.d.), which is linked to the Ministry of Business, Innovation and Employment, states on its website that "It [participatory science] *goes beyond the idea of scientists crowd-sourcing their data,* to build a *true partnership* between scientists/technologists and the broader community" (emphasis added).

The presentation of co-created citizen science along the lines of true partnerships between participants, meaningful engagement and real involvement "beyond crowdsourcing" depicts co-creation as the ultimate form of engagement in which citizens play an active role and share

decision-making with participants. Deliberately or inadvertently, this imagines dialogic and co-created forms of participation as the optimal form, and consequently portrays contributory citizen science as a less-than-optimal process, at best secondary to co-creation. This framing has real-world consequences, as it informs expert judgement and shapes funding policies (especially but not exclusively in Europe; see e.g., ORION Open Science, 2019). To cite a recent article in *Nature* on community science featuring Rosy Mondardini, the managing director of the Citizen Science Center Zurich:

> …now gaining in popularity, is co-creation, in which members of the community work together with scientists from the start. Mondardini's centre advocates co-creation because the scientific literature indicates that it offers the best results for both scientists and volunteers, she says. (Dance, 2022: 642)

As Haklay (2018: 53) notes, the view that there are better and lesser forms of citizen science resonates with a longstanding theory of participation common to disciplines such as geography, environmental studies, urban studies, and public policy, among others. This theory is metaphorically presented by the participation ladder (Arnstein, 1969), where lower rungs on the ladder correspond with *nonparticipation,* middle rungs with *tokenism,* and higher rungs with *citizen power.*

Whereas the aspiration to improve citizen engagement in various stages of a citizen science process (i.e., with citizens actively involved in all stages of research) is certainly important and laudable, the suggestion that co-creation is *superior* to contributory citizen science is problematic. As we illustrate in the next section, presenting three cases from different world regions (Flanders; Uganda; New Zealand), contributory forms with limited roles for participants can be empowering for large groups of people and may even be able to generate more societal and scientific impact than small-scale deliberative frameworks. This is not to argue against co-creative citizen science (all authors are involved in co-creative projects), but to value a plurality of citizen science approaches, leaving room for different types of engagement with problems, communities, and resources.

From nosing around to tracing parasites and controlling car batteries

In 2018, a team of academics, in close collaboration with the Flemish environmental protection agency and a regional newspaper, distributed easy-to-assemble air pollution sensors to 20,000 people in Flanders (the northern, Dutch-speaking region of Belgium). For one month, volunteers took readings of nitrogen dioxide (NO_2) in their street, after which they returned the sensors to the laboratory. The campaign, dubbed *Curieuze-Neuzen/CuriousNoses* (based on a wordplay in Dutch, 'nosing around'), yielded a trove of unique scientific data on traffic-related emissions in the Flemish region. Campaign organizers used the data to validate and improve existing measurement methods and models by controlling and calibrating them with NO_2 measurements collected at official reference monitoring stations; raise critical awareness among the public and politicians of air pollution; and push for collective action for sustainable mobility and city planning (Van Brussel and Huyse, 2019). Thanks in large part to the news media, the campaign stimulated massive interest in air pollution. Following the publication of the campaign results, air quality became a major topic in the local elections, and its importance was amplified during the so-called climate strikes organized by students (Van Oudheusden and Abe, 2021). The data had judicial implications too. In October 2018, the Court of First Instance of Brussels in the case *Greenpeace v Flemish Region,* acknowledged the data collected via the CuriousNoses project as indicative measures to judge violations of Directive 2008/50 on ambient air quality and cleaner air for Europe (Misonne, 2020).

At this time of writing, follow-up projects to CuriousNoses have been initiated in Flanders and Brussels and across Europe (e.g., Ireland's Clean Air Together project, which is modelled on CuriousNoses). One reason why the CuriousNoses projects are successful is that they spring from communal concerns such as air pollution and tackle these issues by way of society-wide mobilization. Project initiators forge ties with vested knowledge networks, comprising scientists, authorities, and the media– thus acting as concerned scientists, who join forces with various groups such as

policy experts, non-governmental organizations, and protest movements. In this way, they seek to advance a 'strategic' type of citizen science that is able to create both scientific and societal impact by using relatively simple technologies and by leveraging the power of big data to produce scientific data on a mass scale, which formal institutions must then take seriously.

As a second case, we turn to Uganda, where in 2019 a multidisciplinary group of university researchers (biologists, epidemiologists, geographers) launched a pilot study by the name of ATRAP (Action Towards Reducing Aquatic Snail Borne Parasitic Diseases). The project sought to explore key aspects in the development of a citizen science framework to monitor snail hosts that transmit schistosomiasis and fasciolosis – two tropical parasitic diseases that pose a major burden on public and veterinary health, respectively. The aim was to use these data to support local targeted snail control measures in remote, resource-limited environments. To this end, researchers trained 25 citizen scientists to report on snail host abundances in predefined water contact sites in and around Lake Albert on a weekly basis. As described by Brees et al. (2021), the selected volunteers recorded and submitted georeferenced data on snail counts, basic water chemistry parameters, and photographs of the identified snails using a freely available mobile phone application. After submission to a central server, a semi-automatic validation flagged faulty reports. Regular feedback was provided by WhatsApp and in person visits, with a refresher training organized on a yearly basis.

Similar to the CuriousNoses case, ATRAP initiators used a highly structured data-collection protocol and a directed citizen scientist recruitment strategy both to maximize scientific output and to tackle the issue at hand. The snail sampling activity has also proven useful to raise awareness of schistosomiasis among communities and to develop preventive public health strategies, for instance through the placement of signposts near high transmission sites. They may spur other activities for, or with, local communities; a point to which we return shortly.

To conclude this section, we consider a third, distinct case by the name of Flip the Fleet (flipthefleet.org), originating in New Zealand. This project is driven by a small, dedicated group of car owners, businesspersons, and data scientists seeking to build a future for electric transport by accelerating the uptake of electric vehicles (EVs). EV owners provide monthly records on their car's distance travelled, efficiency, charging patterns and average speed. At the time of writing, 645 EV drivers have signed up since the testing phase of the project began in July 2016, followed by a public launch in 2017.

Apart from generating scientific data on EV use, cost savings, battery health and environmental impacts, project initiators seek to inform the debate on the use of Low Emission Vehicles in New Zealand. As indicated on the FtF website, they want to create conditions "so that business investment in infrastructure, public policy and our own choices maximize the benefits and pleasure of EV ownership." According to project initiators, this debate about EV uptake is presently underway in New Zealand.

Due to the technical complexity of the IT development and design, Flip the Fleet was initially construed as a contributory citizen science project driven by three citizen-consumers, with other participants contributing data or sharing their stories. However, with time test drivers became more involved, providing advice on ways to enable more participant feedback throughout the data-gathering process. Presently, more local, co-created projects are being tested, suggesting that a contributory citizen science setup may prompt collaborative and deliberative citizen science approaches.

Developing a louder voice

These three examples illustrate the emancipatory potential of contributory citizen science in which experts, scientists, or academics design the experiment and then ask volunteers to help. Emancipation here comes in various forms. In the CuriousNoses case, resident groups and municipalities drew on the campaign's findings to push for tighter traffic pollution policies in cities and many citizens changed their behaviors; for instance, by adopting more sustainable modes of commuting to work, such as by bike (Huyse et al.,

2019). As conveyed to us by a government advisor, even conservative Flemish policymakers, habitually opposed to environmental policies and at best indifferent to citizen participation, acknowledged the need to take into account the CuriousNoses campaign.

The ATRAP project served as a proof of concept to upscale snail sampling and address the pressing need for more accurate data on the incidence and spread of schistosomiasis among local populations. In western Uganda, several of the citizen scientist volunteers who participated in ATRAP are deferentially referred to as "Doctor of Water" or "Snail Doctor" by fellow community members. Thanks to this newly acquired status, one of the citizen scientists is now actively involved in community politics. As a pilot study, ATRAP can facilitate the uptake of citizen science in other parts of Africa (Ashepet et al., 2021), including in Chad, where a second citizen science project modelled on ATRAP is now underway.

In New Zealand, Flip the Fleet empowered consumers to make better car purchasing decisions, as car dealers reported "a highly informed clientele that bring FtF charts to the negotiating table" (Love et al., 2018). The initiative also helped citizens to challenge the political and economic drivers for energy and transport investment in ways that are more conducive to LEV uptake, by sharing with citizen-consumers hard data and accessible instruments to demand attention for a challenge that is simultaneously societal, economic, and environmental.

The emancipatory implications described here are far from exhaustive; nor are they unique (see e.g., Cooper, 2017: 192; Cooper and Lewenstein, 2016; Haklay, 2018). But it is well worth spelling them out in light of calls for true, co-creative partnerships, meaningful engagement, and real involvement beyond crowdsourcing. Whereas civic deliberation about scientific research agendas and processes is a necessary component of democratic decision making, a too singular focus on co-creation risks ignoring that not all citizens have the time, resources, or commitment to participate in full, and that participatory engagement inevitably raises questions of strategizing and power. To paraphrase Wesselink and Hoppe (2011), processes of public participation are not only about 'puzzling' (i.e., dialogue) but also about developing effective strategies to make one's voice heard ('powering'). In pluralistic societies, where parties are asymmetrically positioned to begin with, some actors, settings, and knowledges take primacy over others, due for instance to conflicting norms of evidence testing and public persuasion. This explains why, in the CuriousNoses project, initiators deliberately used scientifically validated methods and protocols, enabling shared measurement and observation by experts and nonexperts alike, as a mechanism to gain credibility with scientists and policymakers. By involving research institutes and governmental agencies in the air pollution campaign and by using the data to validate and improve existing measurement models, the data could not be dismissed as irrelevant, and even became directly useful to experts. Although this approach leaves little to no room for alternative data collection techniques and data valuation *in situ* (Tengö et al., 2021), it can be a powerful tool for the design of new evidence-based policies supported by citizen participation, while spurring public debate about questions of 'livability,' environmental sustainability and social justice (Huyse et al. 2019). It is doubtful that the project would have been taken seriously by formal institutions (e.g., policy agencies) or advanced as quickly and effectively without mass-scale participation in which ordinary citizens played a contributing role as data collectors rather than as agenda setters or co-creators.

This observation brings us to the question of representation (i.e., when actors speak, advocate, and act on behalf of others in the political arena) and the place it occupies alongside deliberation and participation in contemporary democracies. Although the two latter terms are often used interchangeably in citizen science and STS literatures, it is fruitful to distinguish between them. Following Mutz (2016: 3), deliberation relies on joint reflexive-critical debate in which interlocutors listen to others and probe their own assumptions for the sake of mutual learning and collaboration. Like co-creation, it is oriented towards building understanding between various groups and interests. By contrast, participation refers to the mobilization of resources by like-

minded individuals and groups as partisans in order to impact policy. Participation in this sense is about engaging people in decision-making processes and empowering them to have a voice in the decisions that affect their lives.

We contend that all three types of engagement should play a role in a pluriverse of contending and unequal stakes, data, technologies, and institutions. Pushing the argument further, we suggest that mass participation with citizens acting as "mere data points" (rather than fully engaged deliberators) can be highly effective in spurring policy change, behavioral change, and in reaching a wide range of actors, including members of ethnic, racial, and socioeconomic minorities. This is because a low-threshold technology (relatively cheap, easy-to-assemble, autonomous, intuitive) significantly lowers the barrier for such groups to get involved. To again take the example of CuriousNoses, a simple NO_2 test tube attached to a home window yielded a mass of valuable scientific data without consuming too much of participants' time and energy, while also creating a sense of anticipation and a joint purpose.

Providing people with easy-to-use tools that enable mass-scale measurement and rapid data accumulation and processing is not antithetical to meaningful engagement; it is an important step in tackling grand societal challenges such as environmental pollution or climate change (Mahajan et al., 2020). In other words, again drawing on Mutz's distinctions between forms of democratic engagement, citizen science requires representation alongside participation and deliberation. If citizen science is to develop a louder, stronger voice in a world where every problem and person is vying for public attention 24/7, citizen scientists must be prepared to delegate their voices and data to spokespersons and technologies that speak and act on their behalf and in their interest.

We again emphasize that we are not arguing against co-creation as an important, potentially promising approach to citizen science, but against the idea that co-creation is essential for true and meaningful participation to occur and is what we should, in principle, always strive for. Our interest as citizen science scholars, sympathizers, and participants should lie in exploring how various forms can co-exist and mutually inform one another in the interest of generating forms of productive engagement with diverse groups and cultivating varied ways of knowing and acting. A good way to start is to pluralize the notion of citizen science; i.e., to speak of *citizen sciences* (Strasser et al., 2018). When we begin to appreciate the citizen sciences as many, we are better positioned to do justice to diversity and difference. To do this, we should analyze all citizen sciences – including top-down, contributory forms – as constantly moving practices with the potential for transformation and even radical change. We feel this outlook deserves to be given more attention in areas of scholarship and policy that advocate for deliberative forms of engagement as the best way forward. As we have sought to illustrate, low-level, contributory citizen science can be more than a convenient crowdsourcing practice; it can, in certain contexts and under the right conditions also be democratic and empowering.

A plea for pragmatism

As communities and problems require different forms of engagement and different problem-solving strategies, it is clear that a one-size-fits-all approach will not work. Thus, rather than promote one, norm-defining citizen science model, we would do well to think together seemingly opposing ideals, such as *mass citizen participation versus citizen empowerment*, and *representation versus participation or deliberation*. Our plea then, is for a pragmatic engagement with problems, data, technologies, participation, infrastructures, and the citizen sciences, acknowledging that there are various enactments of citizen science "out there." From this perspective, the most important questions to ask at the start of any citizen science process are: What is the problem or challenge? For whom and why? What kind of change do parties envisage: Scientific, societal, systemic? The language of co-creation typically singles out the level of stakeholder participation as the primary dimension against which to appraise (or from the perspective of a funder, *evaluate*) a citizen science project or process, without sufficient consideration for the types of change originators are seeking to achieve and the impacts citizen science

processes are likely to have beyond the remit of civic engagement. Contributory citizen science may, for instance, initiate sustainability transitions in areas such as public health, environmental conservation, or renewable energy. Systemic (macro) change of this kind deserves to be given more consideration when thinking about the role of citizen science in science and society, as do the micro and 'meso' practices of participation or deliberation. Research (e.g., Forrester, 1999: x) shows that in participatory processes, participants not only make meaning for themselves but also enact complex relationships of power, for example, by setting their own agendas. Not only does this suggest that categories of participation cannot be easily separated in practice, but that we should imagine and where possible, artfully weave together different approaches rather than limit ourselves to one mode.

This, we argue, is the best way to avoid, curtail, or manage risks inherent in contributory citizen science processes, such as the risk that aggregating data provided by volunteers is instrumentalized by powerful actors under the guise of opening and democratizing science (Blacker et al., 2021); or the danger that contributory citizen science becomes a one-way consultation (a 'tick box' activity) that strengthens the 'neoliberalization' of science with citizens doing routinized labor for economic reasons (Vohland et al., 2019). Our interest as scholars, practitioners and sympathizers should lie in opening up the various possibilities, albeit in a realistic manner, by carefully considering what is possible in a given context, due for instance to limited time constraints and acknowledging that contributory citizen science remains the dominant citizen science approach across the globe, by far. As the examples in this paper illustrate, citizen science projects initiated by experts can have decisive impacts in ways that benefit both science and society. These projects may spark or sustain various forms of civic engagement and should be understood within broader processes of change, of which citizen science is but a subset. Deliberation can be a viable option in such processes, as can participation and representation. Alongside co-creative citizen science initiatives, we need broad participatory approaches that bring specific concerns into the public arena and that enable the processing of big data on a scale that would otherwise be impossible. This is a more top-down design than a deliberative forum, but it has significantly more reach, which is one of the greatest assets of citizen science that seeks to be a force for positive, society-wide change.

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