



Beyond the Grassroots: Two Trajectories of “Citizen Sciencization” in Environmental Governance

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ABSTRACT

Grassroots, bottom-up citizen science is a burgeoning form of public engagement with science, in which citizens mobilize scientific data to address local and global concerns. Contrary to top-down citizen science projects in which citizens collect data for experts, these grassroots initiatives typically unfold in do-it-ourselves fashion, thereby challenging formally-sanctioned, expert-centric citizen science approaches. This article illustrates these points through a comparative analysis of two potentially paradigmatic sites for environmental grassroots citizen science: Safecast (radiation pollution; Japan) and CuriousNoses (air pollution; Flanders, Belgium). These cases are selected on the basis of their anchors in local self-organized communities, with each case initiated by citizens instead of by formal institutions. Adopting a relational account of these sites as being shaped through both top-down and bottom-up imperatives, we draw out key features (defining moments, key actors, discourses, devices) in the constitution of these networks as credible, potentially influential actors in affairs of environmental governance. We introduce the notion of “citizen sciencization” as a way of understanding and exploring these processes against the backdrop of changing science-society relationships in Japan and Europe.

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INTRODUCTION

We are presently witnessing an explosion of grassroots citizen science initiatives covering a range of pressing environmental issues, such as air pollution, virus outbreaks, and climate change. Contrary to expert-led citizen science projects in which citizens collect data for professional scientists, these initiatives typically take the form of bottom-up, community-driven practices that facilitate citizen engagement with scientific tools and data to address local and global concerns (Bonney et al. 2009; Gabrys et al. 2016). Thanks to the internet and modern crowd-sourcing technologies, they are rapidly spreading across the globe, emerging in developed countries and among remote communities living under extreme conditions such as disaster environments, where human safety is at risk and ecosystems are visibly threatened (Stevens et al. 2014).

As these grassroots networks grow in size, scope, and geographical reach, they potentially reconfigure relations between science and society. By developing innovative ways of assessing environmental risks using their own technologies (e.g., self-assembled pollution monitoring devices), citizens in these networks highlight discrepancies between expert and lay appreciations of risk, initiate contextual learning about their habitats, and involve broader publics in the definition of problems, data collection, and analysis. Using digital tools, they increase pressure on public authorities and scientists to open science and science policymaking to society. In these ways, they challenge the authority of formal institutions, opting instead for inclusive governance, understood as the participation of more stakeholders in policymaking and knowledge production (Irwin 1995; Stilgoe et al. 2006).

This article takes these observations as its entry points to assess how grassroots citizen scientists mobilize discourses and data to tackle environmental threats; and how this mobilization can elicit enduring societal change, for instance in the form of public-awareness raising, behavioral change, and changes to environmental policies and policy making. These aims are attempted through a comparative analysis of two emergent sites for environmental grassroots citizen science: the Tokyo-based volunteer organization Safecast, which measures and monitors radiation pollution in the environment; and CuriousNoses, a large-scale citizen science project that has monitored air quality across Flanders (the northern, Dutch-speaking region of Belgium). These cases are selected on the basis of their anchors in local self-organized communities committed to tackling pressing environmental concerns, with each case initiated by citizens instead of by formal institutions (e.g., government agencies, professional research groups, and industry organizations). Each is a pioneer and a

potentially paradigmatic site for grassroots citizen science globally, with Safecast maintaining the largest open dataset of background radiation measurements ever collected, and CuriousNoses influencing environmental policies in Flanders and Europe. Both initiatives represent possible alternatives to dominant, top-down technocratic environmental policy approaches by enacting new modes of collective environmental stewardship that stretch across disciplines, networks, and communities. Enabled by digital technologies and embedded in robust, supportive social networks, citizen scientists in these networks often succeed in articulating scientifically plausible and socially relevant alternatives for pressing environmental and health issues. They speak credibly about the environment by producing their own hard scientific data and by adhering to scientific measurement protocols, even if they must still justify the role of citizens in producing scientific findings (Berti Suman et al. 2020). They form alliances with policymakers, scientists, and journalists, as well as with activists and local communities, with the aim of inciting long-lasting societal change. Arguably, these strategies enable these citizen scientists to reconstitute themselves as “a new species of expert” that is reminiscent of earlier social movements situated between formal experts and wider publics (Epstein 2000, p. 18).

By comparing these two sites, we seek to provide a contextual understanding of how grassroots (bottom-up) citizen science emerges as a significant, potentially influential actor in environmental governance locally, regionally, or globally. Our aim is not so much to generalize from the particular but to highlight what is of broader scholarly significance and social relevance, as citizens develop similar responses to environmental challenges. Using illustrations and examples, we seek to illuminate how citizen science emerges out of contextually located spaces, sites, and practices, which are also open and networked as well as dynamic and changing. Accordingly, throughout this article, we recurrently use the term trajectory to direct attention to how Safecast and CuriousNoses developed historically and culturally, and how these initiatives may mature from the level of smart, innovative interventions in local affairs to a potentially more durable and strategic level of enduring impact nationally or globally (de Waal and de Lange 2019).

Our work complements scholarship on public engagement in science and technology (Wynne 2007; Chilvers and Kearnes 2016), data activism (Ruppert et al. 2017; Beraldo and Milan 2019), social movements and science democratization (Hess 2005; Hess et al. 2008; McFarlane 2009), and research into the “many modes of citizen science,” which are now emerging (Kasperowski and Kullenberg 2019, p. 2). As noted elsewhere, the general, westernized rubric of citizen science risks subsuming the

sheer variety of citizen practices under one, presently trendy, catch-all phrase (Kenens et al. 2020). Dominant and institutionally sanctioned notions of citizen science (e.g., contributory, collaborative, co-creative citizen science) risk concealing different types of expertise and citizenship, as in these approaches experts select (or discount) grassroots data depending on their institutional stakes and perspectives. Hence, these forms do not engage with the full range of possibilities to validate and act on citizen-gathered data (Gabrys 2017). Taking a cross-national and cross-cultural comparative perspective across issues of environmental concern can help to shed light on these questions and develop empirically and theoretically informed responses to them, particularly as research on citizen science often takes the form of a single case study analysis, or cases are compared within one country (Abe 2014; 2015; Hemmi and Graham 2013).

To put these considerations in perspective, we draw out key features (defining moments, key actors, devices) in the constitution of Safecast and CuriousNoses as credible actors in affairs of environmental governance beyond the formally credentialed (See the section “Two Trajectories into Environmental Pollution Governance”); and we draw out similarities and differences between them (See the section “Side-by-Side Comparison”). Our analysis builds on fieldwork conducted in Japan and Belgium (2014–2020) in the form of ethnographic research; in-depth interviews with citizen scientists, policy makers, scientists, journalists, and others; and document and media content analyses.¹ Drawing on our findings, we introduce the notion of citizen sciencization as a way of exploring the various enactments by which organizations, institutions, behaviors, and technologies become constituted as citizen sciences; thus giving us a sense of how the citizen sciences are collectively shaped. Key in this conceptualization is the encounter between various actors and actions, their discourses, materials, and knowledges at a time of ongoing struggles over environmental issues and public participation in science. As we illustrate below, these encounters are fluid and multidirectional: Citizen scientists may intentionally distance themselves from activists and advocacy groups with the aim of achieving wider social recognition (Van Brussel and Huyse 2018). Governments and credentialed scientists may in turn accommodate grassroots citizen science language and tools for scientific or educational reasons, or seek to facilitate a more active scientific citizenship, with members of the public generating reliable scientific knowledge (Irwin 2015). The meanings and practices of citizen science are thus actively explored and negotiated by various citizen science stakeholders in manners that blur conventional top-down/bottom-up distinctions (See the section “Citizen Sciencization”).

TWO TRAJECTORIES INTO ENVIRONMENTAL POLLUTION GOVERNANCE

In this section we introduce the two grassroots citizen science initiatives on which this article builds and illustrate how they have developed since their inception. For each initiative, we provide key features in the constitution of these networks as potentially credible actors in affairs of environmental governance, and indicate how these networks are further evolving.

SAFECAST JAPAN

On 11 March 2011, a massive earthquake and resulting tsunami hit the Tohoku region of Japan, leading to reactor meltdowns at the nuclear power plant of Fukushima Daiichi, operated by Tokyo Electric Power Company (TEPCO). With the lack of publicly available information on radiation leaking into the environment, citizens without prior knowledge of radioactive contamination—activist-artist Sean Bonner (Los Angeles), financial entrepreneur Pieter Franken (Tokyo), and a former director of MIT Media Lab, Joi Ito (Cambridge)—mobilized their networks to collect data on radioactive materials. At the time, measurement devices were not widely available in Japan, and with an imminent need for reliable and actionable data on radiation pollution, these citizens quickly built a prototype of measurement device for data collection using do-it-yourself (DIY) practices rooted in hacker culture and its ethos of playfully tinkering with technologies beyond their intended aims and limitations.

A series of such practices led to the establishment of Safecast (initially RDTN.org) on 24 April 2011 as an environmental citizen science network for radiation measurement after Fukushima (Bonner 2011). Although Safecast initially started small, it quickly began attracting a variety of international volunteers with different expertise, from web-engineers to designers and artists.

From the start, Safecast has been concerned about the lack of transparency in official communication about radioactive contamination, as the Japanese government hesitated to inform the Japanese public about radiation risks to avoid sparking mass panic (NAIIC 2012). In Tokyo, people rushed to purchase radiation measurement devices, with high demand meeting inadequate supply. Confronted with a lack of trustworthy information, Safecast members began experimenting with citizen-driven radiation measurement devices and transformed an existing Geiger-Müller counter into a portable device for outdoor use. The bGeigie, as this counter is called (short for Bento Geiger Counter), is based on open hardware and sold as a kit containing supplied parts so that users can build the

device themselves. Safecast ran several bGeigie workshops to instruct citizens on how to assemble the device and measure radiation in the air reliably, whilst encouraging participants to learn by doing.

The bGeigie sparked the interest of citizens in Japan and elsewhere, with volunteers around the globe collecting data on radiation levels in the air and sharing these data on the Safecast website in the form of easily accessible radiation data maps, which are recurrently checked and updated by Safecast members. At the time of writing, Safecast maintains the largest open dataset of background radiation measurements ever collected, comprising more than 150 million data points (Bonner 2020).

With this massive, citizen-generated data production system rapidly being developed, formal institutions, both international and domestic, began taking notice. In an official statement released in 2013, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) referred to Safecast's data as one of the "datasets provided to the Committee that were used for the assessment" (UNSCEAR 2013, p. 98).

Meanwhile, in the USA, institutions such as the RAND Corporation and the Defense Agency DARPA expressed an interest in Safecast's radiation mapping devices and measurements (e.g., Tang 2015); while in Europe, the French radiological protection agency IRSN and the Belgian Nuclear Research Centre SCK-CEN each involved Safecast members in workshops and conferences about the role of data crowdsourcing in the management of radiation risks. Although many experts in these institutes remain skeptical of the data produced by citizens, there also appears to be growing recognition among them that crowdsourcing can fill informational gaps (Van Oudheusden et al. 2020; Hultquist and Cervone 2018). Particularly noteworthy here is Safecast's 2014 visit to an International Atomic Energy Agency (IAEA) International Experts' Meeting (IEM6), at which Safecast members Joe Moross and Azby Brown presented their radiation data measurement tools, protocols, and results to a largely "skeptical audience" of radiation protection specialists and mandated experts [SC 20/02/2018].² Although several meeting participants voiced concerns about the scientific reliability and validity of Safecast-generated data and crowdsourcing more generally, the Chairperson in his summary report (IAEA 2014) notes:

But crowdsourcing, for example in the collection and dissemination of radiation data, can also help to instill confidence in information from official sources. But to continue to be effective, these public groups need to maintain their independence; to be seen to work too closely with the authorities will diminish their

effectiveness, and consequently also their credibility, making them redundant. For government authorities and agencies, crowdsourcing certainly is the "genie that will not go back in the bottle". It is necessary to accept that this technology is here to stay and that empowerment of the public is not necessarily a negative development.

Without explicitly mentioning Safecast, the report acknowledges the instrumental potential of crowdsourcing in disaster situations (as crowdsourcing can "help to instill confidence in information from official sources"), while also indicating that citizen data practices decisively challenge the authority of formal institutions ("the genie will not go back in the bottle"; "it is necessary to accept..."). Whereas the report frames the crowdsourcing of data as a potential resource for public authorities and experts, it also underlines the need for public authorities to respect the independence of crowdsourcing "public groups," as these groups must not "be seen to work too closely with authorities" if they are to remain effective and credible in the eyes of the public.

This by and large favorable reception of citizen-driven data crowdsourcing constitutes one of several defining moments in Safecast's international trajectory, as the network gained wider policy recognition in affairs of radiological protection and nuclear safety alongside formal experts and authorities.

Other international exchanges deserve notice here, including a joint ICTP (International Centre for Theoretical Physics)-IAEA workshop with Safecast volunteers held in March 2017 in Trieste (Italy), in which workshop participants (decision-makers, scientists, technologists, and journalists) constructed, tested, and used Safecast's bGeigies. As recounted to us by a former IAEA representative, the IAEA organized these exchanges primarily for educational purposes, with the aim of "teaching about basic instrumentation," such as open-source hardware, software tools, and geographical information system maps.

The IAEA's bearing towards Safecast—perhaps best described as receptive but cautious—contrasts starkly with the dismissive responses of citizen-driven radiation monitoring, as voiced by the Japanese central government and the Japan Atomic Energy Agency (Kenens et al. 2020), and appears more in sync with the unfolding relationships between Safecast and a range of local and regional institutions inside Japan. The latter includes a collaboration in 2013 with Kōriyama City (one of the largest cities in the Fukushima Prefecture) and the Kōriyama branch of Japan Post designed to measure radiation levels across the city, among others. Four years later, TEPCO invited Safecast members to bring bGeigies inside the Fukushima Daiichi nuclear power plant, which is remarkable given Safecast's

harsh criticism of how the power company handled the Fukushima Daiichi crisis (the_Stig 2012).

Safecast's growing recognition from international and some domestic institutions coincides with increasing media exposure. In past years, both international media (e.g., *the Economist*, *British Broadcasting Corporation (BBC)*, and *the Los Angeles Times*) and domestic media (e.g., *Asahi Shimbun*, *Fukushima Minyu*, and Japan's public broadcasting agency *NHK*) have reported on Safecast's data and data practices (e.g., Abe 2019). Furthermore, Safecast members have published a scholarly journal article for the radiological research community, entitled "Safecast: successful citizen-science for radiation measurement and communication after Fukushima," in the *Journal of Radiological Protection*.

Today, Safecast frequently holds information sessions for schools, companies, and community groups (including local citizen radiation monitoring groups), and continues to engage with various types of data production practices in Japan and other countries. At present, Safecast members are developing tools to measure air pollution with a particular focus on particulate matter (PM_{2.5}) and collecting various kinds of data on Covid-19. The network's activities have thus been expanded to include other environmental and public health concerns.

CURIOSNOSES—FLANDERS, BELGIUM

The roots of the CuriousNoses are found in Antwerp, one of the biggest and most densely populated Belgian cities, which is also among the most congested and traffic-polluted in Europe. In 2014, local community groups, including Ringland Academy (a think tank within the broader Ringland citizen movement) and the citizen movement Ademloos (which translates as "out of breath" or "gasping for air"), pooled resources with academics in a concerted effort to improve mobility, quality of life, and environmental sustainability in and around the city. Unlike other protest movements, these groups advanced a new municipal vision of Antwerp, including a "capping" of the traffic-packed ring road, with parts of the highway to be moved underground in a tunnel. Although controversial, the proposal gradually achieved buy-in at the policy level, as citizens and other stakeholders (e.g., city administrators) joined these movements' cause for sustainable urban renewal.

CuriousNoses (based on a wordplay in Dutch, "nosing around") sprung from this early grassroots mobilization as a first-of-its-kind citizen science project on air quality (Van Brussel and Huyse 2018). After an initial measurement campaign in 2016 in the city of Antwerp with 2,000 citizens, project initiators and volunteer professionals (scientists, urban planners, and communication specialists, among others), launched a second campaign in 2018, this time involving 20,000 citizens across the whole of Flanders,

again with the aims of reliably mapping air pollution, estimating the effects of exposure of air pollution on public health, and providing evidence-based health and environmental recommendations to policymakers. To maximize societal impact, the organizers invited citizens to measure nitrogen dioxide (NO₂) levels in their street for the duration of one month (May 2018). Despite charging participants €10 for their testing kits, organizers faced an overwhelming public response and even had to turn down requests to participate unexpectedly. Selected participants were instructed to attach two Palmes diffusion tubes to a V-shaped placard with the CuriousNoses logo outside their home, as a means of standardizing the measurements and maximizing the campaign's public visibility. As organizers recurrently emphasized, all collected data would be quality controlled and calibrated with NO₂ measurements collected at official reference monitoring stations operated by the Flanders Environment Agency (VMM), after which the data would be made publicly available. As in other community-led air projects, the data would also be used to validate and improve existing measurement methods and models, rendering such data ever more "powerful" (Haklay and Eleta 2019, p. 574).

It is important to note the partnership between campaign organizers and VMM, as well as the collaboration with Flemish universities (University of Antwerp; Institute for Labour and Society HIVA, KU Leuven), research institutes (Flemish Institute for Technological Research, VITO), and the unique collaboration with the mass media (the newspaper *De Standaard*). By developing alliances with these renowned scientific and public institutions, CuriousNoses initiators positioned themselves between and among citizens, experts, and authorities. In this process, they publicly distanced themselves from advocacy groups (Ringland in particular) as a way of securing public acceptance and to avoid accusations of partisanship, while retaining good working relationships with grassroots activists (Geenen et al. 2019, p. 113) [CN founding member 13/11/2020].

Among other factors, this tactical positioning within society helps to explain the widespread appeal and impact of the CuriousNoses campaign in Flanders. As Huib Huyse, a social scientist closely involved in both campaigns, conveyed to us, "[CuriousNoses] was founded on frustration" because the results of citizen science projects are rarely adopted by policymakers or are simply ignored; hence, "we worked hard to produce credible, hard data." Hard data here denote quantitative data that are reproducible and verifiable through the application of scientifically validated, universally shared and standardized measurement techniques. Based on their previous experiences in citizen movements, insights acquired after the first CuriousNoses

campaign, and supplementary research, campaign initiators reasoned that to achieve the desired policy and research impact, they would have to wield data in such a way “that no one will question the findings” [CN 26/06/2019]. Accordingly, as two of the campaign’s leading figures, Huyse and Filip Meysman (a biogeochemist at the University of Antwerp), have repeatedly stressed, they were not willing to compromise on scientific relevance for the sake of citizen participation; what counted instead was the delivery of policy-influential insights based on rigorous scientific assessment (Geenen et al. 2019, p. 113; Gijssels et al. 2019, p. 102).

In short, CuriousNoses initiators sought to generate societal impact by spurring a more strategic form of citizen engagement in which citizens, academics, and government collaborate in the collection of policy-relevant data (Van Brussel and Huyse 2018). As indicated earlier, these combined efforts proved highly effective. CuriousNoses culminated in the most successful citizen-led air pollution campaign to date. Thanks in large part to the active involvement of the Flemish newspaper *De Standaard*, CuriousNoses stimulated massive public and media interest in air pollution (data) in Flanders and in other parts of Europe. Even conservative Flemish policymakers, habitually opposed to environmental policies and at best indifferent to citizen participation, acknowledged that “ignoring the campaign has become near impossible” [Interview with government advisor 30/01/2019]. Following the publication of the campaign results in 2018, air quality even became a major topic in the local elections, and its importance was amplified during the so-called climate strikes organized by students around climate issues. In these protests, several students were spotted with CuriousNoses signs (Huyse et al. 2019). Although public support for new environmental policies waned in the run-up to the federal elections (when several political parties openly challenged the feasibility and desirability of the demands of Youth for Climate), clean air remained an item on the Flemish policy agenda. With citizen demands for climate action increasingly heard across Europe (Schaefer et al. 2020) and confronted with European climate decrees to tackle environmental pollution, Flemish policy and research institutes are developing sustainable mobility scenarios with civil society groups, with the aim of reducing air pollution and global warming. Low Emission Zones (LEZs) have emerged in cities such as Ghent and Antwerp, which prohibit certain vehicles from entering the city center because they emit too many toxic substances. Although the emergence of LEZs predates the CuriousNoses campaign, resident groups and municipalities drew on the campaign’s findings to push for tighter traffic pollution regulation and the development of alternatives for car use (e.g., Stad Gent 2018). The

campaign also encouraged residents to explore more sustainable modes of transport to commute to work (e.g., bike, train); and some Flemings have even relocated to regions within the country with ostensibly less air pollution. These observations, which are derived from longitudinal survey data and are reported on in the media, suggest that the campaign induced behavioral change among segments of the population (Renson 2019).

Without seeking to overstate its importance, we conclude that the CuriousNoses campaign has stimulated environmental awareness and behavioral change, and influenced the Flemish policy agenda, in part because of its remarkable transformation from the grassroots to the “middle up” (Berti Suman 2020, p. 425). Initially construed as a citizen movement and subsequently as a campaign to mitigate air pollution in the municipality of Antwerp, CuriousNoses now exemplifies environmental citizen science for the whole of Flanders. The campaign has generated several spin-offs, including citizen science projects on municipal traffic congestion (e.g., *Straatvinken*), citizen science projects in Flemish schools, and a Brussels remake of the 2018 campaign, as reported in *De Standaard* (Renson 2020). There is also tangential evidence that CuriousNoses influenced the Flemish government’s 2018 decision to erect Flanders’ first citizen science knowledge center, Scivil [Interview civil servant 05/06/2019]. More remarkably perhaps, as members of VMM have confided to the first author, various experts first saw citizen science as a potential threat to their work but have come to appreciate it as “an opportunity” to collect more data while “engaging with the public,” and as “an invitation [to us] to do better” [Interviews with civil servants 20/05/2019, 27/08/2019]. These testimonies suggest that CuriousNoses effectively expanded incumbent institutes’ scientific expertise.

Although not exhaustive, these examples are indicative of how citizen science crowdsourcing platforms can achieve societal impact by mobilizing relatively simple technologies and by leveraging the power of numbers to produce scientific data on a mass scale, which formal institutions must take seriously.

SIDE-BY-SIDE COMPARISON

Having concisely outlined the two citizen science trajectories, we can now place them side by side, with a view towards comparing their core features and considering the implications these have for institutional reception, from the choice of these networks to self-identify as citizen science organizations to the kinds of data being produced and how these data are acted on.

CONVERGENCES

As should be clear by now, both initiatives emerged from the grassroots in the face of a pressing environmental matter of concern. Taking this matter of concern as the primary entry point and key defining moment is central to understanding why and how these networks have developed as they have, and the type of citizen science with which they are concerned. The two cases described here seek to provide resources for citizens or communities to settle controversies that existing institutions (e.g., powerplant operators, government agencies, scientific institutions, oversight bodies) are unwilling or unable to manage on their own, typically because data are scarce or are not openly accessible (or both). Hence, citizen groups develop new ways to get this kind of information (Berti Suman 2020, p. 428).

This voluntarist, problem-oriented approach to citizen science contrasts with a top-down citizen science setup, in which scientists or other formally credentialed experts invite citizens to gather data for them, and which rarely challenges existing power relations or impels large-scale collective social action. The contrast is palpable in how Safecast and CuriousNoses mobilize technologies, citizens, data, and discourses, including their choice to adopt the citizen science label at all. To paraphrase a founding member of CuriousNoses, there was “no grand scheme to initiate a citizen science project on air pollution.” Rather, the term was decided on because it “appeared useful at the time” [CN 26/06/2019]. Safecast’s founding members have made similar assertions, arguing, “We chose the term ‘citizen science’ as a way of generating findings that will carry both scientific value and community value” [SC 28/01/2020]; and “(W)e started solving the problem before we realized that we were creating an organization” [SC 29/07/2015]. Thus, in both cases, members pragmatically considered which designations were readily available to them to structure a collective response to an urgent problem.

The structuring of these networks around a tangible problem comes with a well-communicated sense of urgency, with repeated appeals made by citizen scientists to all societal stakeholders (both state and nonstate) to act. Seeking to appeal to both wider segments of society and specific groups, CuriousNoses members have explicitly linked air pollution to concerns about livability, well-being, and climate change. Safecast members see radiation pollution as connected not only to safeguarding people’s health but also to information transparency and the communication of data without restriction. In short, both networks have sought to address an array of environmental issues and audiences (lay citizens, civil society organizations, scientists, public authorities, etc.) under the generic rubric of citizen science, using

multiple registers of communication to build a presence in established news media and on social media.

These communication processes are visibly and expressly mediated by scientific data, tools, and technical instruments, which facilitate broader public participation in science and which structure members’ engagements with credentialed experts, decision-makers, and others. The notion of data-driven research is key, with Safecast claiming to be “pro data” (rather than pro- or antinuclear) and therefore apolitical (Safecast 2019); and with CuriousNoses producing hard data, as we have seen. Thus, in both cases, scientific data are the central focus, providing both groups with a crucial measure of legitimacy among experts (and wider society) and a critical means of underpinning their demands for environmental change and decisive action.

In the approach taken by Safecast, the data are collected and aggregated, and outliers (rare values in the dataset, which can distort statistical analyses) are removed or cross-checked. To enable feedback from experts and to ensure transparency, the data collection methods are posted online and the radiation data maps are made available to all. Crucially, data points on the maps may include official data (e.g., data taken from government sources) alongside citizen-generated data to allow for comparison between data sets. In the case of CuriousNoses, project initiators routinely involved credentialed scientists in the calibration and validation of citizen-generated data to avoid having these data discounted by experts or authorities. Hence, both approaches draw on the same mechanism of legitimization: the data acquire credibility and persuasive power through crowdsourcing and the rigorous application of scientifically validated methods, enabling impartial measurement and shared observation by experts and nonexperts alike (Jasanoff 2017). These mechanisms are amplified through processes of data visualization from below, as users access and collectively feed data into online data maps, thereby making visible what would otherwise likely remain concealed (Berti Suman 2020, p. 429).

By closely adhering to scientific rigor and precision in data collection, and by aggregating and sharing data openly, these citizen science groups emerge as advocates of modern technology and open science. Upon developing scientific and technical competence, they obtain an unusual capacity to contest scientific experts on their own grounds, not by discrediting science (as some radical social movements seek to do), but by openly questioning and supplementing dominant expert-centric research priorities, research methods, technology devices, etc. (Hess et al. 2008, p. 478). This distinguishes them from avowedly more activist organizations such as Ringland and Greenpeace; and as is the case with Safecast, from antinuclear movements. Establishing the scientific credibility of data (practices) is

thus not merely a description of, but an explanation for, the scientific and societal relevance of these citizen initiatives and their continuation and survival in cultures that value modern science and technology.³

This brings us to the roles citizen scientists assume in such cultures as initiators, orchestrators, or facilitators of scientific citizenship. Whereas the term citizen science unsettles conventional distinctions between citizen and scientist, we may ask what types of citizenship and science are being enacted from the bottom up. Clearly, members of CuriousNoses and Safecast are not ordinary citizens in the sense of average persons; rather, they are well-educated, technology-savvy, and resourceful individuals embedded in lively—usually urban—community organizations and robust networks, comprising universities and other knowledge institutes. Although they are commonly referred to as bottom-up or grassroots organizations, these networks are initiated by professionals participating as citizens who mobilize wider publics around matters of concern. These professionals redefine their roles by bringing in particular sets of expertise and learning new skills along the way. This may impel them to move closer towards institutions when, for instance, these institutions express an interest in collaboration; or conversely, reaffirm their ties with local community groups.

For the purpose of this article, we highlight the arduous emotional labor that goes into building and nurturing these relationships with stakeholders, particularly credentialed experts. Safecast has gained access to international organizations such as IAEA and local actors such as TEPCO by establishing interpersonal connections with members of these institutions. In the case of CuriousNoses, the Antwerp-born director of the European Environment Agency advocated the CuriousNoses cause on the European stage. Although this type of relational, diplomatic work tends to go largely unnoticed, it can be generative of new encounters and encourage new collective forms of science governance.

DIVERGENCES

Turning now to dissimilarities between the networks, we are drawn to how different historical and cultural circumstances contribute to shaping grassroots citizen science locally and globally. Given Safecast's setup as an international volunteer organization rooted in global hacker culture and DIY networks, it is unsurprising that its scope of activity reaches beyond Japan to the global stage (Palacin et al. 2020). This international orientation is reflected in the organization's choice to use English as its working language and for public outreach purposes (although the Safecast website also provides basic information in Japanese). By contrast, the CuriousNoses campaign has centered solely on

Flanders rather than on Brussels or Wallonia.⁴ Region-wide citizen participation in the campaign spurred the Flemish government and its agencies to promote citizen science in areas of research, education, and government (Scivil 2020). This policy-wide endorsement builds on a longer Flemish tradition of public participation in science and technology and aligns with the European Union's science policy of responsible research and innovation, which seeks to involve all societal stakeholders in science and technology innovation. It may also be indicative of a growing acceptance among policy elites and administrations that "citizens will take science into their own hands if they have to" [Interview with Flemish MP 26/02/2019].

The situation in Japan is markedly different. Although Japan equally has a long tradition of citizen participation in science (Nakayama 1991, pp. 14–25), policy references to citizen science are few and scattered, and generally reflect a commitment to one-way science communication with only limited public involvement (Van Oudheusden et al. 2020; Cabinet Office 2016). Furthermore, whereas in western societies citizenship is conceived of as a virtue that underpins democracy, the notion conjures connotations of anti-governmental, antinuclear left-wing activism in the context of citizen-led radiation monitoring in Japan (Abe 2020; Kenens et al. 2020). These connotations are as much political as they are cultural. Historically, nuclear-related concerns, such as nuclear safety, have sparked more public controversy than air pollution. The latter is a lingering, long-term problem that is continuously present and cannot be managed away within the foreseeable future; whereas radiation pollution can be made to appear under control until a new incident takes place.

These different temporal and spatial realities have implications for how citizen-generated data are received and appreciated by experts and authorities. The criticisms levelled at CuriousNoses emerge within a policy and research context that is now widely supportive of (contributory) citizen science; hence, it is largely confined to what is being measured and more precisely, what is being missed, such as particulate matter components of air pollution [e.g., VMM Workshop 13/11/2018]. By contrast, establishment experts (e.g., scientists, regulators, and decision-makers) have questioned the scientific validity and reliability of Safecast's data, as well as the normative commitments of opening nuclear policies and practices to public scrutiny (Abe 2015; Van Oudheusden 2020). In addition, Safecast has been accused of enacting a "hidden pro-nuclear agenda," specifically in cases where data generated by its members has contradicted claims made by antinuclear activists (Brown et al. 2016).

These appraisals again underline the centrality of data to these citizen science groups and raise questions about

their data politics (Beraldo and Milan 2019). Whereas in the CuriousNoses approach, data are crowdsourced and presented to policymakers with the aim of inciting collective action on air pollution, Safecast’s approach is to create an open data process that generates actionable data related to environment, health, and safety. As noted elsewhere (Abe 2015, pp. 126–127), Safecast endorses the principle that the data will find its audience. This imperative leaves a great deal of agency (e.g., a decision to relocate based on one’s interpretation of the data) to the discretion of the individual user. With CuriousNoses, the data are not held separate from formal policymaking but pressed into the process of region-wide consensus building on the problem of environmental pollution. This is evidenced by the prevalence of inclusive terms such as ambassadorship and community orchestration in CuriousNoses discourse and the development of close partnerships with formal institutions, which laid the groundwork for a joint campaign for the whole of Flanders. Following Jasanoff (2017), the differences described here may reflect divergent civic epistemologies—cultural norms of evidence testing and public persuasion. Whereas European decision-making environments are typically structured around the integration of all relevant aspects of a problem into a robust whole (e.g., through collective bargaining among stakeholders), decision-making environments elsewhere (e.g., USA) are more conducive to adversarial forms of evidence-making in which data are mobilized to settle (or unsettle) scientific controversies.⁵ From our analysis of the two cases, we infer that grassroots citizen science can

thrive in both these environments but that citizen scientists must adapt their approach to fit the demands of the decision-making setting.

When setting the two cases side by side (see **Table 1**), we see a distinct form of citizen science emerging, with trained and self-learning citizen scientists committed to rigorous scientific assessment and the provision of socially relevant and policy-relevant insights, which in turn summon stakeholders (individual citizens, civil society groups, and policymakers) to act. Although these trajectories are not comprehensive or complete, they give us a good sense of how and why citizen science materializes from the bottom up, and how it may come to matter in affairs of environmental governance locally, regionally, or globally.

CITIZEN SCIENCIZATION

Building on our comparison, we now introduce the notion of citizen sciencization to think through and explore the ways in which grassroots citizen science initiatives potentially achieve wider and enduring societal influence. Responding to a key question in the studies of social movements—*Who does the shaping?* (Hess et al. 2008, p. 473)—we underline the fluid, two-way integration and mutual attuning of concepts, data and tools, and organizational forms. This understanding is deeply embedded in social movement theory and various strands of Science and Technology Studies (STS), including Actor-Network Theory (ANT), which posits that social and natural realities are forged

	SAFECAST	CURIOSNOSES
Key defining moment	2011 Fukushima nuclear disaster	Air pollution-related events in the 1990s linked to large-scale road construction projects in Antwerp
Main concern	Radiation risks and information transparency	Air pollution, primarily traffic-related emissions (NO ₂)
Scale	Global focus	Regional focus (Flanders)
Initiators	Technology entrepreneurs and volunteers from USA, Japan, and the Netherlands	Ringland members (Antwerp-based citizen movement) and professionals (scientists, designers, and urban architects)
Funding sources	Momoko Ito Foundation, Knight Foundation, Shuttleworth Foundation, crowdfunding, and others	Project partners (75% of total cost); citizens charged €10 for testing kit
Approach to data	“Pro data:” data collected by citizens and, ideally, validated with professional experts	Hard data collected by citizens and validated by professional experts
Core values	Independence, innovation, transparency, openness	Community, engagement, sustainability
Relation to formal institutions	Informal collaborations with local and regional institutions in Japan and across the world; agenda-setting for international action	Formal collaboration with Flemish universities, research centers, mass media, and supported by Flemish government; agenda-setting in Flanders

Table 1 Safecast and CuriousNoses side by side.

through constantly shifting networks of relationships involving human actors and nonhuman actants, such as technologies. Rather than taking a network (e.g., a market) as a pregiven structure (which is the default approach in sociology), ANT urges us to account for how a network emerges through the engagements, behaviors, and activities of its constituents; i.e., how the network is performed (or enacted) through the actions of involved actors and actants (Çalışkan and Callon 2009).

Taking inspiration from these frameworks, citizen sciencization denotes a space of encounter where actors and actants interact and co-enact citizenship, science, and citizen-science. As we have seen, formal institutions engage with citizen science discourses, data, and devices for political, scientific, or educational reasons. In turn, citizen scientists accommodate formal institutional pressures, for instance by choosing to generate hard data that can be scientifically measured and validated, or by intentionally dissociating from activist groups to avoid political polarization. Thus, the meaning and practice of citizen science are not predetermined; rather, these features are actively (re)constituted and (re)negotiated by actors within the historical and cultural contexts to which they belong. These encounters may generate new, hybrid meanings and relationships, as actors not only confront existing features but also adjust to various constraints and opportunities such as the global rise of environmental participation and the expression of new forms of citizenship (e.g., urban, ecological, universal, and scientific), for which citizen science can provide a fruitful bedrock.

Bringing a more contextual and symmetrical analysis to bear on change processes involving citizens, science, and data practices provides a much-needed corrective to linear and deterministic conceptions of change, which underlie many present-day academic and policy debates about the real and potential impacts of citizen science, its professed “institutional uptake” or its “mainstreaming” (Sanz et al. 2014; EC 2020). By positing the unidirectional integration of alternatives into dominant (e.g., formal) frameworks, these conceptions ultimately fall short of accounting for multi-way dynamics, and thus for the complexity of the citizen sciences. Citizen sciencization is therefore distinct from (if not antithetical to) the notion of scientization, which for us denotes the application of science to a problem or the action of making scientific, leaving insufficient room for other actors, sources, and sites as makers of forms of knowledge (see Kolawole 2019).

Sensitizing ourselves to how agents and actions together shape their engagements also urges us to reconsider conventional typologies of citizen science, such as ladders and pyramids of citizen participation in science, which exclude a citizen science without credentialed

experts (Haklay 2013); and problematizes overly optimistic and pessimistic renditions of public participation in science and technology. Critics rightly point out that grassroots citizen science can end up reinforcing the very state- or industry-sanctioned forms of governance it is meant to challenge (Mirowski 2017), while ignoring that it can equally play an empowering “boundary-bridging role,” for instance through the supplementation of official data standards with citizen assessments (Ottinger 2010, p. 251) or by generating institutional receptivity towards other knowledge production processes, be they indigenous, local, or speculative (Gabrys 2017). This is not to say that citizen science elicits only beneficial outcomes, as some of its promoters suggest. Void of power and friction, too positive conceptions fail to account for value struggles and the clash of interests in participation (Van Oudheusden 2014).

Rather than viewing citizen science as being virtuous or flawed, we propose a more empirically grounded, textured, dynamic, and relational view, which recognizes both science and citizenship as inevitably messy, essentially contested, and unfinished processes (Chilvers and Kearnes 2016, p. 33). As we have sought to illustrate, citizen science processes can—and typically do—play out in many directions and occupy many spaces, even simultaneously. Their ongoing contestation attests to the emergence of citizen science as a vibrant and potentially generative practice, as citizens offer new insights and resources, and develop new forms of scientific, social, and democratic credibility. This explains why citizen science is relevant today, and why stakeholders of all sorts (public authorities, professional scientists, civil society groups, social scientists, and other citizens) are increasingly taking notice of its varied impetuses, aims, manifestations, and impacts.

CONCLUSION

Through a comparison of two cases, this article sheds light on how grassroots citizen science emerges as a significant, potentially influential actor in environmental governance locally, regionally, or globally. It introduces the notion of citizen sciencization as a way of envisioning and exploring the historical, cultural, and political processes of emergence and (re)configuration of citizen science against the backdrop of changing science-society relationships in Japan, Europe, and across the globe. Drawing on social movement studies, STS, and citizen science literatures, the paper states the case for a more symmetrical and relational approach when studying citizen science, with due attention for the dynamic interplay of bottom-up and top-down imperatives. This focus on movement and multi-directionality urges us to be precise about the changing conditions and potentially

legitimate difficulties and constraints of citizen science processes, as well as the opportunities these processes engender for collective change. The mutual shaping of citizen science is easily overlooked when drawing on deterministic or binary lines of thinking, such as institutional uptake and mainstreaming, which posit the unidirectional incorporation of alternatives into dominant frameworks and structures. As social movement scholars remind us, the shaping of civic movements and trajectories matters to the scoping of new “fields of shared action” that are yet to find their subjects (Melucci 1996, p. 6). Grassroots citizen science is constitutive of this shaping, as it increasingly interferes with, and occasionally hijacks, dominant approaches to data governance in ways that effectively challenge the status quo (Beraldo and Milan 2019). These processes of intervention and reception inevitably vary even within a single case or context, as we have seen. It is therefore important to pay sustained attention to them with the aim of offering a more systemic understanding of the interactions between institutional actors and grassroots civic initiatives in democratic societies. As a sensitizing tool, citizen sciencization can facilitate these aims, offering us a lens through which to explore citizen science in fluid and relational terms, and thus as a process that procures varied forms, depending on historical and cultural conditions. As we have sought to illustrate, initiatives such as Safecast and CuriousNoses have matured and continue to develop, as these networks refocus their attention on other environmental concerns and give impetus to new civic initiatives. These and related developments constitute a topic for future research, as does the question of whether and how grassroots citizen science can deliver on its aims of inciting durable environmental change.

Although we have singled out two cases for in-depth analysis and comparison, our approach is relevant to other citizen science processes. Given the participatory disposition of citizen science, the realities of any citizen science endeavor are bound to be shaped by how various stakeholders engage with the challenge of participation in its social, technological, and political dimensions (Rey-Mazón et al. 2018). Participation is thus actively made, unmade, and remade, at least in contexts that are sufficiently democratic to allow for civic organization from below. By acknowledging this transformative potential of citizen science, we seek to contribute to the development of socially relevant and environmentally concerned research, based on the understanding that complex, intractable problems require a multi-stakeholder approach, whereby more concerned parties are heard and none are willfully excluded. Whereas the rationales of institutions and the fluid, networked assemblages of civic movements around

matters of concern can be difficult to reconcile (de Waal and de Lange 2019), the citizen science initiatives described here open opportunities for enduring transformation, as various stakeholders negotiate their knowledges, expectations, and values. As evidenced by research on sociotechnical controversies, these interactions need not always be agreeable, as conflicts oblige various sides in a dispute to accommodate the relevance of contending views if they wish to remain influential and credible (Rip 1986). As we highlight in this article, innovative, resourceful, and collaborative grassroots citizen initiatives can be successful at gaining credibility and legitimacy among a wider array of societal stakeholders. For members of formal institutions who may feel challenged (or in some cases, threatened) by them, well-organized, resourceful citizen scientists are a force to reckon with as these citizens redesign the field of power, competence, and expertise in matters of environmental concern.

DATA ACCESSIBILITY STATEMENT

The dataset generated during and/or analyzed during the current study is not publicly available due to privacy restrictions, but some data are available from the corresponding author on reasonable request.

NOTES

- 1 We held and transcribed semi-structured interviews in Japanese, English, and Dutch. We asked research participants about key themes, including the history of the grassroots initiative under consideration, the rationales that sustain it, and the people and moments that defined its existence. From a concern with securing credible interpretations, some research participants were interviewed several times. Of the six participants who responded to an initial draft of this paper (which we circulated in November 2020), all affirmed the accuracy of our interpretations, although four added valuable comments, which led us to further develop or emphasize particular points.
- 2 Square brackets indicate that quotes are taken from interviews with members of Safecast (SC) or CuriousNoses (CN), unless indicated otherwise.
- 3 Various STS scholars have taken issue with Safecast’s data narrative, arguing that data are not neutral but inherently political, because they are shaped by prior assumptions about what we, as a society, know and value (e.g., Kuchinskaya 2019). Yet, as Safecast members have argued, presenting data as apolitical can prove useful when navigating a deeply controversial arena such as radiological protection. CuriousNoses members acknowledge that their work becomes political by challenging established approaches, while simultaneously seeking to sidestep politics “along partisan lines” [CN 25/10/2018].
- 4 As mentioned earlier, a CuriousNoses campaign is under way in Brussels. In 2018, Greenpeace Belgium made an appeal to launch a similar campaign in Wallonia.
- 5 Jasanoff (2017) terms the European approach the “view from everywhere” and the American approach the “view from nowhere.”

ETHICS AND CONSENT

Participants cited in this paper consented to having their views included in the research study, with some interviewees asking us to guarantee their anonymity. We each obtained approval from Institutional Review Boards (Sociology Ethics Committee, University of Cambridge; University Park Institutional Review Board, University of Southern California UPIRB # UP-14-00343) for our research.

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The authors have no competing interests to declare.

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