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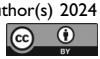

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Becoming Scientific-Environmental Citizens Through Citizen Science in China

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Abstract

This article advocates for a closer study of the forms of citizenship nurtured among individual participants in citizen science (CS) projects by highlighting some salient features of CS in China. Through a detailed examination of the experiences of students participating in the CS activities of a Chinese environmental NGO, it proposes that attention to CS as a means of democratizing science should be complemented by a similar attention to the ways in which CS fosters "scientific-environmental citizenship." The article argues that these emergent forms of citizenship may be revealed by focusing on the experiences, perspectives, values and skills acquired by participants, and the specific polity in which CS initiatives are situated. This attention to the development of scientific-environmental citizenship as an outcome of CS is particularly valuable in contexts where democratic

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participation is otherwise constrained, but also yields a more nuanced understanding of citizenship enacted through CS in democratic contexts.

Keywords
Citizen science, scientific-environmental citizenship, China, authoritarianism, environmental activism, youth

Introduction

Scholarship on the interplay between science, politics and publics has grown considerably in recent decades. One area of focus for this literature is citizen science (henceforth CS), an umbrella term that encompasses diverse participants and forms of practice (Eitzel et al. 2017). Numerous efforts have been made to systematize the diversity of CS by offering typologies and chronologies (e.g., Haklay 2013; Kasperowski and Kullenberg 2019; Kimura and Kinchy 2016; Strasser et al. 2019). Citizens' participation in science and knowledge production are valid starting points for evaluating CS practices. However, the focus in some studies of CS on contesting state- or industry-produced science and achieving the co-creation of science-based decision-making implicitly relies on practices of citizenship rooted in a Western, liberal, and participatory democratic context (Van Oudheusden et al. 2023) which may not be established everywhere. In turn, this approach risks foreclosing analyses of CS's potential to generate "citizenship learning" (Irwin 2015, 32–6) even with lighter forms of participation. Given that forms of citizenship are closely intertwined with the polities within which they operate (Leach, Scoones and Wynne 2005, 16), they may lead to various outcomes in terms of communities' self-determination and participation in decision-making in different contexts.

In response, this article asks: how might the practice of CS nurture an evolving commitment to environmental values and active efforts to solve social and environmental problems? It provides an illustration of this potential through the example of the CS initiatives of a Chinese Non-Governmental Organization (NGO) (hereafter NGOX, a pseudonym), which engages university student-volunteers in collecting data on rural water pollution to identify potential problems and solutions. Drawing on extended interviews with volunteers, it examines their narratives about their experiences of designing and undertaking field investigations of rural drinking water quality. On this basis, it proposes that NGOX's CS activities nurture emergent forms "scientific-environmental citizenship". We argue that, although NGOX

initiatives may not enable "strong participation" by affected communities (Allen 2018), nor bring about more plural and just science and policy processes, yet they significantly influence how student participants reflect on environmental issues and empower them to address environmental challenges in ways that are best suited to the Chinese context.

The illiberal context of contemporary China—where openly contesting state-led projects and data is politically risky—presents a valuable springboard from which to scrutinize the forms of citizenship developed through CS. But this invitation to devote closer attention to individual participants' experiences and perspectives and to the political context in which CS is situated is equally important in democratic contexts. Indeed, we propose that attending to the articulation of scientific-environmental citizenship through CS is instrumental to promoting a broader set of parameters by which to evaluate the outcomes of CS in diverse contexts.

Citizenship and Participation in Citizen Science

The broad and interdisciplinary field of CS has witnessed impressive growth since its emergence, and scholars have pointed out that CS-like practices have taken place for much longer (Davies and Mah 2020; Kimura and Kinchy 2019). The concept of CS articulates the relationships between science, citizens, politics, and society in diverse ways (Fan and Chen 2019; Kimura and Kinchy 2019). Natural scientists typically understand CS as lay volunteers "collecting and/or process[ing] data as part of a scientific enquiry" (Silvertown 2009, 467 cited in Kuchinskaya 2019), sometimes with an important science education dimension (e.g., Bonney et al. 2009; Druschke and Seltzer 2012). By contrast, Science and Technology Studies scholars have more systematically interrogated the power inequalities embedded in these relationships. Some have drawn attention to the range of motivations behind CS (Kasperowski and Kullenberg 2019), and to its different forms of epistemic practices (Strasser et al. 2019), while others have highlighted the democratizing potential of CS (Callon, Pierre and Barthe 2009; Jasanoff 2003), and its potential as a means of advocating for the value of different forms of knowledge (e.g., Brown 2007; Frickel et al. 2010).

Analyses of CS that prioritize the democratization of science have formulated typologies based on the intensity of participation (Haklay 2013) and have advocated for the involvement of citizens from a project's inception (Allen 2018), often referred to as "co-creation" (Herzog and Lepenies 2022, 499). However, these studies fall short of openly questioning how

citizenship is defined (Eitzel et al. 2017). For instance, Hoover (2020, 245) pointed out that the term may be problematic for "Indigenous citizen scientists who do not necessarily feel they share nationhood and citizenship with the scientists with whom they are working." Moreover, this scholarship tends to either imply the existence or prescribe the institutionalization of specific citizen rights to participate in democratic decision-making (Herzog and Lepenies 2022) beyond voting and representation (Vitale 2006).[1] The literature often treats such rights as a prerequisite for community engagement with science or science-based policymaking concerning them. However, these rights are not equally available to all citizens in a given community or nation (see Benyei et al. 2021; Chilvers and Kearns 2020), nor can they be established in all polities (Fan and Chen 2019; Harris 2020). Upholding co-creation as a standard may therefore result in overlooking other facets of citizenship that CS can nurture, and their intrinsic value for the individuals and communities concerned (Harvey 2009; Kimura and Kinchy 2016; Van Oudheusden et al. 2023). Understanding how CS contributes to citizenship requires incorporating the "historical, political and institutional structures that shape often highly contrasting forms of engagement" in different contexts (Leach, Scoones and Wynne 2005, 16) as well as interrogating the "tenets of citizenship, political authority, and legitimation" in these contexts (Fan and Chen 2019, 182; Hoover 2020; Harris 2020). Yet, while many studies have examined the production of CS data as part of environmental justice movements around the world (e.g., Davies and Mah 2020), few have interrogated the models of citizenship performed and developed through CS in non-Western or non-democratic contexts (notable exceptions are Fan and Chen 2019 on East Asian cases; Kuchinskaya 2019 on Japan and Belarus; Aronova 2017 on the Soviet Union). Congruently, the literature on CS and citizenship beyond the West remains limited.

Responding to this gap, this article focuses not on how CS may democratize science, but rather on how CS may contribute to the formation of scientific-environmental citizenship in a non-Western and authoritarian context. Scientific-environmental citizenship embraces recent developments in citizenship studies that go beyond formal rights to draw attention to subjective dimensions of citizenship and to the processes through which citizenship is performed and negotiated in different places and at different times (see Staeheli 2011; Yarwood 2014). Specifically, the term combines "scientific citizenship," defined as "the engagement of members of society with science and expertise in their capacity as 'citizens'" (Irwin 2015, 33), and "environmental citizenship," characterized by an active engagement with

"pro-environmental behavior, in public and in private, driven by a belief in fairness of the distribution of environmental goods, in participation and in the co-creation of sustainability policy" (Dobson 2010, 6). These two forms of citizenship overlap in their shared focus on tackling environmental (and social) challenges through critical engagement with science. The added value of considering them together is to highlight how CS allows individual participants to progressively feel able and entitled to engage in the production of science and science-based decision-making, or to use this knowledge to solve environmental problems in their own polity, regardless of whether such science contests established scientific and political institutions. This approach also builds on scholarship that has highlighted how "first-hand experience and observation [practiced through CS] anchor[s] knowledge into people's everyday lives, thereby transforming knowledge into a tool for environmental action" (Jorgensen and Jorgensen 2020, 1345), and expanding "possibilities for people to perform citizenship" (Kimura and Kinchy 2019, 27; see also Irwin 2015, 31).

This focus on the potential of CS for developing scientific-environmental citizenship is particularly useful in authoritarian contexts like China where civil society participation in public decision-making is tightly controlled (Fu and Distelhorst 2018; Guttman et al. 2018) and hardly accessible to politically marginalized groups such as rural communities (Lora-Wainwright 2021; Zhang 2023) and the youth (Von Mangoldt 2016; Fossati 2018). In China, citizenship discourses are dominated by obedience and loyalty to the state (Hsu et al. 2022) and even civic participation "can further strengthen the state's hegemony" (Teets et al. 2022, 883). State discourse is particularly prominent in relation to environmental challenges, since the promotion of an "ecological civilization" has become a central objective of the Party-state under Xi Jinping (Goron 2018). For instance, the state has issued "guidelines for environmental citizens' behavior" (MEE et al. 2023) that frame participation as supportive of state's efforts. Nevertheless, through the production of scientific data about environmental issues, CS "gives people an expert's stake in processes such as evaluating local environmental conditions" (Conrad and Hilchey 2011). It also increases their capacity to make autonomous claims about environmental challenges and their possible solutions (Walker 2012; Gabrys, Pritchard and Barratt 2016), even if these claims are instrumentally framed as supportive of state goals.

In this article, through the empirical analysis of NGOX, we show how forms of citizenship can be practiced through CS, balancing attention to political influence and limitations on the one hand and individuals' agency and aspirations for personal growth and genuine social contributions

on the other. While this balance will differ in different political contexts, scientific-environmental citizenship sheds light on how citizenship is practiced even in authoritarian polities (Woodman and Guo 2017).

Citizen Science and Student Initiatives in China

The Collaboration-Contestation continuum of State-Civil Society Relations

Citizen science in China spans a broad range of activities and involves large and well-established NGOs alongside a plethora of grassroots organizations (see some examples in Appendix Table A1) (Li 2018; Wu, Washbourne and Haklay 2022). The recent growth of CS in China is enabled by a combination of technological advancement (for example through the diffusion of digital technologies), growing environmental health concerns, and the institutionalization of public participation in environmental governance (Brombal 2020, 36). As shown in Table 1, an increasing number of CS initiatives have focused on biodiversity conservation by analyzing and monitoring ecosystems, as well as collecting new ecological data (Brombal 2020; Wang 2022). In this growing literature, lay volunteers are recruited to collect environmental data for scientific research (e.g., Aczel, Cao and Makuch 2022; Thornhill et al. 2017), even though recruiting volunteers, especially in rural communities, is challenging "unless they are directly impacted by a given environmental problem" (Freese 2018). Despite these obstacles, grassroots practices of CS do exist. In fact, CS in China was initially developed by environmental activists who focused primarily on environmental quality monitoring (Brombal 2020). Faced with the severe degradation of environmental conditions, CS provided them with an opportunity to demand more transparency and regulation of polluters (Brombal 2020, 38; see also Hsu, Yeo and Weinfurter 2020; Mao 2017).

Some of the alarming data collected by these activists influenced policy making. For instance, the air quality data measured by citizens with portable devices provided by the NGO Green Beagle and posted on the internet under an initiative named "monitoring the air for my country" (Zhang and Barr 2013) contributed to pressuring the government to include data on PM2.5 (particulate matter under 2.5 micrometers in diameter) in national air quality measurements (Fedorenko and Sun 2016). Similarly, citizens' mobilization against waste incineration plants in the late 2000s succeeded in increasing industry transparency and institutional oversight (Mao 2017), and the monitoring and public disclosure of pollution in the Xiang River

by volunteers from the NGO Green Hunan helped to put its protection at the top of the provincial government's agenda (Wang and Wang 2020). However, these kinds of citizen movements have become rarer since Xi Jinping came to power in 2013, and (E)NGOs have kept some distance from them (Wang and Wang 2020). Indeed, if the Chinese Party-state has a particular "conditional tolerance" (Lu and Steinhardt 2022) for environmental (E)NGOs whose environmental goals align with its own, it has also tightened legal and political control over their activities and financing capacities. Officials' tolerance for autonomous environmental data disclosure, confrontational approaches and "negative" social mobilization has decreased enormously (Fu and Distelhorst 2018; Li and Shapiro 2020).

As a result, although ENGOs that focus on industrial pollution still routinely collect their own environmental data, they tend to report issues to environmental authorities directly. Disclosing data that exposes local governments' regulatory failures tends to be perceived as confrontational, and is therefore done only with great caution and as a last resort (Wang and Wang 2020). Conversely, sharing data directly with authorities enables ENGOs to portray their action as collaborative and supportive of the state's regulatory efforts and to pursue their environmental goals while avoiding repression. Significantly, the most successful and lasting environmental data disclosure initiative, the Bluemap published by the Institute for Public and Environmental Affairs (IPE), has worked by collecting *government-sourced* pollution data. The governmental origin of that data is one of their key legitimacy claims, enabling them to portray the Bluemap as a tool that supplements and augments the regulatory capacity of the government (Tarantino and Zimmermann 2017).

These examples illustrate the efforts that Chinese ENGOs pursue to strategically position CS practices within the political boundaries outlined by the state. Conversely, state authorities have recognized the potential for CS to contribute to the collection of environmental data and strived to institutionalize CS as part of the state's own monitoring apparatus (Brombal 2020, 38; Hsu, Yeo and Weinfurter 2020). A good example of this is the initiative "Urban water environment public participation," which was launched in 2017 by the Ministry of Environment in partnership with well-established NGOs such as IPE and Friends of Nature, alongside other local NGOs. It consists of a government-made app through which citizens can report urban "black and smelly water" by uploading pictures and enabling local governments to address it. Organizers dubbed this initiative the "largest public participation or public science project in China at present" (Hsu, Yeo and Weinfurter 2020).

Student Participation in CS Environmental Volunteerism

Chinese students' environmental activism and participation in CS activities is particularly sensitive. While their contribution to and support for an "ecological civilization" is actively sought by the Party-state, students' political activism has been feared and repressed since the 1990s. Their involvement in environmental governance is thus both encouraged and contained. Students' environmental awareness is high (Von Mangoldt 2016), and Environmental Associations (SEAs) are now present on virtually every university campus. However, they have very limited capacity, and their activities usually remain confined to the campus itself or its immediate vicinity (Huang and Li 2012; Fossati 2018). Students are strongly discouraged from any contentious forms of activism and commonly feel powerless and unqualified to address social problems (Von Mangoldt 2016, 146–80).

Of the activities organized by SEAs, those that may involve some environmental monitoring are mainly "social practices" (*shehui shijian*, a term used to designate a form of student volunteerism focused on providing social services such as tutoring schoolchildren or basic health checks in poor areas) for which they often rely on NGOs to provide training and support. However, after the *Green Camps*[2] organized in the late 1990s to early 2000s (Wang and Guo 2021), student programs with a focus on "real life" environmental monitoring have been relatively rare. One exception was the *Walking Water* project, run by Nature University alongside other Beijing-based NGOs from 2009 to 2019, which involved students regularly monitoring the water quality of Beijing rivers (Von Mangoldt 2016). Nature University members were willing to take more risks than most registered NGOs to expose environmental problems. The activity stopped when they dissolved in 2019.

While students' "social practices" are encouraged by the government and often directly organized by the Party-state, individuals' aspirations for personal growth and authentic social engagement pursued through volunteering (Sum 2017) also extend beyond the reach of the state (Spires 2018). This was empirically confirmed in a recent survey-based study, which found that although the main "citizen skills" that participants in volunteer activities gain is "to navigate the government to resolve specific problems," a subgroup of volunteers who claimed to be "motivated by the desire to address social problems" were "more inclined to contest the state and hold the government accountable" (Teets et al. 2022, 890–891). Indeed, notwithstanding state discourse and the risk of repression, diverse logics for the relationships between citizens and state coexist in practice (Fu and Distelhorst 2018), providing

openings for individuals to exert their agency (Woodman and Guo 2017), express skepticism toward state messages (Hsu et al. 2022, 830), and appeal to the state to seek justice (O'Brien and Li 2006).

In this context, CS activities may provide unique opportunities not only to encourage and validate Chinese students' desire to address social problems, but also to develop their capacities for autonomous knowledge production, and its most effective use within the opportunity structure of the Chinese state. Therefore, while it would be unwise to evaluate CS in China by parameters of participatory democracy that are inapplicable and misleading in this context, it would be equally unwise to disregard CS in China because of its relatively narrow remit. This article shows how the work of NGOX provides an opportunity for learning about scientific environmental citizenship in the political context of contemporary China.

Introducing NGOX and Their CS Program

NGOX registered as an NGO in 2017. Besides a small group of core staff, it is essentially made of unsalaried volunteers, most of whom are students. The central aims of NGOX are to improve knowledge of drinking water safety and health in the Chinese countryside, and to identify solutions for low-water quality. Every year, the organization selects and supports 12 to 15 self-organized student teams from universities across China to undertake field research in rural areas, to gather knowledge about drinking water conditions and identify potential problems. NGOX trains its student volunteers in basic scientific methods for testing water quality, conducting interviews, writing fieldwork reports, as well as writing and publishing online stories about their activity to gather attention and support from the public. This NGO provides students with test kits, a sample social survey, and limited funds toward the costs of their fieldtrip (which are often insufficient to cover all associated costs). Students collect data on drinking water, conduct a survey among villagers and collect other relevant information; the data is used both to identify cases where a solution to a water quality problem can be introduced, and to feed an online story-telling visualization map. The information students collect is often the first available data for a given drinking water source. However, NGOX does not use or disclose the data in any way that would expose, blame or contest the state's actions or inactions. As such, it fits the dynamics described above: it positions its activities as aligned with state environmental goals and complementary to its own monitoring work. The data collected, conclusions drawn, and

any proposed interventions that may create tensions with local administrations are not publicly disclosed.

Student volunteers constitute an important resource for NGOX. Working with students entails a degree of amateurism and limits the depth of monitoring activities. The testing material the NGO provides and the supervision they offer during students' fieldwork is limited. This, however, gives students an unusual degree of independence, agency, and opportunity for citizenship learning. According to NGOX's core team, the program allows students to investigate environmental issues "in the real world," a formative experience intended to outlast their participation in the program and to inspire them to become environmental advocates later in life (interview with NGOX staff by C. Goron 2021). In this sense, the fieldtrips that NGOX supports are as much about providing scientific data and potential solutions to affected communities, as they are about developing the skills and life experience of the volunteers, including their scientific and analytical capacity, but also a growing sense of responsibility toward the environment.

Genealogy of the Project, Sampling, Methods and Ethical Aspects

This article focuses on the students who are agents of NGOX's CS activities, rather than on the communities in which they conducted their investigations. It analyzes their experiences and the effects that CS had on them. Goron (CG) was initially invited to join a student team supported by NGOX as an observer in the summer of 2018. Following this experience, a collaborative research project was established with Lora-Wainwright (ALW) and Huang (SH), a member of NGOX who was eager to participate in a critical examination of their program. Besides the original team, ten teams who also took part in the program in the summer of 2018 were selected, based on the variety of fieldwork areas they represented. Nine teams responded positively to interview requests. CG undertook group interviews with members of seven teams in person on their campuses, plus two located in northwestern China who were interviewed online via Zoom. Interviews lasted between 1 h 15 min and 2 h, and were recorded; an assistant transcribed interviews in full and SH checked transcripts for accuracy against the original recordings.

All the students interviewed were undergraduates from a range of degree backgrounds. Both male and female students took part. Most students belonged to the majority ethnic group in China, Han, although several teams also included ethnic minority members. Importantly, most had

personal ties to the countryside: the majority grew up in a village (25) or a small township (7). A minority grew up in urban areas (12) but many of them also had relatives in the countryside. All were members of SEAs, of varying sizes and with varying experience levels in conducting environmental activities. Only a couple of students interviewed had previously organized small-scale environmental monitoring activities around their campus or participated in NGOX projects. Students' level of commitment was uneven across teams and individuals but, as found in previous studies, there was no obvious pattern correlating commitment with student's background (see Von Mangoldt 2016). For all of them, participating in NGOX's CS was a unique opportunity to investigate environmental issues independently and scientifically.

The interviews covered several themes related to students' fieldwork experience, including the conduct of their investigations, their findings, interpretations, and envisaged solutions, as well as reflections on their experience, their relationship with villagers and local cadres, and the usefulness of the data they collected. SH collected additional material related to the teams' projects, such as fieldwork reports, and some of the stories and pictures they published on social media. The authors subsequently undertook in-depth data analysis through abductive coding (Alvesson and Kärreman 2007; Linneberg and Korsgaard 2019). This combines inductive and deductive coding by progressively reformulating codes initially stemming from a close reading of participants' responses in relation to concepts, concerns and debates emerging from the relevant literature on CS. The analysis centered particularly on scientific data production and critical assessment, CS participants' desire and capacity to engage in solving environmental issues, relationships with institutions, and environmental justice values.

Enacting Scientific-Environmental Citizenship Through NGOX's Citizen Science

NGOX's CS activities provide student volunteers with a unique opportunity to develop the desire and capability to engage with the environmental issues affecting China. Based on the students' interviews, we argue that scientific-environmental citizenship is nurtured through four "learning processes" (Irwin 2015, 32): (1) developing students' environmental and scientific knowledge and deepening their commitment to environmental values; (2) developing students' skills for environmental activism; (3) enabling students to understand the multiple and complex causes that give rise to

environmental problems such as water pollution; and (4) enabling students to appraise and overcome the limits to their agency.

Developing Environmental Scientific Knowledge and Deepening Commitment to Environmental Values

Students who joined NGOX were arguably already sensitized to environmental challenges. Indeed, several students mentioned the beginnings of their interest in the environment and their own first-hand experience with poisonous air, rivers "turning black" or drying out, and fish dying (teams A, B, C, D, E, F, G, H). However, involvement with NGOX further enhanced their understanding of water quality issues and increased their commitment and sense of responsibility for the environment and people's environmental health.

Increasing Knowledge of Water Safety and the Complexity of Water-Health Relations. Many students underlined how participating in the program deepened their understanding of water quality issues (teams D, E, F, G), raised their awareness of the potential harm of consuming unsafe water (teams D, F, I) and increased their knowledge of what could be done to minimize or avoid drinking contaminated water (teams C, E, I). In addition, many also reported learning about the effects of particular contaminants on human bodies (team F) and the complexities of illness causation (teams C, D, E), especially in relation to water (teams C, F). For instance, members of team D hypothesized that the prevalence of Kashin-Beck disease in the village they investigated might be due to the high turbidity and high levels of nitrate and salt in the water, though scientists contacted through NGOX told them that their measurements were not epidemiologically relevant. Similarly, team E could not link the high prevalence of hydatid disease in their field site with their water test results. Team C was also unable to confirm their hypothesis that the high rates of liver cancer and kidney stones reported by villagers were indeed traceable to specific contaminants in the water. Through discussions with NGOX advisers and other professionals, they learned about the complexities of attributing causality or even correlation between water contamination and particular illnesses.

Developing a Deeper Commitment to Environmental Values. Better understanding of water-related health issues made students realize the value of clean water (team B). This is apparent in the report published by one team (team F), which notes that "water is the source of life" and urges readers: "don't let the last drop of water become our tears." Such awareness also led some students to reflect on their own use of water. For example, one student reported that they had started

to reflect on the use of water purifiers in their hometown, which they had taken for granted until then (team A). Several students reported that their awareness of the importance of not wasting water had increased (teams C, E) and some commented that they had changed their individual behavior to limit water use in their daily lives (team C, team F blog).

Developing a Sense of Responsibility Toward Society. Investigating water quality in rural areas also increased students' sense of responsibility and instilled in them a commitment to "improve lives" for those less fortunate (team E). Firstly, most teams reported villagers' strong interest in their findings (teams A, B, F), which gave them a sense of duty not only to share results (team G) but to do so in a way that was intelligible and meaningful to the villagers (teams B, C, D, I).

Secondly, in some cases, students were directly called upon by villagers "to voice their concerns to others and bring in information and solutions" (teams D, F), or to report findings to the village committee and township officials (teams A, B) and to bureaus responsible for environmental protection (team C). One student recalled: "What impressed me most was this uncle who seemed to give us a task we had to accomplish" (team B). This strengthened students' sense of responsibility to society and shaped their commitment to become engaged citizens.

Thirdly, students described developing a connection to the place and people they encountered, especially those they perceived as vulnerable, like children and elderly people (teams C, F). The connection to these communities nurtured among the volunteers a broader sense of social responsibility, which was also connected with their personal growth (team F report). Some of this originated from experiencing the hardship of rural life, such as sleeping on tables or floors (team D), walking long distances in harsh weather conditions due to lack of public transport (team F story) and overcoming challenges together (teams A, C, D, H), with help from villagers who guided or transported them (teams A, B, C, D, I) or offered them food and shelter (teams C, D, F). One student commented that overcoming difficulties would "make them become better people" (team E). Helping those in need and enduring hardship resonates with prevalent social values in China (Sum 2017), and therefore endowed students' experiences with an additional sense of moral worth, which made their experience more meaningful (teams C, E, F, H), and in turn contributed to shaping their sense of what it means to be an engaged citizen.

Projecting One's Environmental Activism into the Future. Volunteering with NGOX further shaped some students' plans for their future. In the short

term, some expressed the wish to expand their surveys (team F) or undertake water safety training in more schools and villages (team D). One team contacted professors at their university (team C) and several sought to involve professional labs (teams C, D, H). Members of one team specifically explained that NGOX's training and equipment could be used to test water quality on their campus and support their argument about water quality with the school authorities (team C). Another reported actually measuring their campus' water with NGOX's test kit and being shocked to find their water quality was worse than that in the research sites (team B). Some wished to encourage other colleges and organizations to apply for support from NGOX (team C); yet others mentioned their intention to take the knowledge learned back to their hometown and family (teams E, F).

In the longer term, several students expressed a wish to engage in more volunteering activities, including activities related to water, in order to help improve people's lives (teams C, I). Some also explained that their experience with NGOX allowed them to develop a better understanding of and trust in the work of NGOs. One student for instance noted how they learned that NGOs can be "very professional" (team B), especially in helping to improve communication between citizens and the government (teams A, B, D). Another noted that individuals alone cannot do much, but if people organize and come together, they can solve many problems (team B). These reflections are particularly meaningful in the Chinese context, where, as already noted, NGO interventions are often discredited and social mobilization may be discouraged or repressed.

Students' experiences also influenced the life trajectories they envisioned. Some reflected that after joining NGOX's activities, they began to consider taking a major in an environment-related field for their graduate studies (team B), undertaking environment-related work in the future (teams A, C) and applying their disciplinary knowledge (e.g., of chemistry) to environmental protection (teams C, E). Several expressed a wish to "commit to environmental protection" (team B) when they had a stronger set of skills, capacity, and a more secure position in society (teams B, E, I). These reflections converge to show the transformational seeds planted by the experience of participating in CS activities in terms of considering both immediate and life-long engagement with environmental issues. This desire to engage and scale up action is indicative of an emerging scientific-environmental citizenship.

Developing Skills for Environmental Activism

Joining NGOX's CS activities not only increased students' sense of responsibility—it also enabled them to develop practical, scientific,

investigative, analytical, and communication skills, as well as to gain confidence in their ability to address environmental problems. These skills go beyond those learned through other forms of environmental voluntourism available to the youth in China, and are particularly effective in promoting environmental-scientific citizenship.

Nurturing Independence and Honing Agency. Students acquired many technical and scientific skills through their involvement with NGOX, including methods for testing water (teams A, B, C, F), collecting and labelling samples (team D), creating maps of their sites (teams B, C), analyzing and representing their data (team B) and communicating findings and experiences more widely (teams B, C). Beyond these skills, they also learned to design their projects and work with and around institutions to carry them through. First of all, students had to research and justify their selected field site when applying for support from NGOX. Prominent rationales for their decisions included records of water pollution or water-related diseases (teams A, B, C, D, E, F, G), local governments' efforts to solve problems (or lack thereof) (team C), or lack of attention to particular regions, for instance areas with high minority populations (teams D, E) (see Appendix Table A2).

Secondly, students had to develop the ability to work within institutional structures and, in places, to challenge those in order to carry out their fieldwork project. To begin with, they had to gain approval from their university. Although for most teams this went smoothly, some had to compete with other associations, and others had to make a special case for undertaking a project outside campus without an academic supervisor, or for working with an NGO (teams F, I). One team (team E) defied orders by their university not to travel due to weather warnings. Relying on weather forecasts and advice from their host in the village, they decided to travel regardless. Their willingness to risk institutional repercussions (which in this instance did not materialize) suggests that joining NGOX offered an opportunity to test boundaries and build confidence in their own judgement.

Students also had to learn to navigate the challenges of securing access to specific sites. This entailed selecting sites to which team members had an existing connection (teams C, D, F, H), or where some spoke the local language (teams F, H, I), or sites that were relatively close to their campus (teams A, B, G). Four out of the eight teams combined CS activities with tutoring for rural children (teams C, D, E, F), which enabled them to receive additional financial support from their university, and provided them with a contact and accommodation in the village, as well as easier

access to the population. Volunteers also learned that their status as students doing "social practice" could lead to gaining villagers' sympathy (teams A, B, C, D, G), as well as the cooperation of local officials (teams B, C, G, I). Indeed, team I, working in a politically sensitive region, was only allowed access by local authorities once they could prove they were students doing "social practice" authorized by their university (and not activists or journalists), and did not pose a threat of potential negative publicity.

At some point during their fieldwork, all the teams were met by village chiefs, most of whom were welcoming. Some also met with township and county-level officials.[3] In some cases, these local authorities were supportive, in other cases simply indifferent (teams F, H), and in others they asserted their authority by suggesting specific sites (teams B, I). Whatever the case, teams had to adjust to the local context. For instance, team I had to focus on the site suggested by the local authorities, which was closer to the township and may have had a better water pipe network than the more remote sites they had initially chosen. They reasoned that this was preferable to abandoning the project altogether. Moreover, complying enabled them to interview the chief of the local water conservancy bureau. This illustrates a process of learning to accommodate local political constraints, and the potential payoffs in doing so. Team A, who selected a site previously known as a "cancer village" (a village with high cancer rates), decided to visit the site without seeking permission from the township government. This created wariness among the students and stopped them from contacting local authorities to inquire about the local water distribution system, which they later regretted. However, following the official channels may have resulted in not gaining access to the site at all. By contrast, team B were able to access their desired sites despite township officials' disapproval, by reaching out to a superior office in charge of the natural park in which the township is located. These processes provide evidence of students "navigating the state" (Teets et al. 2022) and performing citizenship by honing skills in evaluating and mobilizing political opportunity structures, which may support future engagements with environmental advocacy and interactions with political institutions more broadly.

Critical Thinking About the Value of Data and Action. The students not only learned to collect and obtain data, but also reflected on its usefulness in addressing water quality issues. First of all, they reflected on the scientific validity of their data. Some felt it was limited because they were "still lay people" (team G), "not particularly professional" (team B), or "a little bit amateurish" (team E), even though they stressed that they made their best efforts to ensure

accuracy and avoid compromising the reliability of samples (teams B, D, E, F, G). Secondly, students reflected that simply collecting data would not solve water quality problems (teams B, D). Rather, their narratives echoed Gabrys, Pritchard and Barratt's (2016, 2) concept of "just good enough CS data," which might not meet scientific standards of legitimation and validation, but "could be just good enough to initiate conversations with environmental regulators, to make claims about polluting processes, or to argue for more resources to be invested in regulatory-standard monitoring infrastructure." Similarly, some students argued that while the data they collected may be inadequate on some levels, it was good enough to increase awareness of rural water quality challenges (teams C, D, E), and provide a "reference" point (teams B, F, G) that may attract local government bureaus (teams A, D) or other stakeholders such as bigger non-profit organizations, scientists, or enterprises (teams A, D, F, H) to carry out more accurate and comprehensive surveys and implement solutions (teams A, C, E). Some felt that posting findings on the online map produced by NGOX to draw attention from the wider public would make their activity more meaningful (teams C, G), potentially leading to a "breakthrough" in the mind of the students interviewed for this study (team C). Others highlighted that, on the contrary, the most meaningful form of engagement was sharing their data with villagers and helping them to decrease their exposure to contamination (e.g., by boiling water, teams C, E) or reassuring them that their water was safe (team B). These reflections show that CS led students to develop a critical perspective on the production and use of scientific data, and reveals students' desire to use the data to inform impactful action (see also Dobson 2010 and Irwin 2015).

Understanding the Multiple and Complex Causes Giving Rise to Water Pollution

Carrying out investigations "in the real world" also enabled students to appreciate the wider contexts of rural water pollution. As students came to realize that environmental conditions result from actions and inactions by a range of actors, and that these are often difficult to remedy, they furthered scientific-environmental citizenship.

Learning About the Source of Rural Water Quality Problems. Although some students had direct experience of water pollution in their hometowns, they had a limited grasp of the complexities of rural water provision. Investigating the local water supply source(s) and understanding the challenges to supplying clean water at the intersection between geographic conditions, government

plans and individual behavior was a major learning point (team C). For instance, team A, working in a former a "cancer village," realized that water supply in the village involved a variety of sources with different quality levels, ranging from relatively safe tap water from a water plant—purified water delivered to villagers' homes by the township government—to the unsafe wells dug by villagers themselves. Similarly, students from other teams realized that water sources may change through the year depending on weather and climate. In one case, tap water would run out during drought, requiring use of less clean rainwater stored in household containers (team H). In another, low temperatures caused pipes to burst, which prompted locals to rely on the river, or on privately (and inadequately) dug wells (team E). Some teams developed a strong awareness of a range of challenges and forms of water contamination besides industrial pollution, ranging from soil salinization and pollution from livestock and excessive use of fertilizers and pesticides (teams B, C, E). As a whole, students learned that establishing whether water is safe is a complex and multilayered endeavor.

Forming an Opinion About the Role of Government in Local Water Governance. Better understanding the causes of water pollution also led students to reflect on the role of government in their particular sites. For instance, team A learned that the local government's decision to provide barrels of purified water despite tap water already meeting quality standards may have been made in an effort to rebuild trust among villagers. However, they also found that it had the effect of causing some villagers to doubt whether tap water was safe to drink. Other teams reported that villagers were frustrated by their dependence on local government to fix problems, or by the perceived untrustworthiness of their local government (teams B C, D, G). However, students also came to learn that some local governments' failures could not be simply attributed to lack of commitment, but also to a lack of capacity (teams C, E, I). On a more positive note, some teams found water quality and governance to be better than they expected (teams A, B, D, I). Across the cases we examined, learning about the role of local government in water provision improved students' understanding of the challenges local governments face, the many factors which affected their decisions, and the potential consequences of these decisions.

Getting a More Nuanced Appreciation of the Limited Capacity of Villagers. The very process of having to deal with local authorities during fieldwork also enhanced students' appreciation of the constraints, both real and perceived, upon citizens' ability to remedy problems themselves. Across several teams,

students reported becoming increasingly aware of the limitations on villagers' agency. Key constraints were villagers' limited confidence in their own knowledge (teams D, F, H) and limited capacity to demand change (teams C, G), which reinforced a widespread sense of helplessness and passivity (see also Lora-Wainwright 2021).

As is common in rural China, rural-to-urban migration among working-age adults seeking employment means that villages were mostly populated by children and elderly residents; the latter often felt powerless to be heard and believed they could only wait for the government to intervene (teams A, I). To their surprise, students also found that villagers were sometimes convinced that their water was clean and there was no need to intervene. In one site (team H), villagers used their experience of drinking local water without obvious (to them) adverse health effects to question students' findings. In another (team I), villagers were satisfied that tap water was now provided, even if it was unsafe according to the students' tests. Crucially, students also became aware that in some cases, lack of trust in the local government limited villagers' willingness to pay for interventions such as repairing infrastructure or installing a purified water dispenser (team B).

Understanding these complexities supported students' gradual realization that there may be multiple reasons why villagers do not play a more active role in demanding better water quality, and that while limited knowledge may be an obstacle, lack of entitlement and lack of trust in local government were just as vital. These realizations are crucial ingredients in shaping students' understanding of the importance of local contexts and of challenges to local water governance. Realizing the limited agency exercised by villagers also nurtured environmental justice values among volunteers that underpin their scientific-environmental citizenship.

Learning to Appraise and Overcome the Limits to One's Agency

Finally, participating in CS with NGOX raised students' awareness about the challenges of navigating limitations to their own agency, which is a foundational part of students' scientific-environmental citizenship.

Coping with Material Limitations

The most basic challenges were posed by the fact that NGOX could only afford a limited number of water test kits, which teams across China had to share in a very tight schedule coordinated by NGOX to maximize use

during the summer vacations. In some cases, teams did not receive sufficient amounts of reagents for testing (teams B, C); others received the test kits late and feared this compromised the reliability of the results (teams E, G, H). For some teams the ability to use the equipment was compromised by difficulties procuring batteries (teams D, G) and accessing distilled water in remote areas (teams D, G). For others, the test kit provided could not test for the presence of the particular bacteria that they suspected might account for particular forms of contamination. Beyond these technological challenges, most teams also found the sample surveys provided by NGOX too long and technical for the rural respondents (teams B, C, D, E, G, H, I).

Students addressed these difficulties in creative and enterprising ways: by simplifying the questionnaires (teams A, B, C, F, H, I), sending a team to re-collect samples once they received the test kits (team D), splitting the team to gain in efficiency (teams B, E, G), but also sending their samples to professional labs (teams C, D, H) and organizing a second trip to the village after initial tests were carried out to collect more samples and further elaborate on findings (teams C, H).

Reckoning with their Status as "non-Expert"

Technical challenges were compounded by having to reckon with their status as "non expert." Students doubted their own ability to draw conclusions from the data, given its often mixed quality, quantity, and reliability. This was most frustrating for the teams who were confronted by a high incidence of certain health conditions—such as liver cancer and kidney stones (team C), Kashin-Beck disease (team D) and hydatid disease (team E)—but were unable to find a correlation with their water test results. Moreover, some teams were concerned that villagers would not listen to their advice (team A) and many feared that their data may not be taken as seriously by local governments as it would if they were working with professionals (team F) or led by a university professor (teams G, I). Some were discouraged by local officials' dismissive attitudes (teams C, F, G). However, several teams took this as an opportunity to work directly with villagers or seek attention from other stakeholders.

Facing Challenges in Implementing Solutions

Considering their desire to make a positive difference, the biggest source of frustration for students was the challenges they faced in enabling or enacting interventions. Frequently, team members reflected that they lacked the capacity

to provide solutions (teams A, C, F), and that more stakeholders needed to be involved (team C). Yet, teams pursued a range of different pathways in response to the challenges at hand and the opportunities they were presented with. Remarkably, one team (team H) succeeded in working together with NGOX, another charity, and the village leaders to install a centralized clean water dispenser for the whole village in 2019. Other teams found it harder to address the issues they encountered in the field and therefore adapted to work within the limits of what was feasible for them.

Raising awareness of safe water use was a common focus for intervention (teams D, F). For instance, confronted with endemic levels of poverty, team E had to abandon the idea of installing a purified water plant for which villagers were unwilling to pay, and focused instead on raising awareness of safe water consumption practices. They also made moves to involve professional researchers investigating hydatid disease. This shows that although students were aware of both their limitations and the need to involve other actors to ensure effective intervention, they nevertheless explored ways in which they could leverage their role as citizen scientists to make a difference. Some teams found ways to collaborate with or get attention from the government. For example, team I responded to the lack of capacity in the local water conservancy bureau by advertising vacancies at their university. Team B managed to get more attention from the local authorities by focusing on the water quality issues they found in one particular village that was earmarked for developing tourism. This taught them the important advocacy skill of framing one's claims in a way that aligns with authorities' concerns and priorities. These processes contributed to developing students' understanding of what it would take to bring about desired changes, both in terms of mobilizing various societal resources and advocating for their cause to those with decision-making power.

Discussion

Our data suggests that Citizen Science and NGOX's work are particularly powerful in shaping scientific-environmental citizenship because of their intersecting effects on scientific and environmental awareness and on volunteers' agency. CS nurtures a critical attitude toward scientific data and stimulates reflexivity about the limited potential that data by itself holds for enacting solutions. At the same time, it allows volunteers to realize that even imperfect data opens spaces for participation and practicing scientific-environmental citizenship, as it serves to support evidence-based and therefore more persuasive claims about environmental conditions (Conrad

and Hilchey 2011; Walker 2012; Gabrys, Pritchard and Barratt 2016). Independent production of environmental data by NGOX-supported teams raised volunteers', villagers', and the public's awareness of rural water issues and enabled these groups to envision practical improvements. Volunteering with NGOX also provided students with first-hand experience of the practical difficulties involved in fulfilling their desire to play a positive role in society and to confront the realities of unequal access to clean water. These effects are consistent with a definition of citizenship as a "learning process" which "enhances wider citizenship capabilities and potentialities" (Irwin 2015, 32).

The specific form that CS takes in our case study and the relatively unthreatening social identity of the volunteers as students rather than professional activists or reporters makes CS even more effective in the political context of contemporary China. Because NGOX's CS is positioned as *contributory* to the Chinese state's efforts toward environmental protection and does not pursue broader demands of co-decision powers for the rural communities they investigated, it provides citizen scientists with a relatively safe space for "practiced engagement" (Leach, Scoones and Wynne 2005; Irwin 2015, 36); a space in which they can pursue their aspiration to understand and address environmental and social problems, learning to do so within political constraints and employing scientific data. In this sense, while teams supported by NGOX might often have limited impact on the communities they studied, the projects were individually, socially, and politically transformative for the students involved. For scholars interested in CS, noticing the particular form of CS practice adopted by NGOX evidences that citizenship at large and scientific-environmental citizenship more specifically take on particular characteristics as they adapt to different polities. This underscores the importance of examining those specific political contexts closely.

This article has showcased the value of attending to the development of scientific-environmental citizenship among CS participants in China, but it is equally important to do so in the study of CS in more liberal political contexts. Attention to how citizenship is experienced and performed through CS —rather than focusing on the data produced and its value in advancing more democratic forms of science—supports a more nuanced and varied understanding of citizenship. This illuminates the political horizons of possibility that are open to participants, the ways in which they can learn to navigate them, and how they make sense of their experiences. In turn, it fosters a more inclusive study of a broader range of CS initiatives and a fuller grasp of the spectrum of potential outcomes they nurture.

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Credit Statement

Coraline Goron: conceptualization, investigation, methodology, resources, data curation, writing—original draft, writing—review and editing, project administration–funding acquisition. **Anna Lora-Wainwright**: conceptualization, writing—original draft, writing—review and editing, supervision. **Shuling Huang**: resources, investigation, data curation.

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Notes

1. Examples include Callon et al.'s (2009) "hybrid forums," and Whatmore et al.'s (2009) "competency groups".
2 Green camps (*Daxuesheng Lvse ying*) were launched by environmentalist Tang Xiyang in 1996 and took university students on fieldtrips to some of the most polluted or degraded areas of China every year for more than a decade to advocate for environmental protection. It nurtured a generation of environmental activists and college student environmental groups in China (Wu 2009).
3 In China, villages (*xiangcun*) are overseen by townships (*zhen*), which in turn are overseen by counties (*xian*).

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Appendix

Table A1. Examples of recent citizen science projects in China

Program name	Program overview	Organization(s) name	Date
乐水行 Walking Water	Involves teams of volunteers in monitoring the riverside of Beijing rivers	Friends of Nature, Global Village, green home, Nature University, and others	Since 2007
FLOAT Beijing	Involves the public in measuring air quality data from flying kites in Beijing and disseminating the data through Weibo, and the FLOAT project website	international students	In 2012
城市水环境公众参与 Urban water environment public participation	App platform created for citizens to report urban "black and smelly water" across China by uploading pictures and letting government address it	Ministry of Ecology and Environment, Institute of Public and Environmental Affairs, Friends of Nature and local NGOs	Since 2017
清水为邻 Clean water as link	Involves local teams of volunteers in investigating "black and smelly" water bodies across China	SEE foundation, Institute of Public and Environmental Affairs, Friends of Nature, River Watchers	Since 2016
安全水源计划 Safe Water Source Program	Involves local river watcher teams in carrying out river conservation missions and activities, monitoring river pollution and water source governance	River Watchers; Green Hunan	Since 2014

(continued)

Table A1. (continued)

Program name	Program overview	Organization(s) name	Date
河流守望者 Water Watchers	Involves volunteers in 249 cities across China in monitoring water sources, cleaning up garbage, and treating black and smelly water bodies which affect over 584 rivers	Beijing Water Watchers and Green Hunan, developed into a nationwide network	Since 2011 in Hunan, all China since 2017
成蹊计划 Chengqi Program (foundation)	Involves grassroots ENGOs and supports them in involving volunteers in the monitoring of local water bodies	He Yi Institute and grassroots NGOs	Since 2015
北部湾滨海湿地科考行 Scientific Research Tour of Coastal Wetland in Beibu Gulf	Involves volunteers in participating in monitoring biodiversity in the Beibu Gulf coastal wetlands	Guangxi Biodiversity Research and Conservation Association	Since 2015
城市里的公民科学家 Citizen scientist in the city	Involves volunteers in monitoring and protecting urban wildlife in Chinese cities	Fudan University and Shanshui Conservation Center	Since 2019
守护海岸线科研监测项目 Guarding the coastline scientific research monitoring project	Involves volunteers, social groups and scientists in monitoring and analyzing beach garbage in China	Rendu Ocean and Shenzhen Mangrove Wetland Protection Foundation	Since 2014
守三江水、护万物源 Guarding the Three Rivers and Protecting the Source of Everything	Involves local volunteers in surveying areas in the headwater region of three major rivers (Yangtze, Lancang and Yellow River), collecting data and developing conservation plans, including community-based actions	Alashan SEE and local NGOs	Since 2018

Table A2. Summary of interviews with student volunteers engaged in Citizen Science projects sponsored by NGOX in China

Interview date & mode	Code	Reason for choosing field site (not in order of importance)	Tutoring during fieldwork	Minority area
18 September 2018	A	Report of severe pollution and illnesses ("cancer village"); relative proximity to campus.	no	Hui minority
23 March 2019	B	Relative proximity to campus; pollution records; poverty; efforts to develop green tourism.	no	no
30 March 2019	C	Water pollution records; government effort; contact with village head; contact with local school; report of high rates of liver cancers.	yes	no
20 April 2019	D	Minority area receiving little attention; contact through a student from the village; report of water-related disease; contact with local school.	yes	Hui minority
3 April 2019	E	Reports of hydatid disease; remoteness; poverty; minority area; contact with local school.	yes	Tibetan minority
1 April 2019	F	Reports of water pollution; consumption of untreated underground water; poverty; minority area; contact through a student from the village.	yes	Yi minority
7 April 2019	G	Reports of water pollution; relative proximity to campus.	no	no
13 April 2019 (online)	H	Poor village with water access issues; relative proximity; contact	no	Hui minority

(continued)

Table A2. (continued)

Interview date & mode	Code	Reason for choosing field site (not in order of importance)	Tutoring during fieldwork	Minority area
		through a student from the village.		
13 March 2019 (online)	I	Report of water scarcity; poverty; remoteness; student from the area.	no	Kyrgyz minority