CITIZEN SCIENCE: THEORY AND PRACTICE

SPECIAL COLLECTION: DISASTER, INFRASTRUCTURE, AND PARTICIPATORY KNOWLEDGE

ESSAY

Disaster, Participatory Science, and Infrastructure

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A growing body of empirical research documents how both institution-based citizen science projects and collaboratively led community science initiatives emerge in response to disaster (Dosemagen and Parker 2019; Palen et al. 2015; Rey-Mazón et al. 2018; RAND 2017). For example, in the aftermath of the Deepwater Horizon oil disaster in the US Gulf of Mexico, residents used social media to monitor the associated pollution and collect real-time data for assessments of health-related exposures (McCormick 2012) and ecological damages. Similarly, in the aftermath of the Fukushima nuclear accident, a number of citizen radiation-measuring organizations were established to measure food contamination levels (Kimura 2016). In many other instances, communities are using science as a tool to articulate the problems associated with longer-term disasters such as those related to oil and gas extraction (Wylie 2018) or marine plastics (Liboiron 2021). The COVID-19 pandemic has resulted in numerous additional examples, and the response exemplifies how today's disasters can spur citizen and community science into action. Dissatisfied with quality, timing, and scope of officials' and experts' data, citizen and community scientists have filled gaps in data that help people cope with the acute and chronic effects of disasters and can shape the mitigation and reconstruction processes that follow.

Disasters are the result of materialized risk, and occur when a hazard (e.g., a flood), is linked to exposure (e.g., a town in the path of the flood) and vulnerability (e.g., lack of flood preparedness). Headline-grabbing disasters such as earthquakes in Nepal, floods in eastern Australia, and fires in California and Greece may shape societal understanding of disasters as something acute and geographically specific, but—as the COVID-19 pandemic makes clear—they can also be slow-moving and geographically dispersed. Disasters are fundamentally social, and they tend to accelerate, reinforce, and deepen social vulnerabilities and economic inequalities, and they can reveal how social institutions and socio-technical infrastructure amplify social and environmental inequality. For instance, the 2010 earthquake in Haiti was a major disaster not only because of its sheer magnitude but because of existing social factors, such as poverty and insufficient public health infrastructure, rooted in the history of colonialism and dictatorship (Kelman 2020). These concerns—and their growing urgency amid ongoing political and ecological uncertainty—frame

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the focus of this special collection of *Citizen Science: Theory and Practice* on the ways that physical, social, and digital infrastructure mediates citizen and community science responses to all types of disaster.

As guest editors, we were drawn to this topic because, despite the growing body of empirical research, we have noticed a dearth of analyses that consider how sociotechnical infrastructures—for example, highways, algorithms, and COVID-19 testing stations and procedures—shape disasters and mediate disaster responses. We also recognized the opportunity that citizen and community science provide for inter- and cross-disciplinary analysis; we and the authors of the articles included here represent a number of different disciplinary backgrounds, including the biological and physical sciences, science and technology studies (STS), and disaster studies.

This editorial introduces infrastructure as a conceptual framework as developed in the field of STS and summarizes why we believe it provides an important set of tools that can inform analyses of citizen and community science—especially, although not exclusively, in the context of disaster. Generally speaking, research in STS examines the social and political processes and contexts in which scientific knowledge and technological systems are produced and circulated, as well as the societal and environmental consequences of those constructions. To be sure, disaster response and recovery (DRR) and other related areas that focus on disaster prevention and management have contributed enormously to the understanding of disasters and their social shaping. But the STS concept of infrastructure is particularly helpful in exposing social power and inequality—including the often-hidden yet consequential effects that power and inequality have on social connectivity. In this introduction, our goal is not to provide a full review of the concept but rather to provide some signposts to entice practitioners and scholars of citizen and community science to look into the field more deeply. We also highlight the benefits and challenges of engaging in interdisciplinary work with the depth of attention that it deserves. Along the way, we spotlight the research articles assembled for the special collection as they consider a range of different challenges and opportunities that arise for citizen and community science before, during and after disaster strikes.

DISASTER AND PARTICIPATORY SCIENCE

There are many drivers behind the participatory turn in disaster responses, and this special collection highlights a range of ways that participatory science can contribute. These include the perceived agility of the grassroots, the usefulness of local knowledge, and the potentially large size and scale of lay people's contributions (big data). When governments and expert communities are overwhelmed in responding to disasters, communities often mobilize to attend to unmet needs. Citizen and community science approaches represent important opportunities for collecting information that addresses locally meaningful questions and concerns. Alternately, in cases such as the COVID-19 pandemic, societal preparedness is always inadequate due to the scale of the risk and the speed at which response is required, and there is a scope for new solutions and innovation through citizen and community science.

Many of the articles included in this special collection highlight the benefits of participatory approaches in disaster response. For example, **Rohlman et al.** review various participatory knowledge approaches and develop a bottom-up argument for the utility of "community-engaged disaster research" (CEnDR). Similarly, **Hendricks et al.** are concerned with the maldistribution of power across a continuum of hazard planning phases, from mitigation to recovery, that "tends toward top-down, expert-driven processes that fail to meaningfully include communities most at risk of disasters." A more just and equitable approach, they argue, can be found in citizen participation at every phase, including data collection, design, and analysis. **Hultquist and Tubbeh** examine community responses to Covid-19 in New York City during the pandemic's first year to show how community-led responses mobilized existing data infrastructure to collect, share, and use information that informed delivery of care to city residents.

WHY INFRASTRUCTURE?

STS scholarship also has a lot to say about infrastructure. Defined in formal theoretical terms, infrastructure refers to "pervasive enabling resources in network form" (Bowker et al. 2010: 98). Less formally, we can think of infrastructure as the sociotechnical systems that constitute the built physical, social, and virtual/digital environments we all inhabit. For Bowker and colleagues (2010: 97),

> The term "infrastructure" evokes vast sets of collective equipment necessary to human activities, such as buildings, roads, bridges, rail tracks, channels, ports, and communications networks. Beyond bricks, mortar, pipes or wires, infrastructure also encompasses more abstract entities, such as protocols (human and computer), standards, and memory.

Infrastructure is social as well as material or technological. People who design and maintain the networks are also part of infrastructure, as are large institutions like governments, militaries, and corporations that tend to fund, organize, and regulate infrastructure. In turn, as research by Jennifer Gabrys and colleagues suggests (Gabrys et al. 2016), infrastructure organizes society and can give value to (or devalue) human and ecological life.

From this perspective, building analysis of infrastructure into our accounts of citizen and community science is important because it is the *connective systems* that knit societies together to order society in particular ways. The electrical grid is a good example. The system physically connects our homes and offices to one another and to power generation and transmission stations often located tens or hundreds of miles away, linking entire regions together. The impacts of an ice storm that knocks out one transmission tower can reverberate across the entire grid (Murphy 2001). The same grid also orders society, from bottom to top. It structures how and when we use energy and when and whom we pay for it.

Infrastructures also *reflect the existing power relations in society*. The electrical grid concentrates political power in a relatively small number of energy corporations and utilities, and shapes how energy prices are regulated and public debate over whether energy access is a commodity or a human right (Kallman and Frickel 2019). In another instance, water infrastructure in India has developed since the colonial era in a way that provides water for the wealthy and the well-connected while denying water to many others. In this way, infrastructures are "always productive of social and political difference" (Anand 2017: 226).

Despite its ubiquity, infrastructure is often *socially invisible*, and often physically invisible too. Infrastructure requires continual maintenance—labor that we rarely notice. Some of this work involves fixing or updating physical infrastructure. Less often appreciated is the *maintenance of social relations*, which is also integral to keeping roads, water systems, or communications networks running (Elyachar 2010; Anand 2017). As **Kenens et. al.** discuss, citizen science in response to disasters may be organized in a rush, but there is complex negotiation with the intended and unintended encounters with government while navigating post-disaster accountability politics. It is only when infrastructure stops working as designed that we tend to notice or care or raise concerns about how it works or when it works or for whom. Most people do not give a second thought to the wires running through the walls of our homes until we throw a switch and the room remains dark. We don't think much about highway systems until coastal storms flood interchanges, stranding commuters between work and home or blocking families' escape routes.

STS has also historicized the shape and nature of infrastructures, exploring questions about the particular contours infrastructure takes as it is planned, constructed, maintained, or altered across different time periods and contexts. This temporal sensibility opens up a way to interrogate not only how disaster strikes infrastructure, but also how disaster and its anticipation is often already *incorporated into infrastructure*. As several articles in this special collection suggest, disaster mitigation and response itself constitutes a type of infrastructure, evinced most directly in **Ottinger's** insistence that researchers consider the implications of "infrastructuring" participatory science into the contemporary disaster response and preparedness regimes.

DISASTER AND INFRASTRUCTURE

There are many reasons why research on disasters benefits from analyzing the social and political aspects of infrastructures. One important reason is that disasters render (failed) infrastructure socially visible, allowing researchers to reach and examine infrastructure that is usually hidden or otherwise inaccessible. Gaining access to infrastructure, in turn, can help researchers clarify how infrastructure—and the institutions responsible for building and maintaining it—conditions disaster historically, over decades. This is why, for example, the channelization of the Louisiana coastal wetlands for oil and gas development and shipping over the course of the 20th century literally "engineered" Hurricane Katrina's devastation of New Orleans' Ninth Ward neighborhoods in 2005 (Freudenburg et al. 2009). A longer-term perspective on infrastructure also helps to explain why, in Japan's Fukushima prefecture, regulatory infrastructure that could have provided independent oversight on safety, emergency infrastructure to ease resident evacuation, and legal infrastructure that would allow right-to-evacuate claims were all missing when an earthquake sent a tsunami crashing into the Fukushima Daiichi Nuclear Power Plant in 2011 (Kimura 2016). In both cases, social relations and power distributions historically sedimented into existing infrastructure are central dimensions of disaster, response, and impact.

Infrastructure also shapes how citizen and community science responds to acute disasters and whether it develops or evaporates over longer periods of disaster recovery. It influences whether citizen and community science translates participatory knowledge into meaningful and lasting institutional changes. Indeed, citizen and community science is itself a form of infrastructure. In this collection, **Drill et al.** study the "infrastructure of citizen science" to investigate how various characteristics of citizen science projects interacted with changes in "social infrastructure" during COVID-19 lockdowns in the US, and how that affected participation. In their study on community seed networks in this collection, **Soleri et al.** demonstrate how the networks' social dimensions, in addition to biological attributes of seeds, can contribute to better project structure and enhance the infrastructure of participatory science itself. After all, research also depends on, and is influenced by, infrastructure.

The consequences of infrastructure in disaster settings are as paradoxical as they are profound: As the pandemic has shown, the grid, and also the internet, health care delivery systems, and global supply chains, allow more and more of us to live and work in isolation, even as they connect us and pull us ever more tightly together. Infrastructure's social invisibility is a measure of its power to order social life but also to resist collective efforts to change the system—as decades-long struggles over alternative energy technologies, mitigation of coastal erosion, health care, public transportation, and social welfare support have shown in the US and elsewhere. In this context, **Arancibia et al.** highlight how the entrenched interests of agrochemical companies influenced decision-making within an Argentine university medical school, discontinuing a novel and far-reaching participatory project developed by students, professors, and residents of rural communities to understand the health impacts of pesticides in those communities. Changing infrastructure is difficult and usually achieved only at great expense. As Naomi Klein (2007) has famously argued, disasters are moments of possibility for change…or retrenchment.

THE OPPORTUNITIES AND CHALLENGES OF CROSS-DISCIPLINARY WORK

Citizen and community science offer unique opportunities for cross-disciplinary work—in particular, the opportunity to bring awareness of social structures and power dynamics into research that is often designed to advance understanding in the biological and physical sciences (see Frickel et al. 2017). The authors of the articles in this special collection share the observation that there is a great deal to be gained from cross-disciplinary work; nearly every article describes the desire to bring the lessons from one discipline or tradition into another.

As described by **Soleri et al.**, "there may be an important opportunity for community science to recognize and more systematically explore the social investigations being undertaken in tandem with the biophysical ones. These investigations are more than 'methods' for achieving biophysical goals; they may offer pathways to more just and effective responses to Anthropocene crises." In particular, some authors note the benefit of bringing their own home disciplinary tools to disaster studies. **Simmons et al.** describes how a platform designed for citizen science and used by citizen scientists can complement other online crisis-mapping platforms. **Ottinger** develops an argument for attending to community-building and social organization to ensure that citizen science is actually integrated into disaster response systems.

However, articles in this collection also highlight some of the difficulties inherent in conducting truly cross-disciplinary work. In particular, they demonstrate the challenge of integrating social science concerns with power, organization, and inequality into studies designed to answer biological or physical science questions, or research traditions that traditionally have taken infrastructure and other complex systems at face value—i.e. treating "the social" as a unidimensional and ahistorical addendum to the biophysical—or ignoring the social altogether. This can result in negative impacts on communities, especially when citizen and community science is involved in disaster response.

If we want to take infrastructure seriously—and we hope we have conveyed some compelling reasons for doing so—citizen and community science scholarship could do worse that to adopt the following four lessons from this special collection's conversation with STS. These lessons are basic to STS's own epistemic culture and reflect signature features of the knowledge that field produces:

- Lesson 1. Work toward social explanations of science and technology. That is why we use the language of "sociotechnical systems," with an emphasis on "socio," when talking about infrastructure. A rule of thumb in STS is that technology alone almost never provides sufficient explanations absent some paired analysis of (human) technique and the social communities (organized as disciplines, markets, regulatory agencies, and the like) that design, build, maintain, disseminate, and use the technology.
- Lesson 2. Emphasize the ways that sociotechnical systems influence distributions of social power and inequality. For example, the sociotechnical infrastructure developed to deliver frontline care in response to the COVID-19 pandemic (to those able to access the system) also puts frontline healthcare workers and their families at sustained risk of new exposure. In this way, infrastructure can extend, but also complicate, power dynamics in society.

- Lesson 3. Attend to power relations in citizen and community science. Having participatory components to a research project does not necessarily eradicate power imbalance and inequality. Participation and openness can be shaped in a tokenistic way that does not destabilize the power held by existing elites. Gender, class, citizenship status, and physical and cognitive abilities can shape who can become volunteers to participatory projects and also shape how and where the resulting knowledge circulates. Analyses should shed light on these power relations within a community.
- Lesson 4. Practice self-reflexivity in making knowledge claims. This means thinking critically and writing transparently about, for example, the infrastructure that has been built to support citizen and community science research—including the tools and concepts that organize the work, the funding streams that support it, and the system of professional societies, annual conferences, and journals (including this journal) that warrant and disseminate the work.

As the world reflects on the COVID-19 pandemic in coming years, there will be an enormous amount of literature about the acute and long-ranging responses, including through the lens of citizen and community science. This work will be part of a larger exploration of the complexities of different types of infrastructure and their interplay, and how disasters both elucidate and change them. In addition to the technical and physical analysis of future disasters, a critical analysis of social infrastructure will be increasingly important as a means to reflect upon, critique, and ultimately prepare in different, and hopefully better, ways for 21st-century crises. The editors of this special collection believe that it offers a starting point for these discussions, in the hopes that these cross-disciplinary analyses become a standard part of our understanding of the biological, physical, and technical questions raised by disasters.

COMPETING INTERESTS

Dosemagen and Parker previously served as members of the Citizen Science Association Board of Directors.

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