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ENVIRONMENTAL SENSING AND "MEDIA" AS PRACTICE IN THE MAKING

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Figure 51.1 Participant setting up Speck monitoring device, with logbook of monitoring practices.

Source: Citizen Sense 2014.

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Introduction: Citizen Sensing

From ubiquitous computing to the Internet of Things, sensors that monitor and automate environmental processes are now proliferating. Along with the increasing prevalence of these devices, a diverse range of practices has arisen. Termed "citizen sensing," users equipped with low-cost sensing devices and sensor-enabled smart phones are able to monitor environments and collect real-time data. From recording air pollution levels to tracking the migrations of animals, sensing technologies allow citizens to observe environmental processes in increasing detail and communicate environmental observations to fellow citizens and policymakers. As an emerging set of practices and devices, however, citizen sensing also raises multiple questions about how environmental "citizenship" becomes articulated and even delimited as a technological and evidence-based mode of participation. This chapter outlines the key literature, practices, and technologies that have contributed to citizen sensing, and then discusses through the Citizen Sense research project how a practice-based and participatory study has sought to understand and contribute to this emerging area of citizen sensing and the development of digital media technologies.

On one level, citizen sensing inevitably resonates with a longer history of citizen science practices, where amateur natural historians conduct surveys and gather samples of environmental organisms and events, or alternatively might collect data on environmental pollution to advance social justice issues (Irwin 1995; Corburn 2005). Building on these areas, citizen sensing is also distinct in its use of digital monitoring technologies, such as sensors that enable new orders of data collection and real-time observations of environments. In its earlier uses, citizen sensing as a term often referred to "volunteered geographic information," where users provided data and developed applications for Open Street Map and Google Earth, among other platforms (Goodchild 2007). While sensors were notionally discussed as part of this early research on citizen sensing, which often focused on the validity of citizen-gathered datasets, a more thoroughgoing engagement has largely occurred through the development of low-cost sensing devices, such as the Air Quality Egg, Citizen Sensor, Air Casting, and Smart Citizen, which are projects located within maker communities. With citizen sensing, the focus has also shifted to include not just citizens providing geographic data across mapping platforms, but also the development of open hardware and low-cost physical computing that can generate data on phenomena such as urban air quality.

As an area of practice and study, citizen sensing crosses multiple fields, including geography and computer science, human-computer interaction, and media and communication studies, as well as art, design, and architecture. It also contributes to and is advanced by work in digital humanities, since many of the core issues that citizen sensing raises—in relation to participation, sensing, and citizenship—are longstanding discussions core to the humanities. At the same time, related and more extensive discussions within media theory have attended to questions about the nature and quality of participation within social media (Foth et al. 2011), as well as shifts from consumer to user, crowdsourcer, maker, and hacker modes of media engagement (Ratto & Boler 2014). The 2.0 designation of the internet and beyond captures this user-focused approach, which has proliferated from the internet to ubiquitous computing and multiple other forms of environmentally distributed digital devices (Galloway 2004; Dourish & Bell 2011). Citizen sensing activates digitally informed and practice-based engagements that put these concepts to the test within specific situations and in relation to distinct environmental problems.

The critical issues that define citizen sensing include questions related to which practices of citizenship and modes of participation digital sensing technologies might enable or delimit.

How do sensors and the environmental processes they trace influence relations and responsibilities toward environments? In what ways do the political, material, and affective orientations of sensing devices fulfill their performative potential? And to what extent do the diverse practices of citizens' everyday sensing practices reorient the intended programs of these devices? By enabling practices of environmental monitoring, data collection, and even technological tinkering, citizen sensing arguably prompts distinct types of participation that, on the one hand, activate particular forms of environmentalism and environmental responsibility that are largely data-focused. On the other hand, citizen sensing might be located within a broader context of environmental computing, where digital technologies and their modes of participation are moving from primarily screen- and platform-based engagements to more distributed and environmental sensory encounters. Citizen sensing thus has consequences for how the sites of digital media and digital media engagement might be located.

One way to research these developments might be to undertake an ethnographic study of an existing citizen sensing project. But as many technologies, communities, and practices related to citizen sensing are not yet stabilized as clear "objects" of research, undertaking a citizen sensing project is another way to research these emerging technologies and practices. The remainder of this chapter discusses once such effort: citizens sensing pollution stemming from unconventional natural gas extraction, or fracking, through the use of low-cost environmental sensors.

Pollution Sensing and the Citizen Sense Project

The Citizen Sense research project takes up the topic of citizen sensing as both a theoretical and practical area of inquiry and intervention. Structured in relation to three research areas, namely pollution sensing, urban sensing, and wild sensing, it focuses on environmental areas of citizen engagement to test, query, and potentially advance citizen sensing practices. The first project area, "pollution sensing," concentrates on the increasing use of sensors to detect environmental disturbance, including air and water pollution. The second project area, "urban sensing," focuses on urban sustainability or "smart city" projects that implement sensor technologies to attempt to realize more environmentally sound urban processes. The third project area investigates "wild sensing" and focuses on the use of sensors to map and track flora and fauna activity and habitats. The project areas set out to contextualize, question, and expand upon the understandings and possibilities of democratized environmental action through citizen sensing practices.

Within the first project area, "pollution sensing," the Citizen Sense research team first identified through desk-based research and fieldwork a range of existing citizen sensing projects and technologies. It became clear that a number of citizen sensing practices were already underway, monitoring air and water quality at sites, particularly in northeastern Pennsylvania, near fracking infrastructure and operations. Citizens engaged in monitoring activities might not have referred to their practices as "citizen sensing," and instead might have situated themselves within a wider context of monitoring practices aimed at environmental and social justice concerns, from fenceline monitoring at industrial sites to documenting health effects and keeping diaries of exposures. At what point, then, does citizen sensing become identifiable as a particular set of practices? Do maker-based digital technologies need to be introduced into settings to initiate citizen sensing engagements, or do existing practices provide another way of thinking about and practicing citizen sensing as something more than technology-focused?

In many ways, even from the early stages of identifying citizen sensing practices, the very use of this term prompted questions about how distinct digital practices stabilize and become recognizable. As part of the participatory aspect of the Citizen Sense research project, residents of northeastern Pennsylvania were consulted about which pollutants and environmental disturbances they were already in the process of monitoring, how they described and undertook their practices, what wider networks were important for communicating findings, and how it might be possible to work together to develop a "citizen sensing kit" that would be of use for monitoring air pollution in relation to the fracking industry.

As part of a back-and-forth dialogue, the Citizen Sense team developed a "logbook of monitoring practices" for residents to not only identify existing individual and institutional monitoring practices as well as issues related to their environments, but also make proposals for how to monitor or otherwise act on pollution concerns. Based on these logbook entries, along with images and video submitted by residents documenting their environments, a number of possible monitoring technologies and practices were identified that could assemble into a citizen sensing kit for use and testing. After several discussions with residents, and also through research into which technologies might be most adaptable, affordable, and accessible over a long period of use, the Citizen Sense Kit came together as a range of devices: Speck devices (borrowed from Create Lab at Carnegie Mellon University; see Figure 51.1) to monitor particulate matter ($PM_{2.5}$); analogue badges to monitor benzene, toluene, ethyl-benzene, and xylene (BTEX) compounds commonly associated with petrochemical industries; a "Frackbox" (developed by the Citizen Sense team) to monitor nitrogen oxides (NO_x), ozone (O_3), and volatile organic compounds (VOCs) and also track wind direction, temperature, and humidity; and an online platform to locate and log environmental monitoring data.

As part of the process for distributing kits, the Citizen Sense team hosted a series of events in northeastern Pennsylvania, including a community workshop where the Citizen Sense Kit was introduced, a walk along fracking infrastructure where various monitoring equipment was tested, and a roundtable to discuss broader issues related to fracking and community organizing. Participants at these events included residents, technologists, environmental health practitioners, local ecologists, and community organizers. During the community workshop, components of the Citizen Sense Kit were then distributed to about 30 residents, who in turn used the environmental sensors for up to 7 months. Participants logged the approximate location of their monitoring on the Citizen Sense platform, primarily through the use of the Speck $PM_{2.5}$ monitor but also by logging their observations of industry and other activity that might generate high $PM_{2.5}$ levels. Data was then available to view both in real-time on actual Speck devices and on the platform once uploaded. Observations and readings could be compared across different monitoring locations, and in some cases discussion arose about the different readings, techniques, and events that might be causing elevated levels of pollutants in particular areas. Participants asked whether elevated readings could be attributed to nearby natural gas infrastructure, or if high pollen counts or other industries nearby were causing spikes they observed in their data.

In this brief account of the Citizen Sense Kit, it becomes clear that the kits developed into much more than digital gadgets or makery "stuff." By working in a context with identifiable environmental problems of concern, citizen sensing practices and technologies quickly become bound up with environments, communities, institutions, and wider politics. The accuracy of monitoring devices, the monitoring protocols used, the legitimacy of the data, and the agendas of users all come into play as factors influencing the techniques of environmental monitoring and the data gathered (see Bowker 2000).

In this respect, participation involves much more than merely using a sensor to gather a reading about a particular pollutant. Sensor use might be a more immediate, if limited, way of understanding what characterizes citizen sensing practices. Yet, in the context of monitoring, citizen sensing clearly moves beyond the often celebratory formula of gathering data for political action and change to open into particular worlds of inquiry and political contestation. New relations and communities might be put into play and activated through monitoring practices, or existing communities might re-encounter old problems with the difficulties of finding ways to hold environmental regulators and industry to account. Moreover, the data that is generated and gathered by monitoring devices is not obviously or immediately available in forms that are easily communicated or circulated to relevant agencies. Instead, data is potentially generated in excess, difficult to collate and present, and subject to disputes about its legitimacy.

Participation, Sensing, and Citizenship: "Media" as Practice in the Making

Returning to the questions posed at the beginning of this chapter, sensors can organize very particular ways of accounting for environmental problems such as pollution. Citizen sensing initiatives involve monitoring, reporting, managing, and even self-managing to establish environmental engagement. Data is collected as a form of "evidence" that might enable claims to be made to mitigate the effects of environmental harm. The hope is that, by undertaking a commitment to monitor environmental problems such as pollution over time, and to collect and systematically present evidence, environmental matters of concern will be taken more seriously by citizens, industry, and others. Yet, as has also become clear, citizen sensing gives rise to other difficulties related to the perceived accuracy of monitoring devices, the practices used for collecting data, and the perceived legitimacy of datasets, particularly when communicated to regulators and industry. In many ways, then, citizen sensing practices necessarily open up and reorient beyond the initial programs of monitoring devices, since the trajectory from sensing environments to collecting data and realizing political change does not play out in an uncomplicated manner.

Indeed, citizen sensing raises distinct points about the politics and practices of sense that emerge at the intersection of sensor technologies, citizen participation, and environmental change. Sensors do not simply detect external phenomena for reporting; they become entangled with particular values and means of informing citizen (and collective) action. Ways of articulating environmentalism and environmental problems, as well as attempts to realize environmental justice, become bound up with the distinct capacities of environmental sensing technology. For instance, air pollution as a problem is foregrounded by the capacity of air monitoring devices to not only make available distributed and widespread tracking of particular pollutants but also query state-led, corporate, and institutional approaches to monitoring and mitigating air pollution.

The issues that emerge through a practice-based study of citizen sensing then point back to the core topics mentioned at the beginning of this chapter—participation, sensing, and citizenship—and become newly encountered and constituted. As a challenge and provocation to media studies and digital humanities, practice-based research reworks the usual designations of these topics and concepts to indicate how a rather different set of issues emerge. Participation is not just, or even primarily, a matter of how individuals interact with digital technologies to achieve desired ends or partake of particular (often online) communities.

Instead, participation through citizen sensing unfolds as a set of activities that require multiple other forms of community organizing that may not be recognized as "digital." At the same time, participation with sensor technologies can give rise to a hesitating and decidedly non-linear set of engagements, where learning about new technologies, establishing modes of consistent monitoring, and communicating findings are practices that come together through repeated attempts to use monitoring devices in effective and potentially unconventional ways.

Similarly, sensing as a concept and term is not a simple matter of sensing a pollutant. Instead, the very pollutants to be identified, the means and skills to conduct studies of pollutants over time, and the development or sourcing of technologies that will suitably and accurately "sense" pollutants materialize as particular practices for strategically monitoring environments. Sensing is thus less about a phenomenological encounter between a human body and external set of stimuli, and much more about particular technologies, concerns, and environmental problems, as well as bodies and politics, concretizing into specific occasions that can galvanize citizen sensing in certain ways (Gabrys 2007, 2016b). For instance, someone using an environmental sensor might have health effects only vaguely connected to air quality data, thereby requiring them to also rely on public health research, environmental policy, and community organizing to put together a case for addressing potentially high levels of pollutants. A practice-based encounter with citizen sensing explodes the assumed modes of detection to point toward a complex set of processes whereby environmental harm might be "sensed" and acted upon.

Regarding the "citizen" in citizen sensing, new insights emerge in practice by testing the very articulations of citizenship that technologies may facilitate. The notion that a device might embody and enable particular forms of environmental citizenship can be tested, challenged, and re-routed. By taking up citizen sensing technologies in practice, and through repeated use and asking how they actually do—or do not—allow for environmental citizen-ship, participants might challenge the claims made about devices, while also developing and inventing alternative capacities for citizen sensing technologies. In this respect, if we understand environmental citizenship to entail responsibilities for creating common inhabitations, then the practices of citizenship might emerge less as a scripted technological program and more as an open-ended and inventive set of collective engagements.

Conclusion: Re-orienting Practices toward Open Technology

Within the wider realm of digital technology, there is a proliferation of newly emerging digital practices, from social media activity to algorithms that match data flow with indicative behaviors, as well as electronic meters that modulate energy use, apps that track sleep and fitness, wearables that monitor heart rate, and devices that document how much pollution might be in any patch of air. These are specific practices enacted through digital technologies, which organize, manage, inform, and otherwise mediate everyday activities and give rise to distinct issues (such as surveillance, which is an important topic demanding further research). Citizen sensing is one such newly emerging practice that is concretizing at the intersection of environmental participation, digital sensors, data collection, and environmental citizenship. The diagram of citizen sensing as a practice is largely assumed in advance as drawing together citizens, entities to be monitored, environments, data, and politics in particular ways. Yet, what might begin as a relatively delineated practice starts to unfold in unexpected ways, overlapping with multiple other practices that blur the boundaries of what counts as citizen sensing.

By undertaking a practice-based study, the complexities as well as possibilities of citizen sensing become more fully apparent. The initial diagram of citizen sensing opens up and points to ways in which programs and their devices are reoriented and challenged by putting citizen sensing to work as both a concept and mode of participation. Citizen sensing might then be considered a *technique* in the sense raised by philosopher of science and technology, Georges Canguilhem (2008 [1965]). If technique presents a mode of engagement—here with machines—where the "facts" of environmental monitoring are not known in advance, but rather where capacities, skills, and potential new objects emerge through actual encounters, then citizen sensing is one such technique that requires an ongoing practice to not only understand the contours of digital engagements but also arrive at new and potentially inventive encounters with sensing technologies. A further point, then, is that citizen sensing as a practice has not yet solidified, and its very quality of being in-process may characterize it as a distinctly digital ontology (Gabrys 2016a).

Within newly emerging and established areas of digital research, a number of terms are solidifying to describe particular practice-based engagements, from making and critical making to hacking and tinkering to critical technical practice and participatory design (Agre 1997; Suchman 2009; DiSalvo et al. 2012). Within media studies, practice-based research might largely be seen to engage with the generation of creative form and content. And within science and technology studies, there is a long history of ethnographic observation and description of practices. There is also a much broader literature that investigates practice as both a topic of ethnographic concern and a methodology for undertaking research across the arts, social sciences, and humanities. Digital humanities research has similarly made a point of moving beyond text-based approaches to focus on experimental engagements, and to take up questions of materiality and making, embodiment, and action (Gold 2012; see also Chapters 9, 19 and 25, this volume). However, this distinction is arguably now less pressing given the proliferation of practice-based approaches that no longer depend upon classification apart from discursive or theoretical modes of research. Instead, practice-based research raises questions about how open-ended and inventive encounters with digital technologies might be one way of more fully researching and addressing the *qualities of technique* that are central to our technological engagements.

This chapter not only suggests that citizen sensing might be addressed as an emerging set of literatures, practices, and technologies; it also points to inventive modes for undertaking practice-based research to articulate the open-ended techniques that emerge through digital technologies. Such an approach allows for an understanding of how emerging practices settle—or not—into recognizable forms, as well as how the open, indeterminate, experimental, and speculative aspects of technologies might be an area for understanding how they unfold as provocations. Gilbert Simondon (2012), a philosopher of technology and student of Canguilhem, suggested that technologies articulate cultural values, and that these articulations might also serve as sites of cultural experimentation. According to Simondon, the openness of technology might then be pursued less as a question of open hardware or software and more as an investigation of how open technological engagements might be re-routed to be more democratic, inventive, and explicitly cultural. For Simondon, these lines of inquiry require an attention to and engagement with machines as they are taken up, used, and re-worked through practice.

With these points in mind, citizen sensing research and practice might expand from their usual framing as sensing technologies enabling the collection of monitoring data toward political action to encompass a more inventive and open set of engagements. Moreover, digital

media might be encountered as technologies that are always in the making, changing through practice, and which might be disrupted through programs of use that become sites of active cultural and political engagement.

Acknowledgments

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