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Institutions for Civic Technoscience: How Critical Making is Transforming Environmental Research

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FORUM

Institutions for Civic Technoscience: How Critical Making is Transforming Environmental Research

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This article explores the changing relationship between the academy and new public formations of scientific research, which we term “civic technoscience.” Civic technoscience leverages tactics seen in critical making communities to question and transform how and who can make credible and actionable knowledge. A comparison of two case studies is used. The first is a grassroots mapping process that allows communities to generate high-quality aerial imagery. The second is an academic-led project using environmental sensors to engage disparate audiences in scientific practice. These two projects were found to differ in their ability to form strategic spaces for community-based science, and suggest pathways to foster more robust relationships across the public–academic divide. By altering power dynamics in material, literary, and social technologies used for scientific research, we argue that civic technoscience enables citizens to question expert knowledge production through critical making tactics, and creates opportunities to generate credible public science.

Keywords critical making, technoscience, environmental justice, social movements, Public Lab, civic science

FROM TACTICAL INTERVENTIONS TO STRATEGIC SPACES

Emerging forms of critical making within art and design, such as tactical media, tactical biopolitics, and interventionist artwork, have stressed the importance of tactical interventions (Garcia and Lovink 1997; Bholer 2008; Da Coasta and Kavita 2008; Thompson and Sholette 2004). Tactics according to Certeau are weapons of the weak, as they are employed by those with no physical or social space to form long-standing strategies (Certeau 1984). This focus on tactics has been particularly important in biopolitical artwork like that of Critical Art Ensemble (CAE), which has formulated spaces outside of traditional
laboratories to query science (Da Coasta and Kavita 2008; CAE 1996). However, these interventions have purposefully been short-lived, designed as one-time experiments, such as Jermjenko’s feral robotic dogs project. This article points to a shift occurring in the terrain of critical making, that is, the formation of institutions that aim to normalize and formalize spaces for nontraditional science. New spaces for scientific research are emerging that specifically seek to establish and maintain a presence external to the traditional academy: genspace, X-Clinic, Public Laboratory for Open Technology and Science (Public Laboratory or Public Lab). This formalization of alternative spaces for scientific research and technology development is particularly prominent in fields such as environmental health and justice research, where communities have been struggling to transform the process of scientific knowledge making to better redress, remediate pressing environmental health questions (Corburn 2005; Brown 1997/2006; Frickel 2004; Morello-Frosch 2005/2006; Ottinger 2011). Rather than being short-lived, these communities that blend citizen science with critical making are attempting to establish a formal and lasting presence within domains of scientific research and interface with formal experts.

This article explores the changing relationship between the academy and these new spaces for scientific work. This is done by comparing two examples of such work: first, Public Laboratory’s grassroots mapping process, a do-it-yourself (DIY) research tool and methodology that allows communities to generate satellite like images of higher quality than those produced by actual satellites (Dosemagen et al. 2011; Long and Warren 2010); and second, a tactical project initiated at Rensselaer Polytechnic Institute (RPI) aimed at using microcontroller-based sensor projects as a way of engaging disparate audiences in scientific practice. These two projects differ in their ability to form strategic spaces for community-based science. Encountering problems of institutionally mandated intellectual property agreements and adherence to entrenched disciplinary conventions, the RPI microcontroller projects stalled. On the other hand, Public Lab’s community-made maps are being served alongside raster maps produced by satellites in “authoritative” formats such as Google Maps and Google Earth.

In the case of Public Lab as a strategic space for community-based science external to the academy, we argue that the shift in material technologies for science is supported by changes in the literary and social technologies for science. These material technologies, which are typically low-cost tools that can be built by nonexperts with household materials, are supported by literary and social technologies: open-source hardware and software licenses, as well as public-access websites, listservs, and face-to-face meetups, to build alternative institutions for civicly engaged science. We term do-it-yourself (DIY) research tools initiated by groups like Public Lab as methods for “civic technoscience,” and view this as a strategy driven by values-based research. In relationship to this forum’s focus on critical making, projects like Public Lab exemplify how creation of a strategic space to enact civic technoscience requires transformation of material, literary, and social technologies for science (Ratto, Wylie, and Jalbert 2014).

CIVIC TECHNOSCIENCE: QUESTIONING THE STATE OF INSTITUTIONAL SCIENCE

Practices of critical making, community-based environmental health and justice research, science and technology studies (STS), and participatory design are coming together in the present milieu of open-source software and hardware to generate new alternate spaces and tools for scientific research. The material focus of tactical media, the social critique of laboratory science from STS, and the stress on community knowledge generation, we argue, come together to stabilize novel material, literary, and social technologies for civic technoscience.

Historians of science Shapin and Schaffer, based on their analyses of Boyle’s description of the emergence of the experimental program in the 17th century, identify three different “technologies” that enabled the emergence of experimental or laboratory-based sciences as we have come to know them: material, social, and literary technologies (Shapin and Schaffer 1985; Shapin 2010). Material technologies refer to the apparatus within laboratories, which is used in the generation and validation (via replication) of “matters of fact.” Social technologies include social structures like Royal Societies, composed initially by landed gentry, which acted as authoritative witnesses to matters of fact. The literary technologies refer to the publishing of detailed and methodologically rich papers within peer-reviewed journals as the means of communicating “matters of fact” and building scientific consensus.

The literary technology Boyle invented—the research paper—carried the testimony of the authors, who as “modest witnesses” reported on their observations in a detached fashion that was directed at creating for the reader the experience of watching the experiment. Through modest witnesses “nature” could be presented as speaking for itself, without the interference of the scientist’s agenda or worldview. STS research has critiqued the notion that humans can serve as neutral witnesses. It has also spotlighted the cultural consequences of creating a privileged community that speaks for “nature,” given the social construction of science’s material, social, and literary technologies. The reality is that modest witnessing helped to affirm the authority of the author by creating a conventional method through which results, positive
and negative, could be reported seemingly without value judgments (Haraway 1997; Galison 1999; Daston and Lunbeck 2011). The process of fortifying scientific authority via the modest witness and the subsequent establishment of the academy served the secondary purpose of excluding the nonprofessional, nonpatriarchal participants from the scientific agenda.

That access to scientific research tools and agendas is limited to formal experts is a foundational problem for communities managing environmental health and justice issues (Bullard 1990; Brown 2006; Ottinger 2011). However, research has shown that communities are capable of innovating novel approaches to research and can effectively reframe larger expert-driven research agendas (Brown and Zavestoski 2005; Corburn 2005; Morello-Frosch 2005; Minkler and Wallerstein 2003/2009; McCormick 2009). One example is the fusion of activism and community environmental monitoring by Bucket Brigades, which emerged from the practical need, for lawyers working on an environmental justice case, to get air quality data. At the time there were no tools available for nonscientists to participate in air monitoring. To solve that problem, a technical consultant was hired to develop a bucket grab sampling method mimicking the U.S. Environmental Protection Agency (EPA) standard summa canister (O’Rourke and Macey 2003; Overdevest and Mayer 2008; Ottinger 2009/2010). Analysis of bucket data still requires that the bucket travel to a research lab, so that the sample studied by experts, and the data’s efficacy in advocacy, depend on the ability of the community organization to interpret and frame the data (Ottinger 2010).

Similarly, STS research has spotlighted the inadequacy of lab-based research methods for setting health standards around toxics (Murphy 2004/2006) and has described how social paradigms of disease have made environmental health problems hard to study (Nash 2006; Murphy 2006; Allen 2003; Fricke 2010). However, there has been relatively little focus on how the technical infrastructure of environmental science might be reorganized to address these problems beyond engaging communities in research (Ottinger 2011). Indeed, Ottinger points out that the success of citizen environmental monitoring programs often depends on their ability to interface with formal experts’ epistemic frameworks (Ottinger 2009). Citizen science, with the exception of initiatives like the Bucket Brigades, often turns citizens into data harvesters who assist scientists in acquiring data, such as with the century-long Audubon Christmas bird count. They rarely engage participants in shaping the research agenda.

Fortun and Fortun (2005), troubled by the distinction between “citizen” and “scientists” suggested by citizen science, invoke the term “civic science” and call for an investigative relationship that “questions the state of things, rather than a science that simply serves the state” (50). To broaden the framework to material, social, and literary technologies, we propose a new model: civic technoscience, wherein new material technologies in combination with new social and literary technologies can sustain a civic research space external to the academy and where nonacademics can credibly question the state of things.

**MATERIAL, SOCIAL, AND LITERARY TECHNOLOGIES FOR CIVIC TECHNOSCIENCE: GRASSROOTS MAPPING AND PUBLIC LAB**

Critical making, the practice of generating tools with alternative politics and embedded sociotechnical systems, opens the door to new approaches to scientific instrumentation (Ratto 2011). For instance, within the fields of critical geography, anthropology, and STS, many have critiqued the historical trajectory of map making (Brody 1981; Burnett 2000; Harley 1988/1992/2001; Pagnol 2009). Latour argues that maps are tools of empires, used to transfer knowledge from the periphery to the metropole so that the centers of power may make plans for action at a distance. Closely tied to both the colonial enterprise and then the formation of nation-states, the preeminent mapmakers historically are governments and corporations (Burnett 2000; Latour 1990; Harley 2001; Monmonier 2002; Soja 1989). Given the politics of these two groups, and the process and technologies of map-making in postindustrial, postcolonial nations and major corporations, data are proprietarily owned (Farman 2010; Helmreich 2011; Monmonier 2002). Herein the material technologies for satellite imaging preclude the engagement of people inhabiting the sites they map; communities cannot direct the path of satellites or opt not to be imaged (Farman 2010; Monmonier 2002). While critical geographers, STS scholars, and other academics have written about such concerns, grassroots mapping activists translate such critiques into practice by creating a low-cost do-it-yourself methods that enable noncorporate, nonstate actors to rapidly create and share aerial maps (Warren 2010). Moreover, grassroots mapping creates maps of a quality such that formal data archives find the maps attractive to curate and integrate with their collections. In 2011 Google began integrating Grassroots Maps, served through Public Lab’s online archive, into both Google Maps and Google Earth (Adams 2012). The superior resolution of Public Lab images makes them readily distinguishable from surrounding satellite images in Google Earth and Maps.

**The Mapper Is Embedded in the Map; The Maps Reveal How They Are Made**

Mapmaking, as balloon mapping described in the following demonstrates, need not depend upon capital-intensive systems. Jeff Warren pioneered the development of grassroots mapping in 2010 as part of his master’s thesis.
work at MIT’s Center for Future Civic Media, which interestingly required that any resulting software or hardware be open source (Warren 2010). This requirement imposed by the Knight Foundation, which funded the center, enabled Warren to focus his design work on a different constituency: community organizations. Public Lab started from a collaborative project between Warren and the Louisiana Bucket Brigade, lead by Shannon Dosemagen, to organize gulf communities to map the 2010 Gulf of Mexico (Gulf) Oil Spill using grassroots mapping. A group that participated in the Gulf mapping effort, including authors Wylie and Dosemagen, founded Public Lab as a nonprofit to further develop the idea of do-it-yourself research tools.6

The Public Lab tools exemplified here by balloon mapping have a very different approach to material technologies for science both in how they are built and in their attention to politics of knowledge making. Warren describes the goals of the project as “seeking to invert the traditional power structures of cartography.”7 Grassroots maps are made by attaching a cheap, approximately $60 digital camera to a balloon filled with helium or a kite. The camera is contained inside a homemade housing that is built on site, generally using plastic soda or juice bottles. The tethered balloon is then flown at between 1000 and 2000 feet in the air, with the camera snapping pictures as it travels. The resultant images are thereafter stitched into large-scale maps with the help of Photoshop or free and open-source software developed by Public Lab.8 These maps outstrip Google Maps in terms of resolution. While covering at most a few square kilometers, grassroots maps tend to have much higher spatial resolution than commercial or government satellite imagery: typically 2–7 cm resolution, as opposed to 0.5–3 m resolution for commercial imagery (Warren 2010). Balloon maps also often have richer colors, and grassroots mappers have remapped sites multiple times to assess change over time, increasing temporal resolution (Warren 2010).

The bird’s-eye view from satellites has been equated with the view from nowhere—a “god’s-eye” perspective that sees everywhere and everything at once (Helmrreich 2011; Farmen 2010). The god’s-eye view from nowhere has been characterized as the scientific ideal in laboratory science, wherein the scientist is not an actor in the creation of data but is merely a witness (Haraway 1991). Balloon mapping is by comparison tied to a hyperlocal view. The ground and mapper are literally connected to the mapping equipment by a very long string. One must hike through marsh, go up hills, spot power lines, navigate boats to access a vantage point from which to balloon map sites of interest. This is not an easy process, as one must travel the ground imaged in order to generate the images in the first place. In effect, this process reconnects satellite-like imaging to place. The intimate connection between the mappers and the local context is particularly evident in balloon mapping pictures where both the tether and the mappers on the ground are visible. Such pictures are not rare occurrences, nor do they bother the grassroots mappers, as they reveal, in the map itself, how the map was made and who made it. These contextual details provide grassroots maps an alternative form of validity by showing that they are taken at a particular time, by particular people, and caught by the conditions of the field at that time.

Kholer, in his study of field science versus laboratory science in the 20th century, argues that field sciences, in order to garner legitimacy, often attempted to remake the field into a lab, using ordered grids and evacuating human inhabitants to create “natural” spaces outside of human influence. Practices like those of grassroots mapping open up the question of whether, through critical making, this dynamic can be reversed (Kholer 2002). In grassroots mapping, the tools themselves become vectors for analyzing local conditions, but also provoke unexpected connections in the field. For instance, on a balloon mapping expedition in Louisiana, Wylie noticed spider webs that had caught all the way up the line connected to the balloon, forming a shimmering silk ladder as far as the eye could see. Without the line in the air above them, the mappers would never have noticed the spider webs flying around them. This experience provoked new questions about the surrounding ecosystem and reemphasized that these are dynamic inhabited spaces. In this case the mapping apparatus became a tool for learning something surprising about the environment, as it made possible a new connection to the space rather than acting as a controlled experimental condition (Rheinberger 1998).

Unlike seamless satellite maps, how a balloon map was made can be discerned from the constituent images. Balloon making is a not black-boxed inscription technology that seems to magically produce data without reference to how and who made it (Latour 1987/1979). It carries information on the production process in the map itself. On inspecting a balloon map, the viewer can see separate images that comprise it, and the resulting insight into the bricolage approach encourages the viewer to imagine how the map might have been differently made. Maps made in open-source Mapknitter can be exported to Public Lab’s archive, which is publicly available, with mapper’s notes on the expedition and the purpose of the map. Public Lab facilitates this described mode of map making by providing literary technologies such as how-to guides, video tutorials, community’s listserv, and trainers.

**Situated Tools Are Lively, Produce Unpredictable Results, and Encourage Adaptive Uses Through Social Media and “Share-Alike” Provisions**

Solving technical problems in balloon maps, like radial blurring due to the rig spinning, leads to iterative local improvements to camera rigging, stabilizing, and
triggering systems. Different communities have evolved different solutions to these problems. These solutions are shared between communities online through “research notes” wiki-pages published under creative commons licenses at Publiclab.org. In Louisiana fishbones are being used to depress camera buttons. In New York, programmers utilize a software solution wherein internal memory cards are used to reprogram the camera, thus allowing it to take pictures continuously. Both produce equal results. Balloon mapping rigs developed in Boston used cardboard wings as stabilizers. These wilted in the humidity of Louisiana and that spurred the use of plastic stabilizers made from soda bottles. The modifications made and shared by different users and communities speak to the local conditions where they are used.

These tools are unlike standard laboratory research tools, which stay the same from place to place. They are locally modified and transformed. But these local modifications can also be shared through social technologies like the Public Lab website, which encourages users to write and share notes describing their work. This sharing back to the community is encouraged through the literary technology of open source licensing and software licenses that have “share alike” provisions.9 These provisions require that changes or modifications to the existing software or hardware also be open source so that they can contribute back to the knowledge base of the larger community. This legal structure is supported by sociotechnical infrastructures like the research note, community archive, and mailing list. Unlike traditional expert scientific societies, membership in Public Lab is free and the research notes can be read by anyone with Web access. The literary technology of open source licensing encourages active recognition of the role of individual contributors to research results and technology developments. Contributors to projects are identified individually on the Public Lab website by the number of research notes they’ve offered to a project. On another level, communities can openly trace their research collectively through “Place” pages that document their efforts and local uses of Public Lab tools.

Balloon mapping is a means for local inhabitants to generate knowledge about and “make sense” of what is important to them. The social architecture of Public Lab and the literary technology of open source licensing enable Public Lab members to share that collective representation with broader communities. This generates a locationally and temporally specific record that allows mappers to chart changes over time, capture vital moments, and shed light on sites that are usually ignored. This process is well demonstrated in the balloon mapping work of the Gowanus Canal Conservancy. This community organization aims to become involved in the U.S. EPA cleanup of the Gowanus Canal Superfund site. The canal, historically facturers, has high loads of polycyclic aromatic hydrocarbons. Over the last year the Gowanus Canal Conservancy has mapped the canal seasonally to examine for instance health of bioswales, landscape elements that absorb pollutants and runoff, that conservancy members planted to aid the remediation. Their winter flights revealed areas of melted ice in the canal. Returning after the ice thawed, they confirmed their suspicions from the images that unmarked inflows were coming into the canal at those locations. Some of these inflows were not mapped by the U.S. EPA. Grassroots Mapper, Eymund Diegel reports that: “The high resolution of the balloon and kite pictures, coupled with my interest in historical maps of the Canal have allowed us to use Grassroots Mapping images as credible evidence of historic streams that will affect decisions about how the Superfund cleanup program will have to proceed” (Dosemagen and Wylie 2012).

Grassroots Mapping Generates New Potential for Action and Change

Grassroots maps do more than just offer a critique to how mapping has traditionally been practiced. As was the case with the Gowanus maps, they offer up new opportunities for action—and the ability to correct and transform “official” maps with local findings. Many communities are taking up the balloon mapping platform and applying it to matters of local concern (e.g., imaging natural gas development around homes in Colorado, logging activities, informal settlements for land claims in Peru, and landfills in Massachusetts), as the familiar modernist framework of surveillance can be inverted with balloon mapping (Mann 2003).

Balloon mapping expeditions frequently become community events. People spot a balloon and come out to ask what is going on, and often they find themselves joining in. Public Lab has encouraged this practice by recommending that balloon mappers turn mapmaking into community events. This communal approach is also seen in the practice of protest mapping—where protesters use balloons and digital cameras to map their events. Started in Chile by an organization interested in mapping education reform protests, protest maps and live streaming footage from the balloons were used to demonstrate that protests were peaceful and to correct official figures underestimating attendance.10 This spread to the United States with the Occupy movement.11 One interesting innovation developed by Chilean protest balloon mappers is the use of clusters of party balloons rather than a single red balloon, to blend into the carnivalesque environment of protests and to appear less threatening. An activist artist in New York turned the making of the cluster of balloons into a social event at protests, when he began organizing teams of strangers to each tie a balloon into the collective bunch...
CONSTRaining CIVIC TECHNOSCIENCE IN THE ACADEMY: CULTURALLY SITUATED SENSING

Promotion of the development of alternative material, social, and literary technologies for civic technoscience faces many challenges when initiated from within the academy. Grassroots efforts are free to utilize open-source technologies without the constraints of university-imposed intellectual property agreements. On the other hand, the ability to rapidly maneuver and use developing technologies, and to freely engage problems of interest to community participants rather than those of the research team, is limited by long-standing disciplinary norms and conventions, especially those related to accepted research methodologies.

In order to operate within this climate, researchers sympathetic to civic technoscience must enact different tactics like those de Certeau ascribed to the weak. Strategies for doing this are forged not as acts of political resistance, but in what George Marcus calls para-sites or “spaces, sites, and even objects that facilitate alternative thinking by subjects who are deeply complicit with and implicated in powerful institutional processes.” But they are forged also by researchers “who are attempting to come to terms with changing practices, opportunities, and self-definitions” (Marcus 2000, 5). Efforts for developing alternative modes of material, social, and literary technologies, consciously or unconsciously, must create a kind of double agency under the umbrella of accepted practices. Advocates must bridge divides and create novel third spaces (Bhabha 1994), and create centers of research that proactively stabilize environments for civic technoscience across broader communities of stakeholders (Fischer 2003). Nevertheless, the current state of accepted practices within the academy remains strongly opposed to embracing exemplary civic technoscience infrastructures.

Institutions Are Ripe With Potential Resources to Support Civic Technoscience

An interesting example of this is demonstrated by a research project led by one of the authors, Kirk Jalbert, at Rensselaer Polytechnic Institute. On paper this project tried many of the same tactics for enabling civic technoscience as Public Lab: the tools were meant to be open source, advantage was taken of modifiable technologies, the research agenda was co-developed with the community, and the material technologies aimed to enable community-based sensing and mapping. In the fall of 2010, an interdisciplinary research group spanning the social sciences, engineering, and computer science came together to design modular, open-source environmental sensing devices that could be easily appropriated by local...
communities. Building on successful community-driven design approaches in Ron Eglash’s culturally situated design tools for collaborative STEM education (Eglash et al. 2004; Eglash, Bennet, et al. 2006), the group developed a sensor platform and geospatial mapping software for participatory environmental monitoring.

They soon found interested partner organizations on the Navajo Nation. One partner, the Diné Environmental Institute (DEI) at Diné College, had developed a successful National Science Foundation (NSF)-funded program for environmental monitoring using relatively expensive equipment that necessitating advanced training. DEI’s participation was generated by their interest in expanding their program to a larger community using low-cost tools. A second partner, the Environmental Education Outreach Program (EEOP) at Northern Arizona University, operated environmental education summer workshops with youth groups from across the Navajo Nation. A component of their work tracked sand dune erosion due to climate change, and could benefit from adaptable and expandable monitoring devices left in the field to document site-specific weather events.

The RPI research team developed the concept of culturally situated sensing, where civic technoscience and participatory design could be deployed at field sites on the Navajo Nation to encourage community investments in environmental awareness and also to reconnect with environmental narratives in traditional Navajo culture (Jalbert 2011). For example, at one EEOP field site, the sensors were deployed with the assistance of a Navajo ethnomontanist. In the process of collecting data on soil moisture, participants were also exposed to Navajo nomenclatures and to methods practiced by traditional healers for collecting specimens without damaging living plants.

Together, the collective developed a statement of work (SOW) outlining the goals and deliverables for the project: All software and hardware must remain open source for free sharing, off-the-shelf components should be utilized to reduce material complexity and encourage adaptability, and, most importantly, there should be a recursive social structure that allowed the research team, designers, and community collaborators to steer the project collectively. In the spring of 2011, the collective was offered the opportunity to utilize the university’s Multi-Disciplinary Research Lab (MDL)—an incubator space typically outsourced to major commercial industrial partners. Seemingly a windfall for the project, this collaboration afforded in-house teams of senior engineering students to develop the sensor platform. Perhaps the most remarkable aspect of this arrangement was that in agreeing to the terms of the SOW, the sensor project became MDL’s first real encounter with open-source design requirements in its 6 years of operation. In effect, this new partnership established a potential site of legitimation for alternate material, social, and literary technologies. It also created an opportunity for challenging entrenched engineering and design practices to open pathways for developing socially conscious critical making from within the academy.

However, as the material output of the collaboration became realized in the ensuing year, a number of problems emblematic of conventional academic technoscientific practice emerged. First, despite encouragements to take advantage of readily available and adaptable technologies such as the Arduino microcontroller platform, the MDL team quickly locked into a classic pathology of engineering customized platforms. The secondary effects of this decision shifted the site of material development away from inclusions by Navajo field collaborators—languages and processes of conventional engineering create high barriers of entry for civic participants. A third and more serious problem threatened the project’s public accountability. While the SOW mandated adherence to open-source hardware and software designs, MDL students were instructed by lab administrators to stamp “copyright MDL, all rights reserved” on all components and documentation. After a series of increasingly high-profile appeals, the university’s Office of Technology Commercialization—the final arbiter for intellectual property disputes on campus—ruled the SOW was in fact a binding contract and all directives therein must be honored.

Despite this favorable ruling, the research team was left with half-working technology reluctantly backed by a now cautious MDL and increasingly unsupported as students from the design team graduated from the university. The discouraging details of the culturally situated sensing project illustrate the consequences of working within existing academic infrastructures unable to fully sustain civic technoscience research. Even with the best intentions of a research collective, engineering practices embedded in the sensor platform became inherently misaligned to producing scientific knowledge in public laboratories. What could have been a long-term research design capable of taking advantage of a rich diversity of resources across the university instead remained severely restricted by assertions of how science and technology development “ought” to be done.

**Communities of Varying Practice Are Eager to Rally Around Tools for Action and Change**

It is worth noting that the sensor project did partially succeed in promoting environmental awareness with Navajo collaborators. Changes to material technologies were made by the research collective, such as later stage integrations of open-source components for a “lite” version of the sensor platform. Recognizing successful aspects of similar projects (DiSalvo et al. 2008; DiSalvo 2014), organized workshops were also added to rally
participation and to culturally situate the sensors in the field. While the actual sensor platform remained wholly unqualified to produce useful scientific data, field site visits became powerful locations of community-driven knowledge articulation. With both DEI and EEOP, participants outlined potential use-cases scenarios for deploying environmental sensors in their community. These scenarios provoked conversations questioning how to share sensitive data when Navajo culture has not historically benefited from working with outside stakeholders. Additional discussions focused on how to protect environmentally sensitive data when Navajo culture has not historically benefited from working with outside stakeholders. Additional discussions focused on how to protect environmentally endangered ceremonial sites, which would otherwise not be made public.

Even with all its faults, the sensor project shows how academic practices can be challenged internally, and illustrates that these practices are open to evolving circumstances as critical making enters the university. For example, the collective was surprised to learn that the Office of Technology Commercialization’s intellectual property guidelines had no explicit language for how to deal with open-source research.\(^{15}\) Indeed, forgotten proprietary technology agreements, carried over from a former incarnation of the MDL, were brought to light in the struggle to define who could arbitrate the decision over open-source licensing. The debates became an opportunity for self-reflection in which the university and the lab realized the historical contingency of their prior agreements and a need to adapt to open-source research in the future. Following the sensor project, the MDL now teaches open-source licensing as part of its training on contemporary engineering practices and project management. In a second example, an electrical engineering professor who advised students on the project altered her research after being inspired by the adaptable features expressed in the sensor platform. Her designs for ultraviolet (UV)-radiation biological detectors shifted from a single application to a collection of less expensive, modular designs that could be used in multiple contexts by different types of users.

The pitfalls of the culturally situated sensor project are an interesting contrast to processes developed by Public Lab for community-based grassroots mapping, and underscore the need to shift academic practices to better support civic technoscience research. If the RPI research collective had managed to produce a viable sensor platform backed by university resources like MDL but also adaptable, recursive, and open to use in public laboratories, we can only imagine its potential successes. All of the research partners who worked to develop the sensor platform, including the MDL, played out their respective roles according to disciplinary standards for producing “good science.” Even within the core research team there were epistemological differences on how one might go about developing useful technologies, such as where on the spectrum—stable platforms to modifiable lo-fi devices—they should be built. These differences could be traced to perceptions within different research fields on what counts as viable research. Accounting for the presence of academic participants in civic technoscience requires a better understanding of how critical making might shift these disciplinary traditions. This includes questioning perceptions of how civic technoscience ought to be conducted, where to locate effective sites of research, and being open to acknowledging and changing glaring deficiencies in these hybrid arrangements.

CONCLUSION: NEW INSTITUTIONS FOR CRITICAL MAKING AND CIVIC TECHNOSCIENCE

Already, institutional encounters with organizations like Public Lab, community-based citizen science efforts, and open-source critical making projects are changing academic and regulatory practices in ways similar to those described in the RPI case study. The U.S. Environmental Protection Agency (EPA) held its first citizen science conference in 2012, and Public Lab and Global Community Monitor were invited to demonstrate their civic technoscience tools. The U.S. EPA is piloting a program to test and calibrate open-source citizen science tools alongside proprietary tools it has historically approved.\(^ {16}\) The U.S. EPA has historically developed its own standards for validating evidence internally and testing methods, and resisted the viability and authority of citizen science data. That the U.S. EPA should participate in the legitimization of civic technoscience tools perhaps reflects a radical shift in the model of U.S. EPA–community interactions. We challenge the academy to similarly adapt, and to open its doors to supporting civic technoscience. Imagine networks of skilled technicians in chemistry labs—also citizens of technoscience—volunteering their knowledge. The academy could also open doors to facilities such as photographic darkrooms, and could give public access to tools such as spectrometers during off-peak hours. The majority of laboratory equipment is after all often purchased with public money through government grants. Some universities, such as the University of California at Davis, Parsons The New School for Design, Rhode Island School of Design, and Northeastern University, are already opening their doors to Public Lab research groups and classes.\(^ {17}\) In these cases, the viral nature of open-source licensing may directly challenge institutional intellectual property policies. It will be interesting to see over time how these disjunctures are managed, and how these university-based groups interact with the groups not institutionally affiliated. We are excited by the emergence of scholarship that recognizes the everyday complexities of how knowledge and power are co-produced and configured by available science and technology. Producing reflexive scholarship that actively seeks engagement in
reforming how knowledge and power are produced and by whom should be further encouraged. To reach these goals and to understand how technoscience has already transformed the possibilities for life on Earth requires, we suggest, a civic technoscience: a practice, research, and design space that enables each of us to question the state of the things around us and to share that information for public good. Ultimately, we believe civic technoscience results in collaboratively generated knowledge of our shared conditions previously unmet by existing scientific institutions.

NOTES
1. See http://www.nyu.edu/projects/xdesign/feralrobots
4. Civic technoscience questions and transforms how and who can make credible and actionable scientific knowledge by changing the material technologies used for scientific research (Shapin and Schaffer 1985).
5. Examples include DIY biospaces such as genspace http://genspace.org and http://diybio.org. There are also organizations focused on improving environmental sensing, such as X-Clinic, http://www.environmentalhealthclinic.net, and Sensemakers, http://sensemake.rs, and individual projects like MIT’s Safecast tracking of radiation sensor data, http://blog.safecast.org/worldmap, and University College London’s ExCites, http://www.ucl.ac.uk/excites. All of these groups are designing and developing alternative tools for scientific research. With the exception of Public Lab’s focus on environmental justice, few of these organizations self-consciously work with traditional environmental justice communities. There is a strong academic lineage of community-based participatory research, however; see Corburn (2005), Brown (1997/2006), Frickel (2004), Morello-Frosch (2005/2006), Ottinger (2011), and Minkler and Wallerstein (2003), much of which focuses on the development of research tools by communities.
6. Public Lab’s founders include Liz Barry, Shannon Dosemagen (author); the group came together to found Public Lab and apply for a Knight Foundation grant to support the development of an online, open-source public research and development community.
8. Mapknitter.org
9. This page describes the Creative Commons and CERN open hardware licenses used by Public Lab: http://publiclaboratory.org/licenses
10. For more on this case see Public Lab research note: http://publiclaboratory.org/wiki/santiago-chile
12. See also articles by G. Marcus and K. Fortun in Cultural Anthropology’s 2012 issue, “Writing Culture at 25.”
13. This project was sponsored by Eglash’s National Science Foundation (NSF)-funded Triple Helix. See http://www.3helix.rpi.edu/?p=2799
14. See MDL: http://rpi.edu/academics/engineering/mdl
15. See http://www.rpiotechnology.com
16. See http://www.epa.gov/airs science
17. See http://publiclaboratory.org/places

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