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Ignoring Ignorance:
Notes on Pedagogical Relationships in Citizen Science

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Abstract
Theoretically, this article seeks to broaden the conceptualization of ignorance within STS by drawing on a line of theory developed in the philosophy and anthropology of education to argue that ignorance can be productively conceptualized as a state of possibility and that doing so can enable more democratic forms of citizen science. In contrast to conceptualizations of ignorance as a lack, lag, or manufactured product, ignorance is developed here as both the opening move in scientific inquiry and the common ground over which that inquiry proceeds. Empirically, the argument is developed through an ethnographic description of Scroggins' participation in a failed citizen science project at a DIYbio laboratory. Supporting the empirical case are a review of the STS literature on expertise and a critical examination of the structures of participation within two canonical citizen science projects. Though onerous, through close attention to how people transform one another during inquiry, increasingly democratic forms of citizen science, grounded in the commonness of ignorance, can be put into practice.

Keywords
DIYBio; citizen science; pedagogy

The point of the dandelion project was to show that true original research could be conducted at the amateur level it might be possible to pursue a new idea of citizen science, where the "citizen" part goes well beyond crowdfunding scientists or crowdsourcing data collection. Anybody could collect data, anybody could do the lab work, anybody could analyze it...Dandelions are targets of convenience: they can't run away, they're easy to recognize (although not as easy as I'd hoped…), they're plentiful, they live near humans, and nobody will care if we sample them.
—Tristan, founder of the Bay Area Dandelion Project

Thus we observe here as elsewhere in human affairs, in which almost everything is paradoxical, a surprising and unexpected course of events: a large degree of civic freedom appears to be of advantage to the intellectual freedom of the people, yet at the same time it establishes insurmountable barriers.
—Immanuel Kant

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Citizens and Scientists

The phrase citizen science is shorthand for scientific projects reliant on the citizenry for assistance.[2] To highlight a particular aspect of the social relationship between citizen and scientist within citizen science we can imagine the citizen and scientist as ideal types for a moment. The design of a citizen science project belongs to the scientist, whose long apprenticeship culminating in contributory expertise (Collins and Evans 2002, 2007) provides both the judgment to distinguish which scientific problems are worth pursuing and the technical acumen to work through those problems. Citizens, regardless of their technical acumen, lack the judgment to determine which scientific problems are worth pursuing. And it is precisely the application of judgment that marks a boundary between citizen and scientist and determines the structure of their relationship within citizen science projects. Scientists are those who pursue disinterested knowledge, while citizens are motivated by an array of interests, ranging from activism to education**.** Policing the boundary between disinterested and motivated ends, a boundary reified through research design, enables citizen and scientist to work for common cause, if not via common motive or to common end.[3] Within citizen science, research design is scientific judgment made durable.

Empirical work within STS has often demonstrated that the dividing line between the ends, motives, and causes of citizens and scientists in practice is a fuzzy one. For example, Ottinger (2010a, 2010b) has demonstrated how seemingly objective scientific standards can serve either as a bridge for democratizing science or as a boundary to citizen participation. While standards are one tactic for democratization, the form of inquiry also regulates the interaction of citizen and scientist. In documenting the role AIDS activists played in challenging the standards of medical trials for experimental treatments, Epstein (1995, 426) finds clinical trials "more open to outside scrutiny than other forms of science and technology." In contrast to Ottinger's (2010a, 2010b) case, here the lack of standards offer an opening for citizens to conduct science. Suryanarayanan and Kleinman (2012) demonstrate how the experimental norms of agricultural entomology came to be the epistemological measuring stick in the controversy over Colony Collapse Disorder (henceforth CCD), muting the voice of beekeepers. A powerful conclusion from empirical studies of expertise within STS has been that who counts as a scientist and what counts as science are historically contingent questions inextricably tied up in the context of inquiry. To the question of whether citizens do science, the STS literature answers affirmatively; citizens can and often do the work of science.

[2] I will employ a rough and ready distinction between citizen and scientist throughout. Scientists are those certified by an educational institution in a scientific field, and citizens are those not so certified.

[3] Evans and Plows (2007) come closest to my intentions in this article by arguing for citizens to participate more generally in disinterested science. On this point, they draw a distinction between technical experts and lay citizens and consider the technical elements of expertise to be the most onerous to make equal. For reasons that will become apparent, I believe the opposite; the sentimental and habitual nature of seeing like an expert is the most onerous to reproduce, while the technical elements are actually quite straightforward. I do agree strongly with their rejection of the deficit model of relations (2007, 842).

Yet, it is the scientist perched in field or, more commonly, the laboratory that enunciates (Foucault 2002) the truths of science. Scientists are able to regulate the membrane between themselves and the citizenry by controlling what counts as expertise and who counts as an expert in a given context. As STS has long shown, in some locations and in some knowledge practices, the membrane is more permeable and citizens meet scientists on nearly equal ground. But nowhere is the membrane between citizen and scientist (and between scientific disciplines) less permeable than in the laboratory and during an experiment. The laboratory and the experiment are twinned machines for purifying impure ends, motivations, and causes and rendering scientific judgments durable (Latour and Woolgar 1979; Latour 1990). As such, the experiment and the laboratory constitute Epstein's "forms of science and technology," which remain closed to outside inquiry.

This article takes up the relationship between citizen and scientist in a new way by asking: Can the experiment and the laboratory be opened to citizens? If so, under what circumstances might it be possible? Answering in the affirmative, I argue that citizens can do the work of scientists and that DIYbio laboratories are well positioned to facilitate this "new idea" of citizen science. My argument is developed in the context of the Do It Yourself biology (DIYbio). To date, much discourse on DIYbio has revolved around the axle of democratization by viewing DIYbio as the movement of technology downstream (Kuiken and Pauwels 2012; Toccehetti 2012; Wohlsen 2011) with an attendant shift in scientific norms and ethics towards those found in computer hacking (Delfanti 2011; Delgado 2013), or alternatively viewing DIYbio as a mediating institution between scientist and citizen (Kera 2012; Meyer 2012). While DIYbio as a polyphonic movement has elements of all the activities noted above, there is another, more radical stake within the idea of allowing anyone access to a biological laboratory.

Meyer (2014) has surfaced the transformative aspect of DIYbio rhetoric: "DIY biology aims to constitute a distinct and political form of self by providing people with access, by enabling them to transform themselves into active producers of science." Inherent in the DIYbio version of producing science is, as Keulartz and van den Belt (2016) argue, the creation of novel organisms through tinkering and engineering. The radical stake lies in the direct claim that DIYbio might transform people into active producers of science, with the implication that citizens meet scientists on equal ground; as peers whose judgment is equivalent, rather than as technical adjuncts.

The claim is that with access to technical means (a biological laboratory), a transformation of judgment will follow. But the stakes of transformation run through an avenue left unexplored by Meyer and those within DIYbio. Whether people are "transformed into active producers of science" or become someone's adjunct is a question of pedagogical practice, not access to technology. Taking a step further, to claim that those ignorant of the daily workings of science are capable of transforming themselves into producers of science requires pedagogically respecifying our relationship to ignorance. To move from democratic rhetoric to democratic practice, we must conceptualize ignorance, not as an irreducible problem to educate away via literacy or to control for via research design, but as a prerequisite to inquiry (Firestein 2012).[4]

This claim cuts hard against our common sense. Conventionally, ignorance is conceptualized as a lack, a loss, or a lag: a gap to be made whole through education. This conceptualization dominates our thinking in ways obvious and subtle. Yet, lag, loss, and lack are not the only way to conceptualize ignorance. If we change our focal lens from the distribution of knowledge to the production of knowledge, we can begin to conceptualize ignorance as something other than a lack or lag. As all scientific inquiry must, we can conceptualize ignorance as possibility. This idea runs through the STS literature on expertise, often forming the ground over which the figures of scientist and citizen are laid. Ottinger's (2010a, 2010b) participants find a potential scientific instrument in buckets, AIDS activists (Epstein 1995) find in scientists' ignorance of life with HIV the possibility of a new kind of clinical trial. More conventionally, agricultural entomologists successfully sidelined the knowledge developed by beekeepers about CCD (Suryanarayanan and Kleinman 2012) by painting the beekeepers' knowledge as a lesser version of their own.

Ignorance as possibility has been voiced most powerfully by the philosopher Rancière (1991). Per Rancière, ignorance holds the possibility of becoming a meeting ground rather than a dividing line. In what follows, I will work with three of Rancière's ideas: (a) ignorance is a necessary condition for inquiry, (b) equality of intelligence is not an end to be achieved but a point of departure, and (c) we must take care at every step to emancipate, not stultify, with our pedagogy. The last item requires explication. Stultification and emancipation are the concepts Rancière uses to move his theorizing into the concrete world of pedagogical action. He distinguishes two modes of pedagogy. Stultification is the explication of knowledge from master to novice, which reinforces social barriers between the two; emancipation is the verification of effort by one for another, which leads to intellectual emancipation. Rancière thus conceptualizes the workings of human intelligence through two distinct aspects: human intelligence, which Rancière presupposes to be everywhere equal, and the human will, which can be directed. Thus, according to Rancière, humans are equally intelligent, but their will leads them in differing directions to differing effects. The difference between master and student, therefore, is one of degree, not of kind. Through Rancière, the rigging between social classes, such as citizen and scientist, is exposed and made ready for re-rigging.

Earlier I noted that contributory expertise (Collins and Evans 2002, 2007) consists of both judgment and technical acumen. At this point, a finer claim can be made; contributory expertise consists of judging the conditions under which ignorance will be productive of new knowledge.

[4] My use of ignorance in this article stems from the work of Rancière (1991) within the philosophy of education and those who have built upon his work (Varenne 2009) within anthropology of education. In contrast to conceptualizations of ignorance emerging from within agnotology (Proctor and Schiebinger 2008) or the sociology of ignorance (see also Kleinman and Suryanarayanan 2015), which focus on the production of ignorance as the product of an educational process, Rancière (1991) and Varenne (2009) have conceptualized ignorance as the starting point of an educational or cultural process.

Within DIYbio, the stakes of scientific judgment run through both the transformation of people and organisms. On the back of this claim we can attend to the "new idea of citizen science."

Nothing above, or to come, is meant to deny that the unequal distribution of ignorance is problematic. Nor is it intended as a criticism of citizen science in general. The accomplishments of citizen science need no defense. I will only paint the outline of a radically egalitarian form that citizen science might take and discuss why DIYbio is an ideal location for that form to take root. By drawing on Rancière, we can see a path towards making good on Meyer's observation that DIYbio aims to transform citizens into active producers of science.

Structurally, the article is organized into three sections. The first section offers a typology of citizen participation within citizen science (Wiggins and Crowston 2011). It then takes up the Christmas Bird Count as a paradigmatic example of a citizen science project. The barriers between citizen and scientist in the Christmas Bird Count are examined and found strongly inscribed in the design of the project. The second section offers a close reading of the Blackawton Bee experiments (Blackawton et al. 2011), in which a working scientist verified that a class of 8- to 10-year-old schoolchildren in Blackawton had performed "real science." In contradistinction to the Christmas Bird Count, the Blackawton experiments point to the possibility of a "new idea" of citizen science through respecifying the relationship between citizen and scientist as one of intelligences meeting on common ground. The third section situates the Bay Area Dandelion Project (henceforth BADP) in the context of "community projects" at the DIYbio lab Biocurious by asking what type of projects and what forms of participation are possible in a "community project" in a DIYbio laboratory. And here a problem emerges: rather than respecifying the relationship between scientist and citizen as had been done in Blackawton, the BADP reproduced the relationship between citizen and scientist found in the Christmas Bird Count. The article concludes with some pedagogical recommendations addressing how DIY laboratories can become spaces in which citizens can do "real science" and offer fundamental contributions to fields and problems passed over by their professional peers.[5]

A Typology of Citizen-Scientist Relationships

A typology prepared by Wiggston and Crowston (2011), based on the goal orientation of a cross-section of operating citizen science projects, paints a rich picture of interaction between citizens and scientists across a variety of citizen science projects. They organize the possibilities into the following typology.

Action	What might otherwise be called activist (Ottinger 2010a, 2010b). Citizens oriented towards local issues.
Conservation	Regional projects that usually focus on ecological conservation and involve government agencies.

[5] By "professional" I mean anyone employed as a scientist.

Investigation	Citizen science in the paradigmatic form of the Christmas Bird Count. Citizens work on projects determined by scientists.
Virtual	Generally, projects taking the form of SETI@Home or iFoldit: projects that rely on citizens lending computing power or participating through the gamification of a given topic.
Educational	Projects explicitly focusing on educating the public on some aspect of science, usually through participation.

Within the typology developed by Wiggins and Crowston, the educational component is at the same level as scientific literacy; it is an education about science rather than an education into science. A "new idea" of science can find no place within this typology of citizen science.

The Christmas Bird Count

The canonical example of a citizen science project is the Audubon Christmas Bird Count.[6] The Christmas Bird Count, an annual avian census conducted every year since 1900, has been a spectacularly successful example of citizen science. Over its long life, it has been responsible for advancing the causes of ecology and conservation, and the education of future scientists (Dickenson et al. 2010). It was one of the earliest big data projects and for that reason stands as an exemplar of scientific innovation. Here, a fundamental question about bird migration, set by an earlier generation of ornithologists and updated by successive generations of ornithologists, is given an answer by drafting a temporary army of citizen bird watchers, mobilized just for the occasion. Together they have created an impressive longitudinal study of migratory birds in the United States. Together they have made visible the effects of industrialization, pollution, changing settlement patterns, and habitat loss. The Christmas Bird Count has reproduced itself successively over several generations with new birds, new birders, and new ornithologists all finding a place in the project. Birds being birds, let us look closely at the reproduction of bird watchers and ornithologists.

First, I turn to the bird watcher. Bird watching is a hobby with a distinct material culture (Law and Lynch 1988) and, more to the point, a distinctive "pedagogy of sight" (Jack 2009). As with gardening, one starts as a novice birder and, through an apprenticeship, can eventually become recognized as a master birder. One learns to operate a guidebook, to look through binoculars, to recognize habitat, to dress appropriately, and to conduct oneself as a birdwatcher,

[6] The Christmas Bird Count began in 1900 as a modification on the traditional Christmas "side hunt," in which hunters would shoot as many different birds as possible to see who could shoot the widest variety. Hence, the form of the project is older than the science.

i.e. not to scare the birds with alarming noise or jerky movements. In the beginning one learns to operate the guidebook in conjunction with binoculars by carefully examining birds for distinguishing features. Per the Cornell Citizen Science Toolkit (2016), first start with the bird's silhouette to identify the bird's group. Second, move to the bird's field markings by examining the bird's body for visual landmarks. Pay particular attention to the head and wing. Third, look at the bird's posture. How does the bird carry itself? Fourth, note the size. Find a known length and roughly measure the bird. Fifth, observe the flight pattern. Does the bird fly straight or up and down? This can be the difference distinguishing a crow from a raven. Finally, note the habitat. Certain birds live in certain kinds of habitat.

For the ornithologist, there is also a lengthy apprenticeship. One moves from the broadness of undergraduate education to the narrowness of graduate education in a long apprenticeship into an ornithological specialty. Along the way, one learns the manner of formulating an acceptable scientific question, the ways of academic writing and presentation, and a myriad of other formalities. Once one is accepted into the profession and chooses to pursue a citizen science project (perhaps to increase the impact of a grant), one must comb through the academic literature on how to incorporate citizens into projects, how to adjust questions and methods to fit citizens' capabilities, and how to handle the inexactness of citizen-supplied data (Silvertwon 2009; Gura 2013), taking care to note the difference in identification accuracy, for instance, between a novice and a master birder.

The important point here is that one can become both an ornithologist and a birder. But, one cannot move from being a master birder to being an ornithologist. The epistemological divide, which mirrors a social barrier, separates the birder and the ornithologist and is absolute. The table below delimits the possibilities of participation.

	Citizen	Scientist
Ornithology	No	Yes
Bird Watching	Yes	Yes

Table 1: Citizen Science in the Box

Leaning on Rancière, we can ask what kind of pedagogical relationship exists between the citizens and scientists of the Christmas Bird Count? Arguably, no pedagogical relationship exists. The design and structure of the project prevents a relationship from developing. In Kant's terms, the barrier formed is insurmountable.

Blackawton Bees

It is fair to ask what an alternative relationship between citizen and scientist might look like in practice. Outside of the taxonomy that inscribes scientist and citizen into separate epistemological boxes, how might a "new idea" of citizen science proceed?

An experiment carried out with the most naive citizens offers an example (Blackawton et al. 2011). This article describes how a professional biologist led a class of schoolchildren in developing a series of unique experiments on how bumblebees solve puzzles. The children were not handed the experiment but developed them in conjunction with the biologist. The experiment was designed, carried through, analyzed, and written up by twenty-five schoolchildren aged 8-10 in Blackawton. The experiment, designed to test bee's ability to discriminate between differing spatial configurations, was novel and included a control group. The answer is affirmative: bees can, and do, learn to recognize and act upon novel spatial configurations. This does not mean that the experiments were meaningful or important within the history of science, but there was novel and real discovery for the children. Despite the absence of jargon and the lexical change of "experiments" into "games," this was not an exercise in learning about science. It was "real science" as it occurs in situ, full of the intellectual adventure that comes with finding out new things.

What is meant by real science? The Blackawton paper offers a simple definition: "the process of playing with rules that allows one to reveal previously unseen patterns of relationships that extend our collective understanding of nature and human nature" (Blackawton et al. 2011:168). I want to draw attention to the unstated assumption lying dormant in the phrase "previously unseen patterns of relationships." Science must start, in this conception, from a place of ignorance, for science is about discovering the previously unseen. The scientist is one who addresses this directive globally by directing his or her work towards holes, gaps, and unknowns in the long history of science, with the previously unseen element being directed at a global "we." The Blackawton games are predicated on modulating this concern with "previously unseen patterns" to the localized level of a public school. Making ignorance productive is what marks Blackawton as "real science" rather than scientific literacy. The stakes of the Blackawton Experiment are simple: the children of Blackawton do science. This is not an exercise in literacy. They are doing science together, each verifying that the other is engaged and working.

The experiments, or games, were created by the children without reference to previous scientific work and conducted with the assumption that the children's ability to construct games was equal to, if not as sophisticated as, the biologist's ability to construct experiments. Surprisingly, the technical aspects of the experiment were not difficult for the schoolchildren to work out. Games were created without much difficulty. Finding meaningful questions and figuring out how to approach the task of playing with the rules of experimentation in a novel manner was more onerous.

What does the scientist give up, or bracket out, to do "real science" with schoolchildren? Clearly the dichotomy was overcome, the boundaries were broken, and something radical happened. Just as clearly, the scientist has given up some trappings of his professional station. The first trapping to go is the literature review.[7] Second to go is the specialized jargon of science. The language used by the children of Blackawton, like the games themselves, is straightforward

[7] The literature review is the gateway to grants, awards, and the resulting benefits of status and prestige (English 2008). Through the literature review, one demonstrates mastery of the contours of a discipline and the importance of one's own research.

and relevant to their everyday lives, the prime example being the substitution of game for experiment.

What remains is the scientist's judgment that what the children accomplished was "real science." Could the children have made this pronouncement for themselves? No, the "real science" of Blackawton is underwritten by the scientist's expertise. The literature review, so carefully ignored in the experiments, is reintroduced by way of contextualizing the Blackawton experiments as "real science."

A sharper point can be drawn. Recalling Suryanarayanan and Kleinman's (2012, 227) exegesis of the historical relationship between beekeepers and entomologists, we can observe that the beekeepers' ignorance of the history, and therefore the rules, of experimental science, were used as a lever to disable the beekeepers from doing "real science" and revealing previously unseen patterns about CCD.

History is reintroduced gently and as needed by the Blackawton scientist. The Blackawton scientist, like Rancière's ignorant master, simply verifies that the schoolchildren are working by asking them to improvise and explain and by harnessing the schoolchildren's wills to his in order to create the conditions for science. The scientist meets the children on the common ground of their mutual ignorance of bee behavior. The children are not technical adjuncts but real and vital collaborators, whose judgment in creating "games" leads to "real science."

To summarize the argument so far, ignorance is a powerful, yet often ignored, element of scientific inquiry. Further, ignorance can be used in two ways. In one direction, ignorance, conceptualized as a lack of judgment, can be used to hold the citizen-scientist relationship in place, à la the Christmas Bird Count or Colony Collapse Disorder. In another direction, ignorance, as a meeting ground, can be used to take steps towards transforming the relationship between citizen and scientist, à la Blackawton.

Making good on the claim that DIYbio can be a site where citizens can do "real science" requires modulating from a one-time experiment in an elementary school, where the schoolchildren are compelled to participate, into an ongoing program that holds and directs the attention of adults over an extended period of time. This is a thornier problem requiring a more complex approach.

Introducing the Bay Area Dandelion Project

This section introduces the BADP, a citizen science project housed at the DIYbio lab Biocurious during the late spring and summer of 2012, while I was conducting dissertation research working as a volunteer and acting as a part-time member at Biocurious. My fieldwork at Biocurious lasted two full years and encompassed the origin and the end of the BADP. When I entered Biocurious, it was in the process of opening a public lab and was very much an open experimentation with respect to the organization of biological inquiry. Everyone at Biocurious in its first year of operation helped to constitute what Biocurious has become. In a double sense my participation in the BADP was constitutive of the contours of the project. The BADP's failures are my own.

The BADP belonged to Tristan, a fellow Biocurious volunteer, who first attempted to launch the project in the fall of 2011 when a call went out to volunteers and members for community projects to be sponsored by Biocurious. The founding of the BADP is a testament to the emphasis on networking at Biocurious in particular, and Silicon Valley in general. Tristan and I met while volunteering at Biocurious. Friday evenings our volunteer shifts overlapped, and we often chatted about goings on at the lab. We shared a mutual interest in what might be called minority views on evolutionary theory, as at the time Tristan was reading Stephen Gould and I was reading Tim Ingold. It was in one of these conversations that the idea for the BADP was hatched. At Biocurious, connections like this were commonly made and informal projects were regularly launched.

The idea behind the BADP was to investigate the taxonomy of dandelions in the Bay Area through two interconnected methods operating on two levels of specificity. Initially, dandelion leaves would be collected from around the Bay Area, mapped with GPS coordinates, and returned to Biocurious where the leaves would be scanned and dried, and a morphometric analysis of the leaves would be conducted. The second level of analysis would utilize dandelion DNA and techniques drawn from population biology to make further claims about dandelion speciation. We planned to ask for public help at all levels of the project, but we especially required help in collecting enough dandelion leaves. To this end, Tristan nervously wrote the following on our public blog: "a large dataset is needed to draw useful conclusions. Consequently, the success or failure of a Dandelion Project is totally dependent on ~~my enlisting a bunch of flunkies~~ the joined effort of a group of highly esteemed colleagues." If the BADP was a product of networking at Biocurious, it was also marked by the organization of projects at Biocurious.

Community Projects at Biocurious

Biocurious opened its laboratory doors to the public in September 2011, a year after a successful end to one of the earliest Kickstarter campaigns, and two years after being formed as a Meetup group. Through the Kickstarter campaign, Biocurious raised 35,000USD—enough to rent a warehouse in the heart of Silicon Valley and purchase basic lab equipment. This was widely reported in the press through quotes from future board members as an example of "democratizing biology" by making the tools of inquiry available to the public.[8]

While the public comments coming from Biocurious board members emphasized the role Biocurious was playing in democratizing science, the three-part governance structure Biocurious adopted told a different story. Volunteers (unpaid labor) staffed the lab, took out the trash, and enforced lab policies. Members (paying customers) had access to the lab for a monthly fee. A six-member board of directors set internal policy and corporate strategy and communicated with the media. Hence, despite Biocurious' presentation of itself as an experiment in "democratizing

[8] To give some idea of the intensity of media coverage when Biocurious opened: On my first day of fieldwork, I entered the lab alongside a BBC camera crew. In fact, escorting media and policy researchers would be one of my main activities as a volunteer at Biocurious in the fall of 2011.

science" in the numerous media and policy accounts, as a practical matter Biocurious operated like a startup company. The "democratization of science" trope within DIYbio was touched on in the introduction, but a brief note about the trope's life at Biocurious is in order. Not only did the board members and media endlessly recycle the trope uncritically, it was also repeated in Penders' (2011) review of Wohlsen's (2011) *Biopunk* in the journal *Nature*, which concluded of DIYbio: "the objective, after all, is the democratization of science."

And despite the media coverage Biocurious attracted upon opening the laboratory doors, the first few months in the life of Biocurious were marked by consternation over the lack of activity in the laboratory. Classes were full, networking events attracted crowds, and dozens of people stopped by for a tour every week; yet the laboratory was rarely used outside of organized classes and a handful of members whose activity was, at best, sporadic. Through a series of conversations in the lab among members and volunteers that trickled up to the board members, it was eventually decided to launch a pair of community projects to provide scaffolding for potential members without a laboratory background who might be intimidated by the steep learning curve required to carry out lab work. What was needed was a project that would encourage activity in the laboratory and produce new members whose activity would encourage and expand Biocurious' pool of corporate sponsors whose donations and special classes kept the doors open.

In this sense, the proposed community projects at Biocurious were explicitly pedagogical, being designed to teach the rudiments of biology and lab work in the hopes of increasing participation in laboratory activities. Hence, the projects required a leader, or better yet two or three, with laboratory experience. The question hanging was: What kind of pedagogy would these projects employ? And would they emancipate people to do independent work in the lab?

In late fall 2011, two projects were selected (by whom and on what grounds remain mysterious) to be the initial "community projects" at Biocurious—Bioprinter and Bioluminescence. Both of these projects were engineering exercises. The first aimed at engineering an E.coli plasmid to emit bioluminescent light on a schedule tamed enough to serve as domestic lighting.[9] The latter project aimed to repurpose an obsolete inkjet printer into a printer capable of printing biological materials onto a growth substrate with the long-term goal being the design and creation of printed organs. While designs on harnessing bioluminescence have a long history (from Aristotle forward), bioprinting has a shorter life, dating from the early 2000s. In keeping with the stakes of DIYbio, both of the winning community projects conducted scientific inquiry through the transformation of novel organisms and machines.

Despite the presence of simple DNA analysis, a popular draw that could serve to introduce those without lab experience to Biocurious and serve as a bridge to other projects, the BADP had no appointed leaders. No pedagogues who would lead potential biohackers to their DNA barcoding lessons could be found. In contrast, the winning projects, had respectively 14 participants and 3 leaders and 16 participants and 3 leaders. By losing this vote, the BADP failed

[9] Eventually this project would morph into the Glowing Plant project whose constant references to the glowing plants in the movie Avatar were an homage to the initial impulse of the Bioluminescent group.

to gain the small, yet significant, amount of institutional support (time, space and publicity) that the winning projects enjoyed. Following the November straw poll, the project fell dormant. The winter brought no forward progress and I assumed the BADP was moribund. I joined one of the winning community projects in January 2012.

Who were the leaders of the winning community projects? For the most part they were professional scientists with expertise in a technical area specific to the winning project.

At this point the community projects could have taken the direction of either the Christmas Bird Count or the Blackawton experiment. Community projects, however, invariably followed the former, with the difference between "leaders" and "participants" in the community projects and the scientist and citizens on the Christmas Bird Count being one of intensity, not of type.

The Spring of the BADP

In the spring of 2012, Tristan took a brief sabbatical from Biocurious. When he returned in late May, he presented his idea for a study of dandelion morphology and genetics to the Bioluminescence group. I immediately decided to rejoin Tristan on the project. Neither Tristan nor I was a trained plant biologist, but Tristan had more laboratory experience than I did, so he took the lead. Our inexperience as biologists would quickly become apparent during the course of the project. Yet our ignorance of basic problems within plant biology, many of which we bumped into and overcame, did not stop us from marking a stultifying distance between ourselves, with our burgeoning expertise in the biology of dandelions, and those we would seek to enlist.

One example is the way we presented the BADP research plan. In plain language, the morphometric analysis was intended to identify interesting, or simply peculiar, forms of dandelion development. Morphometric analysis is commonly used in studies of evolutionary development. Following the identification of interesting forms through morphometric analysis, a more involved genetic analysis would be carried out via microsatellite analysis. Hence, the design was twofold, with the first level relying upon members of the public to collect data, and the second level relying on trained laboratory workers. Herein lies a clue to the cause of the BADP's failure. The language we used to talk about the project was entirely technical, without regard to audience or our stated intentions. This is not to say our analysis was overly technical, but the language we used to describe our analysis to the public certainly was.

When we discussed our protocols around Biocurious, the social boundaries we had created in our language and protocols were quickly pointed out as problematic. For example, members and volunteers suggested that we use cell phones, rather than requiring physical samples, to encourage participation, and that we use a reference measure so we could let people take a picture of dandelions and email it to us. But, we decided on physical collection in the name of permanence over convenience. We decided that samples were to be physically collected and labeled with a system we devised that tracked collector, location, date and sample number. The samples were to be sent to the lab while fresh. Then Tristan or I would scan them by using a flatbed scanner and assign them a number so they could be cross referenced to a physical collection of dandelion leaves to be preserved for posterity. By insisting on the delivery of physical samples, we created a serious barrier to participation in the BADP. But we did not view it as a barrier at the time; our view was that the collection was intended to last, an archive for future researchers.

A couple days after the Bioluminescence group meeting, I bought a web domain and initiated a public-facing project blog. Tristan and I had discussed how public the project should be, and he decided that all the protocols we developed must be made publically available. With this in mind, I set up the Dandelion Project website. However, we did not bother to think through the ramifications of leaving our unnecessarily technical project proposal as our public face. And since we were both at the lab on a regular basis, we saw no need to schedule regular meeting times. Therefore, we saw no reason to hold public meetings or to invite the public to participate as anything more than leaf collectors.

During this interregnum, I also made contact with a few Bay Area environmental organizations that graciously agreed to let us pitch the BADP at their meetings. Ideas were discussed among them, Tristan, and me, but the dates and, more importantly, the technical level of the talks, could never be agreed upon. This possible outreach tour died a quick death.

In early June, we made our initial attempts at analysis. Tristan and I collected dandelions from the office parks surrounding Biocurious, then returned and scanned the samples with the flatbed scanner. The next day, Tristan and I did our initial lab work by extracting DNA from two dandelions. When we took the next step a few days after and attempted gel electrophroeesis with our extracted dandelion DNA, our DNA failed to show up on the transilluminator.

July and August 2012 were spent discussing possible next moves and trying to pitch the project around Biocurious, with no luck. We looked for financial support (we passed a hat at meetings with little success) and volunteer support, but we attracted neither labor nor cash. Meanwhile, the two sponsored community projects continued to grow, and a plant biology group (out of which would eventually grow the Glowing Plant project) formed at Biocurious. In early September, Tristan and I received an email asking if the BADP could be rolled into the newly formed, yet well-attended and well-funded Plant Bio project. At this ambiguous juncture the BADP withered.

Though we set out to do a "new type" of citizen science outside the existing taxonomy, the passage of time has rendered stark what should have been obvious to us that summer. We threw up many unintended and thoughtless roadblocks to participation. We never extended an invitation for the public to join us in the laboratory, and instead of allowing participants to use a cell phone to take photos of dandelions and email them to us, we asked people to cut a dandelion leaf, package it, label it carefully with a sticky note, and then deliver the samples in person or via overnight delivery to Biocurious. This was a ridiculous amount of work to ask of people already pressed for time. Rather than modulating our language and participation requirements, we acted like gentlemen of the Royal Society, spending time leisurely clipping interesting dandelion samples, using our academic accounts to read the latest literature on speciation, experimenting with lab equipment and protocols, and in short, indulging our liberty to inquire at the expense of those who might join us.[10] The last noise made by the project was an email received eleven months after the de facto end of the Bay Area Dandelion project. An inquiry about the project was posed on the Biocurious website by someone who prefaced their email with the words "happy to be your flunky."

Where did we go so wrong? Were we simply inept? In many ways, yes, we were simply inept. The distance between the knowledge we gained of dandelion speciation and the knowledge of our would-be collaborators was slim. We reified this minuscule distance through increasingly baroque protocols until it could not be bridged. If the Blackawton experiments demonstrate how respecifying ignorance can reconfigure the relationship between citizen and scientist, the BADP demonstrates that even a slight differential in knowledge and access to equipment can be reified into a disabling form of ignorance.

Conclusion

I opened with a large claim: citizens can do science provided that the pedagogical encounter allows for it. This claim was developed through an argument that examined differing conditions under which citizens participate in science. Following Rancière (1991), I argued that pedagogical encounters can either emancipate or stultify and that a "new type" of citizen science can be founded by emphasizing the latter, rather than the former. In line with this claim, a pedagogical approach emphasizing egalitarianism was introduced.

Empirically, the article began by examining Wiggins and Crowston's (2011) taxonomy of participation within citizen science projects. I then elucidated the conditions of citizen participation within the Christmas Bird Count, a paradigmatic example of citizen science. Within the Christmas Bird Count, it is possible for a scientist to participate as a scientist and a citizen (bird watcher), but not for a citizen to participate as a scientist. It was concluded that within the confines of citizen science as exemplified by the Christmas Bird Count, it is possible for citizens to learn about science, collect data, and perform similar technical and educational tasks, but a hard barrier prevents citizens from participating in the work of science.

Next, an alternate model of carrying out science with citizens in the form of "games" developed by elementary students was introduced. At Blackawton, "real science" was done by schoolchildren in conjunction with a professional scientist. By setting aside the trappings of his professionalism, the scientist was able to meet the children at a point of equality that allowed them to do science. Finally, the BADP project was introduced in the context of community projects at Biocurious. Though full of rhetorical flourishes about practicing "a new idea of citizen science," as a material project the BADP failed to make good on its rhetoric. But while the BADP project may have failed in its "new idea," the "new idea" remains a real, if difficult, possibility within DIYbio.

[10] Google Scholar at one point flagged my account for fraud because I had searched for so many articles outside my normal search radius.

The last point was echoed by one of the few professional scientists at Biocurious. A recent PhD graduate who led a community project at Biocurious expressed his hopes for what citizen science within DIYbio could be and his disappointment with what citizen science within DIYbio often is:

> It does seem unreasonable at first glance to think you can take a PhD program and condense that to get [DIYbio lab members] up to speed [technically]… I figured I would be beating my head against the wall teaching these people [technical aspects]…but its not… Its the people and the organization and perhaps that makes me sound quite naive… is it just the space or it is biohacking in general… it doesn't have to be this way, which is inspiring and demoralizing.

In this lament, the community project leader echoes Tristan's "new idea of citizen science." Hence, from multiple perspectives within Biocurious, the possibility and frustration of democratization were deeply felt. But without recourse to the traditional scientific apprenticeship, where are we to turn for a way out of this box? What form might an education into the techniques of science and scientific judgment take within DIYbio? Here Rancière is prescient, for he offers a way forward. But to take Rancière seriously is to chart an unfamiliar path to anyone who claims to possess a measure of expertise. None who set out to educate set out to stultify. Yet, as Bourdieu (1992) knew all too well, simply establishing a pedagogical relationship is often sufficient to reproduce social positions.

On that note, let us revisit Blackawton. What was accomplished in Blackawton was, in Rancière's terms, the verification of the children's intelligence by the scientist. As Rancière (1991) has argued for all emancipatory pedagogy, the children's wills were harnessed to the biologist's will and together they discovered something neither had known beforehand. The experiments, or games, that the children conducted were unique and meaningful, and for the biologist, constituted "real science." Ignorance, respecified as possibility, was the mechanism by which the Blackawton experiments were carried out, and the Blackawton scientist successfully used his pedagogical position to overturn, however briefly, the citizen/scientist dichotomy.

This is an unabashedly radical vision of what can be accomplished through citizen science. But this "new idea" of citizen science recalls an old idea. Namely that ignorance, rather than expertise, is an engine of new knowledge (Rancière 1991; see also Vitek and Jackson 2008, 1-4), and that interrogating the world by playing with both the rules of nature and of inquiry is available to any human—be they children, AIDS activists, or beekeepers—with the will to participate. And this point illustrates something of the difficulty in the pedagogical relationship. It is simple to conceptualize ignorance as the starting condition for new knowledge. All scientists do this on a daily basis, for this habit of mind is the basis of the scientific method. Yet, taking this basic habit of mind and putting it into pedagogical practice cuts strongly against our common-sense notions of science and scientific expertise.

The radical and egalitarian claim made by the Blackawton experimenters is that science is a "play with the rules of inquiry that enables one to reveal previous unseen patterns of relationships that extend our understanding of nature and human nature." Of course, the "real science" of Blackawton is not science as we are accustomed to seeing it carried out. It is not a mediation between the scientist and citizen (Kera 2012), nor is it hacking a previously settled body of knowledge to a new end; but it is "real science" in the classical sense of inquiry into yet unseen relationships. Thus, citizen science need not be an impoverished form of "real science" characterized by what it lacks.

Earlier I argued that contributory expertise (Collins and Evans 2007) has two elements: technical acumen and the judgment to distinguish meaningful problems. We often associate scientific breakthroughs and discoveries with technical acumen rather than scientific judgment. But, as a comparison of Blackawton with the BADP demonstrates, it is scientific judgment, rather than technical acumen, that underwrites "real science." At this juncture, we can take a further step and observe that the scientist's technical acumen elides a further operation of scientific judgment: the question of who is allowed within the closed circle of collaborators. The Blackawton children were allowed into the circle of scientific expertise through the largess of a biologist out to prove a point; Ottinger's (2010a, 2010b) and Epstein's (1995) activists forced their way into conversations through concerted organizing and action; and Suryanarayanan and Kleinman's (2012) beekeepers were unable to overcome the monopolization of expertise on CCD by agricultural entomologists.

It is one thing to undertake pedagogical experiments with bees and dandelions, but many quarters of DIYbio aim not only to transform themselves into the "active producers of science" that Meyer's (2014) points to, but also to create novel forms of bees and dandelions through genetic engineering (Keulartz and van den Belt 2016). Therefore, DIYbio brings the question of judgment to the forefront by placing a double demand on scientific judgment. Necessary to making good on Tristan's "new idea" of citizen science is calling attention to the way we transform one another through inquiry, bending each other to desired ends. And this requires more than access to the technical means of a laboratory. It requires cultivating the judgment necessary to form our shared ignorance into common ground.

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