Lessons Learned from Citizen Science in the Classroom

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ABSTRACT

Mueller, Tippins, and Bryan's contrast of the current limitations of science education with the potential virtues of citizen science provides an important theoretical perspective about the future of democratized science and K–12 education. However, the authors fail to adequately address the existing barriers and constraints to moving community-based science into the classroom. We contend that for these science partnerships to be successful, teachers, researchers, and other program designers must reexamine questions about traditional science education and citizen-science programs and attend to certain dimensions, including: framing these projects around the nature of science, creating a dialog with experts and allowing access to the primary literature, and fostering the ability of the public to critique information and evidence. We argue that the resource constraints of scientists, teachers, and students likely pose problems to moving true democratized science into the classroom.

This article is a response to:

Mueller, M.P., Tippins, D., & Bryan, L.A. (2012). The future of citizen science. *Democracy & Education, 20*(1). Article 2. Available online at http://democracyeducationjournal.org/home/vol20/iss1/2/.

In their article "The Future of Citizen Science," Mueller, Tippins, and Bryan (2012) argued that as K–12 science education becomes more constrained by increasing administrative directives and diminishing resources, a restructuring of classroom practice toward a more inquiry-driven, civically relevant, and democratic process could create a more scientifically literate citizenry. Although their prognosis was timely and presented a noble idea, there are practical concerns about the transition of science education to be more guided by and integrated into the public sphere. In this essay, we respond to the notion of integrating citizen science into the classroom, drawing from our experiences in a community-based citizen science program centered in a high school science classroom and cooperatively developed by students, teachers, environmental management agencies, and scientists. We propose that learning communities that seek to engage successfully in such reform must forfeit some traditional ideas associated with both classroom education and citizen science programs and instead reframe partnerships around the nature of science. Teachers and administrators need to be adaptable enough to promote epistemology over content while scientists and program developers must allow classrooms to take ownership over scientific investigations. We continue by outlining some practical lessons we have learned working within the U.S. education system

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that may facilitate or limit the future, as envisioned by Mueller and colleagues.

Historical Problems with Formal Science Education and Citizen Science

Criticism of formal science education is nothing new. Although teachers and education administrators have always been concerned with students' ability to apply their scientific knowledge to make informed decisions regarding personal and societal problems (Lederman, 1999), contemporary classroom practice is often criticized for being overly focused on content and training (Curtis, 1993). Critics point to teachers' and students' underappreciation of the general nature of science (King, 1991) as well as teachers' lack of expertise, as perceived by the public (e.g., Jordan & Duncan, 2009). Indeed, instructors are under considerable pressure to teach scientific inquiry akin to more democratic citizen science projects, but many teachers view their role as champions, and not necessarily purveyors, of scientific knowledge (Jordan, Gray & Golan-Duncan, 2008). It would stand to reason, then, that if teachers view themselves primarily as communicators and not as generators or critics of knowledge, they would engage in inquiry exercises designed outside the classroom rather than seeking input from their students or their community (Jordan, Gray, & Golan-Duncan , 2008). Such constraints arguably limit the ability of classrooms to produce students capable of applying scientific knowledge and processes outside the classroom context as well as to contribute to the generation of new scientific knowledge relevant to a community.

In addition to the problems associated with formal science education, informal citizen science programs, intended to nudge science into the public sphere with various learning, citizenship, and conservation goals, have also been shown to have shortcomings. As Mueller and colleagues pointed out, power dynamics have limited the success (in terms of learning and ownership) of many citizen science programs. As a result of restricted participation, several evaluations of citizen science projects have noted limited participant motivation to change behavior or civic engagement (Jordan, Gray, Howe, Brooks, & Ehrenfeld, 2011a). Further, the inability to practice scientific reasoning regarding issues of public interest might underpin the struggle that these informal learners face when engaging in many aspects of scientific reasoning in citizen science projects (Evans et al., 2005; Crall et al., 2012; Jordan et al., 2011a; for a contrary example, see Trumbull, Bonney, Bascom, & Cabral, 2000).

A recent report funded by the National Science Foundation (Bonney et al., 2009) broadened the term citizen science to public participation in scientific research (PPSR) and outlined three major categories: (a) contributory projects, which are scientist designed, with the public often relegated to simple data collection; (b) collaborative projects, which are scientist structured, with citizens given freedom to refine project design, analyze data, or communicate findings; and (c) cocreated projects, which are fully democratized, with the public actively engaging with scientists though all steps of the scientific process. As the report pointed out, a majority of citizen science projects fall into the first category, with limited autonomy afforded to the public. Although some notable examples of cocreated projects exist (see discussion of Sherman's Creek Conservation Association and Reclam the Bay in Bonney et al., 2009), the last decade of research on citizen science programs indicate that scientists, practitioners, and participants currently lack the tools and frameworks required to enable themselves to ask and answer questions of mutual interest or concern.

To address some of the issues associated with formal and informal science education, we present lessons learned from a case study of a cocreated citizen science project centered in a classroom. This project matched a teacher and her ninth-grade honors biology class with the data needs of a local watershed partnership. Primary research control was given to the class, yet was informed by science professionals. The result was a yearlong study that sought to determine the current level of public support for a proposed environmental policy through the collection of survey data on the public's "willingness to pay" (see Loomis, Kent, Strange, Fausch, & Covich, 2000) for ecosystem service restoration in the watershed community. The information generated was intended to be useful for watershed managers and of sufficient quality to yield a student-authored report to be submitted to a scientific journal for publication (Nicosia et al., in revision). Additionally, through this process, students and teachers were expected to increase scientific and civic literacy because the investigation was tied to existing classroom curriculum. At the end of the project, students presented their work at the watershed partnership's science and technical committee meeting and at other environmental agencies in the area (Moore, 2011). In this response, we identify some of the challenges to developing such a program based upon our experiences.

Reframing Classroom and Citizen Science Structure Around the Nature of Science

The underappreciation of the roles that culture, social groups, available tools, and personalities play in influencing the questions asked and what constitutes appropriate evidence is one of the more pressing limitations of democratizing science in the classroom (Lederman, 1999). If science is going to be democratized in the classroom, educators and scientists must, from the onset, embed new frameworks that explicitly address the influence that norms and values have on science that is independent of scientific content. Specifically, classrooms and administrators must widen their scope and reframe their programs to embrace the uncertainties and pitfalls, including bias and measurement and analytical error, of generating scientific knowledge. Further, scientists need to be willing to give up some control in their research while offering structure and affording the tools of science to the classroom. This necessarily involves allowing learners to make mistakes and reflective activities that are luxuries rarely available to classrooms and school districts. As Ford and Wargo (2006) pointed out, if we are seeking to engage teachers and their classrooms in authentic scientific practices, we need to make scientific epistemology and approaches accessible. Such frameworks should move beyond scientific experimentation, as is often the norm for teachers (Grandy & Duschl, 2008). Further, these experiences should include practices that acknowledge that all participants, regardless of training, contribute valuable perspective.

Frameworks that begin these conversations and may facilitate democratized science into the classroom already exist. For example, Lederman (1992) highlighted characteristics of scientific knowledge important to integrate into curriculum and improve scientific literacy, namely that science is subject to change, empirically based, subjective, and culturally embedded and relies on inference. However, even though promotion of the nature of science has existed for some time (McComas, Almazroa, & Clough, 1998), studies indicate that influences that are independent of teacher understanding of content or the characteristics of science often drive classroom practice (Lederman, 1999). Therefore, it is important to develop a starting point at which the philosophical underpinnings of scientific investigations can be discussed, while citizen science designers have an opportunity to understand existing teaching constraints in the classroom.

In an effort to address the need for a guided framework, scientists and teachers participating in our study engaged in explicit discussions about the nature of science related to existing classroom curriculum. From these conversations and past research (Lederman, 1999), an investigative framework developed, again by both the scientists and the teachers, which led to the construction of curricular tools which matched the nature of science with applied classroom practice. The purpose of these discussions was to create a starting point for the investigation that was mutually agreed upon and, to the extent possible, diminished both scientist and teacher preconceived notions about the structure of the program. This was done in a manner to avoid obstruction of routine classroom activities. A major limitation in our approach, however, was that while teachers reported considerable enjoyment in their work with scientists, they still felt somewhat limited in their ability to "create" science. In turn, while the scientists in our project reported enjoyment in the outreach, they found it difficult to find the time to devote to the project. These perspectives have been previously found to limit teacher-scientist partnerships (Andrews, Hanley, Hovermill, Weaver, & Melton, 2005).

Dialogue with Experts and Access to the Primary Literature

As Mueller et al. pointed out, there are issues of accessibility that limit science democratization as well as inherent issues of equitable representation in the production of knowledge. The authors discussed the idea of access in global terms, facilitated or limited by the distribution of technology to communities across the world. Although we agree that such a technological divide exists, our perspective is at a smaller scale, and we contend that limited access to current scientific knowledge and communities of scientists exists in almost all forms of publics. If the public is going to meaningfully contribute to science or if science is going to be used as a meaningful tool for the public, then learning communities must be allowed to create a dialogue with experts and be equipped with access to information about what is currently known within the domain in which they are investigating.

Classrooms, like many publics, have no access to the background information that drives scientific questions, thus limiting teachers' and students' ability to engage in dialog about scientific issues (Driver, Leach, Millar, & Scott, 1996) and, perhaps more important, to develop investigation plans that generate appropriate data and analyses that addresses their questions. In terms of democracy, developing an appropriate level of understanding of how professional science is carried out as well as employing the sufficient rigor to produce meaningful knowledge present issues that are not easily overcome and may perpetuate the trend of top-down citizen science.

In our program, the watershed partnership generated several questions and gave them to the classroom for review. Students then engaged in background reading available through open-source science outlets on the web (e.g., Google Scholar). Considerable time was devoted to scaffolding students' ability to read and to evaluate scientific papers for content. After exhausting open-source content, students generated a list of references not accessible to them, which a university library then provided. Students summarized key parts of these papers and distributed the summaries to the class. Two key studies were particularly useful to the design of the class's investigation. One paper provided a detailed methodology (Loomis, Kent, Strange, Fausch, & Covich, 2000) while another provided detailed content about the relationship between urbanization and watershed degradation (Kennish et al., 2007). This research, together with the watershed-partnership planning documents, guided the students and teacher in generating a few workable research plans, which they forwarded to university and government scientists for review and comment. After the class reviewed the recommendations, the classroom structured the study and paper via a collaborative website (wiki).

As the students continued to refine the structure of their investigation, representatives from the class were in close contact with university and government scientists. Classroom discussions were summarized into specific questions and an ongoing dialog was created between all members of the learning community via email, with monthly visits from scientists. After the study was complete, the scientists served as a peer review panel and provided feedback on the final report. Students refined the paper and selected a journal for submission.

The dialogue with scientists and the access to literature were important parts of our program and added considerable structure, allowing the investigation to be broken down into achievable tasks; however, it may also have limited creativity in the classroom's scientific problem solving. Previous studies have found that providing materials and tools to science students prior to an investigation strongly influences student planning, how an investigation is framed, and the timing of ideas shared among students (Jordan, Ruibal-Villasenor, & Etkina, 2011b). In our study, scientists suggested the analytical method used (i.e., willingness-to-pay model) based on the class's questions and its feasibility. The degree to which the selection of this otherwise useful method limited students' creativity in the design of the investigation, and ultimately the conclusions that were drawn, is unknown. The influence of tool availability on the research design of cocreated citizen science projects would benefit from further investigation.

Fostering the Ability to Critique Different Forms of Information and Evidence

Last, we address the issue of how to foster the public's ability to critique information and evidence. Although standards for what constitutes quality information vary considerably, science has settled on the importance of generating reliable forms of evidence (Ben-Ari, 2005) from which conclusions are reasonably based. Although the last decade has seen increasing interest in understanding the multiple ways knowledge is generated, as evidenced through increasing research on the value of traditional and local ecological knowledge (Gray, Chan, Clark, Jordan, 2012), tools that promote the skills required to evaluate information are not routinely applied in the classroom or in the majority of current citizen science projects (Bonney et al., 2009; Jordan et al., 2011a). If the evidence generated through democratized science-classroom partnerships are going to be robust to outside scrutiny, teachers, scientists, and citizen science program designers must develop tools that foster the ability to critique evidence encountered (e.g., peer-reviewed literature, websites, newspaper articles) and the evidence generated through their projects (e.g., datasets, statistical analyses).

To address this in our program, we attempted to foster student ability to critique science by generating rubrics for what constituted quality information to be considered in the study. In our experience, rubrics proved useful both as a learning tool for students and as way to evaluate conceptual change in students over the course of the project. At the beginning of the investigation, students were exposed to the idea of a rubric as an evaluation measure. We introduced the idea by using a topic already familiar to students (evaluating the characteristics of friendship). Students worked as a class to come up with the categories (loyal, trustworthy, etc.) and the different levels of friendship (best friend forever, school friend, etc.). Students then collaborated in small groups before eventually working individually to create a rubric. After they were more familiar with the concept, students created rubrics to evaluate scientific evidence and journal articles (Figure 1). Throughout the project, students applied their rubrics to the information they incorporated into their report and their own work. Although time consuming, the rubrics fostered student reflection and served as a qualitative way to organize the criticisms students developed based on the standards they also developed. Making individual and community standards explicit encourages the creation of norms for evidence to be considered for decision making both in classrooms and in other communities. Although not a simple task, as many students resisted continuous detailed revision and had difficulties determining discrete categories (see similarities in "Analyzing Information" and "Drawing Conclusions" in Figure 1), rubrics may play an important role in democratization of science since they have the ability to explicitly represent standards for what constitutes quality evidence to be used in decision making.

Moving into the Future

Although community-relevant investigations in the classroom are a hopeful vision for addressing current issues related to public interaction with science, practical problems still remain. Mueller and colleagues point to democratization as a goal for these partnerships; however, because of resource constraints it is doubtful

	Distinguished	**Satisfactory**	**Borderline**	**Unsatisfactory**
Information Gathering	Perfectly explained information with clear sources and data cited	Enough information to be specific without confusion	Attempt to gather information, but few sources	No attempt to gather appropriate sources
Analyzing Information	Collecting data and coming up with clear conclusion	Use the data collected in conclusions	Refer to some data in conclusions	No use of data in drawing conclusions
Drawing Conclusions	A conclusion that has perfect support	A conclusion that has support with no more than one flaw	A conclusion with questionable support	No logical support for the conclusion
Conducting Investigations	A clear and logical explanation with no confusion	Logical explanation but does not show a lot of evidence	Explanation with little evidence	Idea is presented with no logic or evidence
Communicating Ideas	Ideas are presented in a logical sequence	Ideas are logical	There is an attempt to present an idea	Ideas are presented with no logic and are not understandable
Making Decisions and Inferences	Use clear and powerful support. Explanations are clear with data with no errors	Use support with at least some data	Little support and a few error	Not understandable and no support with many errors

Figure 1. Example of student created rubric used to evaluate journal articles for use in their investigation project.

that scientists and classrooms will soon be equal partners. Although power can be more equitably distributed, as was the goal of our study, the real and perceived hierarchies among scientists, scientific knowledge, teachers, and students that are built into the structure of formal science classrooms present major challenges. In our project, care was taken to provide the classroom with options throughout the process (e.g., which research question would lead the investigation, which analytical tool was most appropriate and preferred to answer the questions posed, what literature and information would be included in the study). While teachers and students negotiated the best way to proceed and found this empowering, project scientists often had to intervene, sharing norms of scientific investigation (such as promoting random survey design). Additionally, considerable support was required to help students to extrapolate their findings beyond the case study and in more complex statistical analysis (beyond students' initial descriptive statistics). These more complex tasks were undertaken by a smaller group of eager students, which created an inequitable distribution of both interest in the project and labor in the classroom. The scientist intervention and the creation of the smaller interest group reduced some of the ownership felt by the teacher and students while improving the appropriateness of the study to be submitted for academic peer review.

Mueller et al. pointed out that a lack of resources may have contributed to the current state of formal science education as we know it today, and citizen science, although promising, does not—in many of its current forms—go far enough to resolve issues of participation in science or in promoting science literacy. We agree. However, where the authors' focus is on the multidimensional characteristics of communities that theoretically need to be addressed in order to integrate citizen science, formal science education, and democratized science, our view is considerably more applied. In our experience, coconstructing science in the classroom is labor and resource intensive, as it requires contributions from myriad actors and a willingness to embrace an uncertain research process in the hopes that scientific knowledge and literacy are outcomes. Wide enactment will require significant support and commitment from a large learning community, and citizen science architects, scientists, teachers, and students will need to develop norms and structures for these collaborations that are often counter to the currently dominant expectations of the K–12 classroom and many citizen science projects.

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