Links and Distinctions Among Citizenship, Science, and Citizen Science

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ABSTRACT
Mueller, Tippins, and Bryan (2012) presented a new conceptualization of citizen science that is meant to facilitate emerging trends in the democratization of science and science education to produce civically engaged students. I review some relevant trends in the field of citizen science, for clarity here referred to as public participation in scientific research (PPSR), and present overlooked styles and outcomes of PPSR. Education efforts should seize the opportunity to emphasize the key and distinct roles students can play in both the science and the values elements that inform decision-making processes.

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I APPLAUD THE PREMISE that schools' educational aim should be to create citizens and that science education can play a key role in that process (Mueller, Tippins, & Bryan, 2012). In the mid-nineteenth century, education reform began a shift from the "memory culture" that was the study of classical languages to the development of intellect through meaningful understanding of the natural world via the study of science (DeBoer, 1991). According to DeBoer (1991), prominent scientists made the case that the ability to reason scientifically would "free individuals from the dominance of authoritarian teaching and empower them to derive truth independently" (p. 17). Mueller, Tippins, and Bryan (2012) extended this reform effort by drawing attention to the ways in which citizen science can unite the concepts of citizenship and science.

Mueller et al. (2012) defined *citizen science* as an exceedingly inclusive set of activities such as community-centered science, participatory community-action research, street science, scientific literacy, and humanistic science education. Despite the abundance of practices that Mueller et al. (2012) placed under the umbrella of citizen science, their vision for citizen science was based on participation in school science classes/projects alone. *Citizen science* is already commonly used in the United States in the field of informal science education (ISE), which focuses on learning that takes place outside of school settings (Shirk et al. 2012). In ISE, citizen science refers to methodologies for public participation in scientific research (PPSR; Bonney et al., 2009). Mueller et al. (2012) implicitly acknowledged the ISE perspective when they use the classic Christmas Bird Count as their primary example of the current state of citizen science.

The important difference between Mueller et al.'s (2012) use of the term *citizen science* and the ISE definition is not the distinction between formal and informal science education but between explicit and implicit citizenship practices. The Mueller et al. (2012) conceptualization is strikingly true to the literal phrase *citizen science*, uniting the concepts of citizenship and science. In ISE, citizen science is slowly being replaced by PPSR.

Building on the Mueller et al. (2012) idea that citizen science expand its meaning to explicitly include citizenship practices, in formal and informal science education domains, I use PPSR to present a perspective on the current scope and outcomes from the ISE field. Although the earliest PPSR projects, and those that are currently the most common, were not designed for students, Mueller et al. (2012) illustrated inherent flexibility in PPSR, which, just as schools should, operates to empower political agency. It does so by correcting information asymmetries between advantaged and

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disadvantaged communities, experts and laypeople, and many other groups of "haves" and "have-nots."

PPSR project goals are formed at the intersection of scientific and public interests, and PPSR learning outcomes have been of intense interest to the ISE field. PPSR was not designed explicitly for putting individuals on science career tracks, though that can be one goal of informal science education. PPSR broadened the audience that could be actively engaged in ISE efforts, allowing those efforts to reach beyond zoos, aquariums, and nature centers and into people's hobbies and leisure time (Bonney et al., 2009).

In this essay, I review the PPSR types and their learning and social outcomes, and then I explore the role of science and values in decision making and policy making. I propose that increasing public engagement in the production of knowledge increases the necessity to distinguish the utility of scientific knowledge from other perspectives (values, opinions, and experience) essential to decision making. Engaging students in science relevant to local concerns and policy is not enough. Students need to learn how decisions are made, and perhaps help reform that process. The first step is clearly articulating the complementary roles of science and values.

PPSR Types

The current PPSR practice is much broader than Mueller et al. (2012) illustrated with the Christmas Bird Count, which was designed over a century ago. Several typologies of PPSR have developed in this rapidly emerging field (e.g., Cooper, Dickinson, Phillips, & Bonney, 2007; Craig, Whitelaw, Robinson, & Jongerden, 2004; Haklay, 2012; Wiggins & Crowston, 2011; Wilderman, 2007), and each provide a different perspective on PPSR. Most useful are the three classes of PPSR, identified by Bonney et al. (2009) and based on the types of scientific activities in which scientists and the public each participate: contributory, collaborative, and cocreated models. According to Bonney et al. (2009), contributory projects generally are designed by scientists and the public contributes data; the same is true for collaborative projects, but the public also may help to refine the design of the project, analyze data, or disseminate findings; co-created projects are designed by scientists and the public together, and some of the public participants are actively involved in most or all steps of the scientific process (Shirk et al., 2012). Although the typology describes a formation of PPSR projects that is top-down to bottom-up, the criteria that makes this so is oversimplified. "Designed by scientists" actually means "designed by professionals, not designed by the public." That is, the responsibilities attributed to "scientists" actually describe multidisciplinary endeavors with input from scientists, educators, natural resource managers, evaluators, programmers, and others, and often meet multiple scientific, educational, and conservation goals. Nevertheless, from a democratization perspective, PPSR styles represent different degrees to which the public is involved, in control, and able to express its authority relative to ways scientists, educators, and other professionals are involved, in control, and expressing their authority.

Unfortunately, in using the Christmas Bird Count example, Mueller et al. (2012) drew from only the contributory model, which is probably the most common, but simply because it has been around the longest, rather than because it has the highest utility. The increased areas of participation and interaction afforded in cocreated and collaborative models make these more likely to foster the school-civic engagement model Mueller et al. (2012) envisioned. All the PPSR models are based on the same premise: People have greater motivation to learn and engage through experiential or interactive processes and when the subject is relevant to their lives (Falk, 2001).

PPSR Learning and Social Outcomes

Mueller et al. (2012) pointed out current PPSR practices' apparent minimal learning impacts. To date, there have not been enough studies published that have examined PPSR learning outcomes to draw definitive conclusions about the effectiveness of PPSR as an education tool. The lack of published studies may partially reflect the file-cabinet phenomena (i.e., studies that find no learning outcomes may be less likely to be published than studies that find learning outcomes). The ceiling effect, which occurs when overwhelming majorities of individuals enter projects with high knowledge or skills, and so no change can be detected, is also known to be a problem for those evaluating PPSR projects; finer survey instruments are being developed to advance the field of PPSR project evaluation (R. Bonney, personal communication, January 2011). As Mueller et al. (2012) pointed out, PPSR projects have achieved educational goals such as increasing public understanding of science knowledge (Brossard, Lewenstein, & Bonney, 2005), enhancing engagement or interest in the topic, increasing scientific thinking (Trumbull, Bonney, Bascom, & Cabral, 2000), improving natural history skills, increasing awareness or understanding of science, and changing attitudes and behaviors toward science (Brossard et al., 2005). Some PPSR projects have failed to achieve some goals, such as changing attitudes toward conservation (Jordan, Gray, Howe, Brooks, & Ehrenfeld, 2011). From the studies of learning outcomes to date, it appears that each of the PPSR models can increase knowledge, awareness, or understanding of scientific concepts related to the PPSR project's study (Bonney et al., 2009). PPSR can also increase public knowledge of social and political processes, such as community structure and environmental regulation (Bonney et al., 2009).

Perhaps more relevant are the social outcomes of PPSR, such as building social capital, promoting environmental action, and engaging in greater ownership and advocacy (Cornwell & Campbell, 2012). For example, in a stream-monitoring project, participation did not increase learning but did increase political participation, size of personal networks, and feelings of community connectedness among volunteers (Overdevest, Huyck Orr, & Stepenuck, 2004). A community's capacity to collectively solve local problems is related to the degree of connections among people (Putnam, 2000). From an environmental justice perspective, citizens engaged in data collection for environmental monitoring can correct information asymmetries and enhance regulatory process accountability in industry and regulatory agencies (Overdevest & Mayer, 2008). Thus, some kinds of PPSR can increase the civic capacity of communities and can influence the social dynamics of industry compliance (Overdevest & Mayer, 2008).

Some processes and frameworks for linking PPSR to citizenship practices and decision making have been developed and explored (e.g., Conrad & Daoust, 2008; Vaughan, Whitelaw, Craig, & Stewart, 2003), but more development is needed, particularly as we try to understand the effects of PPSR in the American system. Both cited examples are from Canada. Some studies have found PPSR participants frustrated by being able to share only the knowledge that fit the data forms and protocols as prepared by professionals without their input (Ellis & Waterton, 2004) or by being unable to gain the level of authority they sought (Lorimer, 2008). When participants have used their improved understanding of science (that they gained from PPSR) to challenge those with scientific authority, and exploit the uncertainty in science, they have been able to balance the level of authority and coproduce conservation practices (e.g., sea-turtle nest relocations, Cornwell & Campbell, 2012).

Distinguishing Science and Values in Decision-making Processes

The relationship between science and advocacy has been problematic for professional scientists. When a professional contributes scientific knowledge to inform policy and also expresses personal values on the issues, the science-based information can be attacked, accusations of biased research and loss of objectivity compromising the scientist's credibility. Wilhere (2012) defined inadvertent advocacy as "the act of unintentionally expressing personal policy preferences or ethical judgments in a way that is nearly indistinguishable from scientific judgments." Wilhere (2012) pointed out inadvertent advocacy as problematic because it erodes trust in science and perpetuates an ethical vacuum that undermines the correct integration of science and values in decision making. When nonprofessionals become citizen scientists in order to contribute both scientific judgments and personal ethical judgments, could they face similar problems?

I agree with Mueller et al. (2012) that there are more dimensions to science than is typically taught. Despite the popular-science movement (Lewenstein, 1992), science education in practice too often teaches stereotyped hypothesis testing rather than other types of reasoning or the societal context in which science is situated (Cooper, 2011; National Research Council, 2009; Sawyer, 2006). Creating a type of citizen science in schools that produces learning and social outcomes already seen in PPSR can enable students to become civically engaged in solving problems in their communities. To avoid inadvertent advocacy, this prospect necessitates teaching how knowledge and values should combine to create decisions.

Knowledge alone, whether local or scientific in its origin, does not lead to solutions to problems or to policy decisions per se. Yes, scientific information is needed for science-based policy initiatives, but more than just that is required, though rarely articulated, when striving for workable solutions and policy decisions. Solutions to local problems and policy decisions combine a mix of social values and scientific information in two distinct ways. In the context of PPSR, students and other members of the public can bring their perspectives, ideas, values, and opinions to a PPSR project to provide the social context for the enterprise of science and how knowledge is produced (Bucchi, 2008; McCallie et al., 2009; see also Burns, O'Conner, & Stocklmayer, 2003; Kerr, Cunningham-Burley, & Tutton, 2007; Leshner, 2003). Such public input also can act as the reference point or benchmark for decision makers to make meaning of science-based knowledge when judging options that may include social, environmental, and economic trade-offs.

Because science is a human endeavor, ethics, value judgments, and contexts of the people practicing the science fundamentally pervade all aspects of the scientific enterprise, including the questions asked and the methods used (Barry & Oelschlaeger, 1996; Robertson & Hull, 2001; Shrader-Frechette, 1996). More public participation means the scientific endeavor has the opportunity to reflect a broader segment of society—which is appropriate, since science is ultimately in the service of society.

People should express, and debate, their policy preferences and values. For example, science provides a type of reliable information (say, a 20% chance that fish will be lost from a stream if pollutants are allowed in runoff) that, when used in conjunction with values, opinions, experience (say, fish are valued for food, recreation, aesthetics, and economics), can be useful for decisions (the 20% chance, or the uncertainty around it, is too great to allow pollutants in the vicinity). The cautionary flag that I wave is that when the value judgment is expressed as though it is the scientific information, inadvertent advocacy and its subsequent problems arise.

Conclusion

All models of PPSR are advancing toward being a means for civic engagement, empowering people to contribute to the formation of knowledge and the articulation of values as needed for decision making in policy, management, and environmental issues. In citizen science, students and other people now have the potential to contribute to both parts of the decision-making equation: the science information as well as the values. People can disagree in their opinions, hold different values, draw on different experiences, but information and knowledge derived from science (with its inherent self-correction processes) should be reliable, repeatable, and indisputable.

Professional scientists debate their role in decision making: Some express concern that contributing to discourse about value preferences will lower their credibility in discourse about the science (Noss, 2007), while others argue advocacy is an obligation (Barry & Oelschlaeger, 1996). The solution is to always be clear in distinguishing benchmark value preferences from scientific information (Wilhere, 2012). Similarly, participants in PPSR projects can consider their engagement in advocacy and other civic actions based on their personal values as distinct from their PPSR science contributions, thereby ensuring that both are useful to inform policy and decisions. Indeed, the expectation of students in citizen science, as envisioned by Mueller et al. (2012), is that they will learn to enter public discourse as citizens and as scientists. Without clear distinctions, discourse can go astray in misplaced debates about the scientific information (e.g., climate change deniers) while society avoids answering profound questions about collective societal values.

Scientists and policymakers often urge decisions to be based on science. In order for science to be a valuable, effective way to inform policy, the science-policy nexus needs to be complimented by a values-policy nexus. By distinguishing and clearly articulating value elements and scientific knowledge, we open the door to necessitate public discourse to determine our values (Wilhere, 2012). I urge the Mueller et al. (2012) concept of citizen science to strive toward participation mechanisms that harbor the balance of involvement to attain both.

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