



A framework for addressing ethical issues in citizen science



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ABSTRACT

The collaboration between laypeople and professional scientists known as “citizen science” is an important trend in research and data gathering. Citizen science offers important benefits to science and society. For example, citizens can help scientists with data collection and provide advice on research design and implementation. Citizens can also gain a better understanding of scientific concepts and methods. Additionally, citizens can help scientists better understand and address issues of concern to their families and communities. However, citizen science also raises ethical issues that should be addressed when projects begin and throughout the course of scientific investigation. To promote ethical research, scientists should develop guidelines for involvement of citizens in research, communicate effectively with participants and local communities at the outset of their involvement in research projects, carefully oversee their work, develop appropriate publication practices, and provide lay-volunteers with education and training on the responsible conduct of research. Researchers also need to be cognizant of clarifying these roles and responsibilities as well as promoting appropriate and safe citizen participation and transparency of the study methods, data analysis, and communication of results.

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1. Introduction

The collaboration between laypeople and professional scientists known as “citizen science” is an important trend in research (Cohn, 2008; Stilgoe, 2009; Silvertown, 2009; Riesch and Potter, 2014). Citizens have helped professional scientists gather data on animal and plant populations (Cohn, 2008; Gardiner et al., 2012; Donnelly et al., 2014), canine behavior (Hecht and Spicer Rice, 2015), celestial objects (The Planetary Society, 2014; Citizen Science Alliance, 2014), environmental pollutants (Conrad and Hilchey, 2011), fisheries (Fairclough et al., 2014), whale sounds (Citizen Science Alliance, 2014), meteorology (Citizen Science Alliance, 2014), and invasive species (Starr et al., 2014; Gallo and Waitt, 2011). Laypeople have played a pivotal role in study design, subject recruitment, and data interpretation in community-based research in public, environmental, and mental health (O’Fallon and Dearry, 2002; Savage et al., 2006; Horowitz et al., 2009). While these collaborations between scientists and laypeople offer

numerous benefits for science and society, they may also raise ethical questions and concerns (Resnik and Kennedy, 2010; Riesch and Potter, 2014). This commentary will describe citizen science, discuss its benefits, and explore the ethical issues it creates.

2. What is citizen science?

If you ask a layperson to describe a scientist, they will probably sketch an image of “professional” researcher—a man or woman in a white coat, working in a laboratory at a university or private company. However, the idea that scientific inquiry is conducted mostly by professional researchers is a relatively modern notion. Prior to the expansion of academic and industrial research in the mid-1800s, most scientists were “amateurs” who were not employed as researchers. For example, Benjamin Franklin (1706–1790) was a diplomat and politician and Gregor Mendel (1822–1884) was an Augustinian friar (Silvertown, 2009). Even Albert Einstein (1879–1955) was working as a patent examiner when he published ground-breaking papers on the photoelectric effect, Brownian motion, and special relativity (Denis, 1996).

The term “citizen science” has taken on several different meanings since it was coined by Irwin (1995) and Bonney in the

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1990s (Riesch and Potter, 2014). For the purposes of this article, we define citizen science as a range of collaborative activities between professional scientists and engaged laypeople (citizens) in the conduct of research. In citizen science, laypeople are actively involved in one or more aspects of the research process, including research design, data collection, subject recruitment, data analysis and interpretation, or publication (Riesch and Potter, 2014). Laypeople have an opportunity not only to assist with scientific research, but also to learn more about scientific concepts, methods, theories, traditions, and values. Scientists can learn much from their citizen partners including invaluable local knowledge and enhanced capability to effectively perform research. We use a broad definition of the concept of citizen science in order to include a variety of collaborations between citizens and scientists. Laypeople are distinguished from scientists in that they are not professional researchers, though they may receive some training or expertise in scientific methods and concepts and they may receive some payment for their work. Being paid to collect data does not necessarily make a layperson into a professional scientist, since being a professional involves much more than receiving money for one's work and includes specialized education and training (Shamoo and Resnik, 2015). Laypeople participating in research as human subjects are not citizen scientists, unless they are also involved in scientific activities, such as data collection, etc.

Citizen science encompasses several different types of collaborations between professional scientists and laypeople (Silvertown, 2009). In community mapping and monitoring (CMM), laypeople assist scientists with data collection in the field. For example, for 115 years the Audubon Society has sponsored the Christmas Bird Count from mid-December to early January each year. Thousands of laypeople take part in this annual event in which participants record data concerning the number of birds they observe from different species. The British Trust for Ornithology's Garden BirdWatch (GBW) employs thousands of birdwatchers in an annual survey of birds and other garden wildlife. In the last 20 years, citizens have contributed 7.3 million hours of labor and submitted 100 million observations to the GBW (British Trust for Ornithology, 2015). The Open Air Laboratories Network (OPAL) sponsors several science activities that make use of citizens, including projects that involve collecting data on lichen and fungus growth on Sycamore trees, surveying invertebrate populations in ponds and lakes, and making meteorological measurements (Davies et al., 2011). Citizen bird watches and other CMM projects provide scientists with important data concerning avian biodiversity and changes in populations, which can inform public policy (Battersby and Greenwood, 2004; Ellis and Waterton, 2005; Audubon Society, 2014). Though most CMM projects collect general survey data with no specific hypothesis in mind, some are hypothesis-driven. For example, the Evolution MegaLab (2014) involves citizens in collecting data used to test hypotheses concerning the evolution of banded snails in response to predation and changes in climate (*Cepaea nemoralis* and *Cepaea hortensis*).

Community-based participatory research (CBPR), often used for environmental health investigations, is an approach in which scientists work closely with the local community in developing and implementing research likely to be of concern to members of the community. In CBPR, citizens provide scientists with advice concerning the design of research projects, potentially including the research goals, design of questionnaires and survey instruments, subject recruitment, informed consent, and data interpretation and dissemination (O'Fallon and Deary, 2002). CBPR projects often include advisory boards composed of citizens from different constituencies in the community. For example, the GuLF STUDY (Gulf Long-Term Follow-Up Study) is a CBPR project conducted by the National Institute of Environmental Health

Sciences that aims to follow the long-term health of approximately 33,000 workers involved in cleaning up the 2010 Deepwater Horizon oil spill (GuLF STUDY, 2014). The GuLF STUDY includes a community advisory board composed of representatives from local health departments, businesses, cultural and religious organizations, and groups representing workers involved in the cleanup (GuLF STUDY, 2014).

Interest group research (IGR) is an approach in which citizen groups with a particular social, political, or environmental agenda partner with scientists to conduct research. The interest group sponsors the research and scientists develop and implement studies, usually without the help of laypeople. Citizen involvement typically comes at the level of raising funds and setting the research agenda. For example, the Environmental Working Group (2014) is a non-profit organization that sponsors research on environmental and public health issues, such as consumer product and food safety, farming practices, energy, industrial chemicals, and water quality. Public Citizen (2014) sponsors research on topics such as climate and energy, public health and safety, government reform, and access to medications. Both groups also include public relations and lobbying branches that advocate for legislation and policy related to their interests. Interest groups, with the help of scientists, may also collaboratively collect, analyze, and report data related to particular issues or concerns. For example, the Clean Air Coalition of Western New York (2014) has collected data on a factory that was releasing hazardous pollutants and the Louisiana Bucket Brigade (2014) has monitored petrochemical pollution.

3. Benefits of citizen science

Citizen science offers important benefits to researchers and the public. First, citizen participation in research can provide a valuable resource for scientists (Cohn, 2008; Stilgoe, 2009; Silvertown, 2009). Many citizen science projects require a considerable expenditure of time, effort, and labor. For example, the Christmas Bird Count uses data collected from tens of thousands of citizen volunteers. Scientists would not be able to conduct such a large-scale project without aid from the public. Enlisting the help of citizens in the data collection process can also free up scientists to conduct other activities, such as data analysis and interpretation. In this era of decreased public support for research, such "free labor" by engaged citizens is increasingly vital for success. Citizens can also provide valuable advice for conducting scientific research which is of direct concern to the local community. CBPR projects have benefited from active public participation at various stages, from research design and subject recruitment to data interpretation and dissemination (Corburn, 2005; Savage et al., 2006; GuLF STUDY, 2014). Public involvement in the development and implementation of community-based studies can help to ensure that research addresses important community needs and takes into account local contextual factors, such as culture, language, and racial/ethnic concerns (O'Fallon and Deary, 2002).

A second benefit of citizen science is that it serves as a vehicle for public engagement, education, and outreach (Bonney et al., 2009; Dickinson et al., 2012). Laypeople who participate in research projects can gain a better understanding of scientific concepts, methods, traditions, and values (Cronje et al., 2011; Riesch and Potter, 2014). Citizen science initiatives can also enhance people's appreciation for nature and for their local environment (Haywood, 2014). Enhancing the public's understanding of science can also increase the public's support for research and helps promote effective policy decisions based on sound, relevant science (Resnik, 2009, 2011). Finally, public participation in research can empower citizens, increase their

self-efficacy, and develop the social capital of a community (Corburn, 2005; Danielsen et al., 2005).

A third benefit of citizen science is that it can democratize the research process by giving laypeople a stake in the scientific issues of concern to them and their families. Citizen science gives laypeople some input into the scientific process and control over its direction. Instead of feeling alienated from science, laypeople may view themselves as part of the process of discovery. They may identify with scientific research because it addresses their interests (Riesch and Potter, 2014). For example, someone who is concerned about water quality may volunteer to help scientists take water samples in order to contribute to research that he views as important (Rosen, 2013). Likewise, a bird-watcher may participate in a bird counting project to help protect wildlife. Citizens can also influence research projects so that they are more responsive to the needs of disadvantaged or marginalized groups (Epstein, 1998; Corburn, 2005; Ottinger, 2010).

4. Ethical issues

Although citizen science benefits scientists and society, it raises ethical issues that need to be addressed before and throughout the course of scientific investigation (Riesch and Potter, 2014).

4.1. Data quality and integrity

The first issue is that the data collected by citizens may not meet scientific standards (Riesch and Potter, 2014). Problems with the quality or integrity of the data could undermine the validity of a citizen science project (see Box 1). Although difficulties with data quality can occur in any type of research (Shamoo and Resnik, 2015), citizen science projects may have more issues with data quality because citizens probably have not had training in scientific data management or research integrity, and therefore may not understand how to collect, record, or manage data properly. They could make systematic errors that adversely impact the quality of the data (Dickinson et al., 2010; Wiggins et al., 2011). Worse yet, they might even fabricate or falsify data in an attempt to sway particular outcomes or actions or meet deadlines. Lay people may also petition to use techniques for data collection or analysis that have some merits (e.g. because they are inexpensive or more likely to identify potential hazards) but which are somewhat less reliable than other techniques and therefore not preferred by the scientific community (Ottinger, 2010).

There are several strategies scientists can use to address this issue. Before data collection begins, scientists can provide citizens with appropriate training on how to make observations, use scientific instruments (if used), and record data and manage research records. They can instruct citizens on how to keep records that are thorough, complete, accurate, well-organized, and backed-up (Schreier et al., 2006; Crall et al., 2011). They can also provide citizens with some basic education in the responsible conduct of research. While research is ongoing, scientists can review and audit the data collected by citizens to determine whether there are any anomalies or other unusual findings that indicate possible problems with data collection that need to be addressed (Dickinson et al., 2010, see Box 1). They can also ask citizens questions about how they are collecting, recording, and managing data to make sure that they are following appropriate guidelines, and they can ask citizens for additional documentation to support their data, if needed (Dickinson et al., 2010). When research is completed, scientists can review the data again to ensure that it meets scientific standards. They may need to discard or correct data that they believe have been collected improperly (Riesch and Potter, 2014). In some cases, scientists may find it appropriate to reconsider accepted standards for data collection or analysis in

Box 1. Data quality and integrity

In 2008–2009, Project FeederWatch, a survey of birds that visit feeders and backyards in North America, received 1,342,633 observations from volunteers. Biologists who reviewed the data flagged 378 reports (0.01%) as unexpected and requested supporting documentation from citizen volunteers. They received 291 responses (77%) to their request. 158 of these responses (54%) confirmed the observations recorded in the databases, 45 (15%) resulted in corrections in the database, and 88 (30%) provided too little evidence to confirm the report (Dickinson et al., 2010).

Ottinger (2010) describes efforts by African-American residents in Norco, Louisiana, to perform air-monitoring studies during the late 1990s in response to pollution from a nearby Shell Chemical plant. To collect air samples, the citizens used inexpensive, easy-to-use devices colloquially called “buckets,” whereas the Louisiana Department of Environmental Quality used more sophisticated “Summa canisters.” Many regulators expressed skepticism about whether the buckets provided sufficiently accurate data, but Ottinger (2010) reports that these concerns were partially alleviated because the air from the buckets was analyzed using the same standardized analytical technique used by regulators and industry. Another concern about the buckets was that they were used to collect short-term air samples, whereas state regulatory standards were based on average pollution levels over longer periods of time.

Crall et al. (2011) tested the ability of lay-volunteers compared to professional scientists to correctly identify invasive plant species, map their abundance, and estimate their distributions. Volunteers and professionals (professors, graduate students, and land managers) received training on plant identification and the research methods used in the protocol. The study found that professionals more accurately identified species as compared to volunteers (88% vs. 72%). Volunteers had a false negative rate (species identified when not present) for species identification of 28% as compared to 12% for professionals, and a false positive rate (species identified when not present) of 1% as compared to less than 1% for professionals. Volunteers’ ability to identify species correctly was positively associated with their self-reported comfort level at identifying species (Crall et al., 2011).

response to legitimate citizen concerns about the potential for conventional techniques to underestimate hazards (Corburn, 2005; Elliott, 2014; Ottinger, 2010).

4.2. Data sharing and intellectual property

Data sharing is a key component of ethical research (Shamoo and Resnik, 2015; Soranno et al., 2015). Data sharing allows others to build on completed work and promotes dialog, debate, and critical feedback. The methods used and data collected by citizen scientists should be available to the public following the conclusion of the study (Riesch and Potter, 2014). Premature release of the data could compromise the validity or integrity of the research and mislead scientists or the public, because investigators may need to review, edit, audit, or analyze data prior to sharing it. Investigators should set clear expectations in this regard by informing citizens about rules and procedures for sharing data, including whom data may be shared with, when, and why (Riesch and Potter, 2014). All data sharing requests should go through the lead investigator. Citizens should be able to keep a copy of the data they collect but should provide the investigator with the original records, if requested. Data that includes confidential information concerning human research subjects should be de-identified prior to sharing (Shamoo and Resnik, 2015).

Data ownership and intellectual property (e.g. patenting) issues may sometimes arise in citizen science because citizens and local communities may assert ownership over the information that has been gathered and expect to have some control over how it is shared and used (Riesch and Potter, 2014). Data ownership and intellectual property issues are especially important to address when citizens are collecting or providing information concerning traditional knowledge of local species, medicine, climate, ecology, and geography, since members of indigenous populations may be wary of outsiders claiming ownership and control over their culturally-embedded knowledge (Shiva, 1999; see Box 2). Scientists who work with citizens should clearly discuss data ownership and other intellectual property issues with citizen volunteers at the beginning of the project, and periodically and as needed, to ensure mutual understanding. They may also find it useful to negotiate agreements that recognize the interests of all stakeholders (Climate and Traditional Knowledge Workgroup, 2014). To facilitate this process, scientists should work with representatives from the local population and anthropologists and attorneys who are familiar with its language, history, traditions, and culture.

Box 2. Data sharing and intellectual property

In 1990, researchers from Arizona State University (ASU) collected 200 blood samples from members of the Havasupai American Indian tribe. Although the consent form stated that the samples and data would be used for research on behavioral and mental illnesses, the researchers had told tribal leaders that the study would focus on the genetics of diabetes. Members of the tribe later learned that the investigators had used the samples and data to study diseases other than diabetes and shared these samples with other researchers. They strongly objected to using the samples and data to study schizophrenia, inbreeding in the tribe, and the tribe's evolutionary and genetic origins. The tribe filed a \$50 million lawsuit against ASU and the investigators, alleging that the use of the samples and data violated the informed consent provided by the participants. In April 2010, ASU and the tribe agreed to settle the lawsuit out of court. As part of the settlement, ASU formally apologized to the tribe, returned the samples, and paid the tribe \$700,000, which was divided among forty-one participants (Mello and Wolf, 2010).

Indian farmers have been using extracts from neem tree seeds (*Azadirachta indica*) as a pesticide for centuries. In the early 1990s, U.S. researchers discovered a way to make a stable, storable neem tree extract. In 1992, the U.S. Patent Office awarded W. R. Grace, a multinational agribusiness corporation, a patent on neem tree extracts (Marden, 1999). In 1994, the European Patent Office (EPO) awarded a patent to the U.S. Department of Agriculture and W. R. Grace for an antifungal agent derived from the neem tree. Soon after the EPO patent was granted, a coalition composed of Indian and European scientists and politicians argued that the patent was not novel, and should therefore be revoked, because Indian farmers had been using the fungicide for many years. Members of the coalition gathered 500,000 signatures for a petition opposed to the patent. In 2000, the EPO agreed to revoke the patent on the grounds that traditional knowledge of the tree's properties undermined the novelty claims on the patent application. Members of the coalition hailed the EPO's decision as an important step to help prevent biopiracy of indigenous knowledge (Hellerer and Jarayaman, 2000). W.R. Grace appealed the ruling but lost its appeal in 2005. U.S. patents on the neem tree are still valid because U.S. patent law does not recognize traditional knowledge as negating novelty claims in patent applications (BBC News, 2005).

4.3. Conflict of interest

Most of the discussion concerning conflict of interest (COI) in science has focused on investigators' funding and financial interests, such as stock ownership, intellectual property, or relationships with private companies (Krimsky, 2003; Resnik, 2007). COIs raise ethical issues for investigators because they have the potential to bias research or undermine the public's trust in science (Elliott and Resnik, 2015; Shamoo and Resnik, 2015). While citizen scientists are not likely to have equity or intellectual property at stake, some may have relationships with private, non-profit, political organizations that sponsor research (see Box 3). For example, a citizen scientist might receive funding from or advise an environmental group, or serve on its board of directors. Some might also be involved in lawsuits (such as litigation against companies for violating environmental laws or creating a public

Box 3. Conflict of interest

The town of Woburn, Massachusetts, was the site of a pioneering effort at community-based participatory research (Brown and Mikkelsen, 1990). Local residents became concerned about a cluster of childhood leukemia cases in the 1970s that they attributed to chemical contamination of the local water supply. After a report from the Centers for Disease Control (CDC) yielded inconclusive results, residents collaborated with researchers at the Harvard University School of Public Health to perform another study. The researchers trained 235 citizen volunteers, who conducted 5010 interviews of Woburn residents to identify childhood disorders and pregnancy complications. The study results, which were released in February 1984, found an association between childhood leukemia and two polluted city wells. The study was criticized by a number of groups, including the CDC and the Environmental Protection Agency (EPA), and one of the prominent concerns was that volunteers with clear political goals were involved with the study. This worry was exacerbated by the fact that several of the Woburn families affected by leukemia initiated a lawsuit in May 1982 against the companies that were suspected to have caused the contamination. To help address these concerns, the researchers performed tests designed to rule out biases associated with the volunteer interviewers (Brown, 1987).

A study of the air quality near oil and gas hydraulic fracturing sites in Arkansas, Colorado, Pennsylvania, and Wyoming published in 2014 used community-based citizen scientists to obtain air samples (Macey et al., 2014). Most of the sites were chosen because members of the community had experienced symptoms, such as headaches, dizziness, or respiratory irritation when breathing air at those sites. Community volunteers received extensive training on procedures for taking and storing air samples and keeping research records, including quality assurance (QA) and quality control (QC) methods. Samples that did not meet QA/QC criteria were excluded from the final dataset. The study found that atmospheric concentrations of eight volatile organic compounds (VOCs), including benzene, formaldehyde, and hydrogen sulfide, exceeded federal guidelines. The journal requires authors and reviewers to disclose competing interests, but it does not define competing interests. The authors of the study disclosed that they had no competing financial interests; however, four of the authors disclosed that they receive funding from non-profit organizations whose mission is to reduce exposures to toxic chemicals. The authors also acknowledged that over a dozen non-profit environmental groups known to be opposed to hydraulic fracturing had made contributions to their research. Some industry-sponsored studies have reached the opposite conclusion concerning the impact of hydraulic fracturing on air quality (Bunch et al., 2014).

nuisance) related to the research they are assisting with (Brown, 1987). COIs can also arise when corporations fund front groups that purport to engage in grassroots lobbying and public-interest research but which are largely crafted by public-relations firms in order to advance corporate interests (Beder, 2000; Shrader-Frechette, 2007).

Non-financial COIs are likely to be a more significant issue than financial COIs in citizen science, because many laypeople who collaborate with researchers are likely to have other personal or political interests at stake. Indeed, one of the reasons why some citizen scientists volunteer to help researchers collect data is to advance their political objectives (Corburn, 2005; Stilgoe, 2009; Riesch and Potter, 2014). For example, citizens and environmental groups opposed to the use of hydraulic fracturing (“fracking”) to extract natural gas from the ground have collected water quality data for the Shale Network, a project funded by the National Science Foundation (NSF) to provide information on the impact of shale gas exploration on water sources (Rosen, 2013). Although the NSF did not fund the project with an explicit political goal in mind, some citizens regard their involvement in data collection as an opportunity to help gather evidence on the harmful effects of fracking. While policies adopted by journals, government agencies, and academic institutions tend to focus on financial COIs, non-financial COIs should also be addressed, because they can impact the objectivity and trustworthiness of research (Shamoo and Resnik, 2015). For example, opponents as well as proponents of hydraulic fracturing might distort or even fabricate data collected for a study in order to promote their political agenda.

A common strategy for dealing with COIs is disclosure (Elliott and Resnik, 2014; Shamoo and Resnik, 2015). Disclosure embodies the virtues of openness and transparency. While disclosure is not a panacea (Elliott, 2008), disclosing COIs related to one's research allows others to evaluate these interests to determine their likely impact (Resnik and Elliott, 2013). Disclosure upfront also avoids the situation in which COIs are discovered after-the-fact, which can lead to suspicion that undermines the trustworthiness of research. In some cases, the impact of one's interests may be negligible; in other cases, it may be substantial. Citizen scientists should disclose their financial and non-financial COIs to their professional-scientist collaborators. Their professional collaborators can then decide how to deal with these disclosures, i.e., whether to share them with appropriate parties, such as academic institutions, funding agencies, or journals. One of the unique issues related to COIs from citizen scientists is that lead investigators on a project may need to deal with hundreds or even thousands of disclosures from volunteers. Dealing with this many disclosures can present challenges for record-keeping and public communications. Since sharing all of this information with journals or other parties is impractical, the best way to deal with this issue may be to disclose political or other interests in aggregate. For example, investigators for the Shale Network could include a statement in papers and other public communications saying that several hundred volunteers involved in data collection have indicated they are strongly opposed to hydraulic fracturing.

Another strategy for responding to COIs in scientific research, including citizen science, is to make data publicly available after publication so that the data analysis and interpretation can be independently evaluated (Michaels, 2008; Soranno et al., 2015). Sometimes COIs are so problematic that the best strategy for dealing with them may be to avoid them altogether (Shamoo and Resnik, 2015). A COI may be problematic because it creates a significant potential for bias that cannot be managed adequately by disclosure alone. For example, government funding agencies usually prohibit peer reviewers from reviewing research proposals submitted by current or (recent) former students or advisors or

colleagues at the same institution (Shamoo and Resnik, 2015). It is conceivable that some COIs in citizen science should be prohibited because they are problematic. For example, if a citizen scientist is a party to a lawsuit against a company accused of violating environmental regulations, then perhaps he or she should not be involved in a research study pertaining to that lawsuit because the potential for bias would be great. Nevertheless, a policy of this sort could harm disadvantaged communities that engage in citizen science to collect evidence that can help them fight environmental injustice in their communities. Since it is difficult to say in the abstract what sorts of conflicts should be prohibited, investigators working with citizens should make these decisions on a case-by-case basis.

4.4. Exploitation

Because citizen scientists are usually providing assistance to researchers without the expectation of financial compensation, there is the potential for exploitation (Riesch and Potter, 2014). Exploitation occurs when an individual or a group takes unfair advantage of another in a transaction or relationship (Wertheimer, 1999). Exploitation involves three elements: (a) lack of consent; (b) harm; and (c) inequity. Not all of these elements need to be present for exploitation to occur. Mutually beneficial exploitation can happen when both parties consent to and benefit from a transaction or relationship but the benefits are distributed inequitably (Wertheimer, 1999). For example, one might claim that some types of pharmaceutical patents based on traditional knowledge are exploitative because they do not provide local populations with a fair share of the benefits of commercialization of that knowledge (Shiva, 1999, see Box 2).

Mutually beneficial exploitation could occur in citizen science if lay-volunteers or local communities do not receive a fair share of the benefits of research. To avoid exploitation, scientists should offer citizens a fair share of the benefits, some of which may include ownership of intellectual property (discussed above), authorship (if appropriate, discussed below), formal recognition (such as a certificate or letter of thanks), education related to the research being conducted, or money. Additionally, volunteers may benefit from the sense of accomplishment they experience from contributing to a project that they regard as valuable, and they may gain greater appreciation for their local environment as well as greater capabilities to take action on behalf of initiatives that they care about (Haywood, 2014; Riesch and Potter, 2014). Scientists should make sure that citizens are comfortable with the work they have been assigned and the expectations for completion (e.g. deadlines, deliverables, etc.). Scientists should not put citizens into unsafe situations or circumstances or unduly burden citizens with work that they feel they may be unable to perform on time, given their other commitments and interests.

Assigning authorship credit on publications is a perennial issue in scientific research (Shamoo and Resnik, 2015). Authorship disputes are common in science because authorship is important for career advancement, priority, and prestige. Granting authorship where it is due is important for allocating scientific credit fairly and for promoting accountability and honesty in research (Shamoo and Resnik, 2015). Scientific journals have developed authorship guidelines to help deal with unethical authorship practices and authorship disputes. Many journals follow the guidelines developed by the *International Committee of Medical Journal Editors* (2015), which recommend that authors make a substantial contribution to (a) research design, (b) data acquisition, or (c) data analysis or interpretation. Authors must also read the submitted manuscript and agree with its conclusions and take responsibility for their part of the research. Contributors who do not meet the criteria for authorship should be listed in an

acknowledgments section at the end of the publication ([International Committee of Medical Journal Editors, 2015](#)).

Though citizen scientists may not require authorship for career advancement, it is still important for professional scientists to give citizens appropriate credit to demonstrate gratitude for their work and as a matter of basic fairness. Citizen scientists should be granted authorship if they have made significant contributions to scientific publications ([Riesch and Potter, 2014](#)). For example, if a citizen volunteer has made a significant contribution to data acquisition or study design, then he or she should be given the opportunity to be named as an author on the paper. In many cases, however, the contributions of citizen scientists will fall below the threshold for authorship. For example, if thousands of volunteers have collected data for a bird count or water sampling project, it is unlikely that any single individual has contributed a high enough percentage of the data to be listed as an author. The most appropriate way to give credit in this situation may be to acknowledge the contributions of the group of volunteers in the paper. Each individual could also receive a copy of the paper and a letter of recognition.

Another concern related to the issue of exploitation is the potential for citizens, scientists, or the wider public to be misled about the nature of citizen involvement in particular research projects. For example, laypeople may volunteer for a research project expecting to have a significant influence on the research design but subsequently find that their role is primarily just to help collect data. Alternatively, researchers reading published work stemming from a citizen science project might think that the scientists in charge of the project were more closely involved in supervising data collection and vetting the resulting data than they really were. Particular citizen-science initiatives may also have significant potential to enhance citizens' self-efficacy, scientific knowledge, and community involvement, but because of poor implementation these benefits may go largely unrealized. Many of these potential problems can be addressed by explicitly stating the roles and responsibilities of citizens at the outset of the research project and in subsequent public communications. It may also be helpful for those initiating citizen science projects to learn more about the potential benefits and challenges of citizen science and to determine what forms of public participation are most appropriate ([Elliott, 2011](#); [Haywood, 2014](#)).

5. Conclusion

Citizen science offers important benefits to science and society. Citizens can help scientists with data collection and provide advice on research design, data interpretation and dissemination, subject recruitment, and informed consent. Citizens can gain a better understanding of scientific concepts and methods and be energized by the prospect of having some control over the process and its direction. Citizen science can also build social capital resulting in more communities which are more informed and effective at addressing issues of concern. However, citizen science also raises ethical issues that should be addressed before projects begin and throughout the course of scientific investigation. Some of these include: (1) data quality and integrity, (2) data sharing and intellectual property, (3) conflicts of interest, and (4) exploitation. To promote ethical research, scientists should develop guidelines for involvement of citizens in research, communicate effectively with participants at the outset of their involvement in research projects, carefully oversee their work, develop appropriate publication practices, take steps to address conflicts of interest, and provide lay-volunteers with education and training on the responsible conduct of research.

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