From The Rightful Place of Science: Citizen Science (D. Cavalier, Ed). A series by the Consortium for Science, Policy, and Outcomes. 2016. Arizona State University Press.

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TWO MEANINGS OF CITIZEN SCIENCE

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An Initial Story of Citizen Science: Democratized Citizen Science

In 1981, AIDS was recognized as an epidemic. In 1985, the HIV antibody test became available to the public. Before there were effective treatments, people without symptoms were learning that they were infected. Seasoned activists in the gay community came to realize that the future of their health required a close working relationship with immunologists, virologists, molecular biologists, epidemiologists, and physicians.

These AIDS activists took a four-pronged strategy to gain credibility and authority. First, by attending conferences, critiquing research papers, and receiving tutoring, activists learned the language of researchers and pharmaceutical companies, and the culture of medical science. Once activists were able to talk about viral assays, reverse transcription, cytokine regulation, and epitope mapping, scientists were receptive to discussions. Second, activists represented people with HIV/AIDS and helped ensure that enough people would enroll in treatment trials and comply with protocols to make the trials scientifically

useful. Third, activists shifted the discourse away from historic abuses of clinical trials tainted by lack of informed consent, moving instead to a conception of experimental treatments as a social good to which everybody should have equal access. They argued for the right of human subjects to assume the risks of experimental therapies and to be informed partners in research. Finally, activists and researchers who believed drugs should be tested in real-world situations with heterogeneous groups changed the protocols for clinical trials.

Ultimately, research improved as treatment activists—members of the lay public—influenced not only the design, conduct, and interpretation of clinical trials, but also the speed with which they were carried out. On the basic premise that AIDS clinical trials were simultaneously research and medical care, the timeframe for testing the safety and efficacy of AIDS drugs was reduced to months, rather than years (adapted from Epstein, 1995).

A Second Story of Citizen Science: Contributory Citizen Science

eBird is a free, online citizen-science project that began in 2002, within which a global network of bird watchers contribute their bird observations to a central database. Well over three million people have engaged in eBird: in 2015 alone, over 1.5 million people engaged with eBird via the website or mobile devices. Over the years, 270,000 participants have submitted data (<10%) and an estimated 1% have submitted 99% of data. The 1% includes the world's best birders as well as less skilled but highly dedicated backyard bird watchers. Since 2006, eBird has grown 40% every year, which makes it one of the fastest growing biodiversity datasets in existence. It has amassed more than 280 million bird observations from almost two million locations, with observations from every country on the planet.

The most frequent use of the eBird database is through handheld apps that people use to figure out where to go birdwatching. In the early years, 2002-2005, with the slogan "Bird-

ing For a Purpose," the project failed to engage a sufficient number of birders. In 2006, project managers changed their strategy, and introduced the tagline "Birding in the 21st Century." The shift in philosophy, as illustrated by the shift in slogans, made the project successful. eBird moved away from appealing to a birder's sense of duty, succeeding instead by helping birders embrace the excitement of getting better at their hobby while simultaneously impacting the future.

The project leaders showed other birders how using eBird makes them better birders. And better birders make better science, because they provide better data. For example, they submit complete checklists. Initially, 75% of submissions to eBird were incomplete checklists; now over 80% are complete. The last two State of the Birds reports (created by a coalition of conservation organizations) relied on eBird data to examine species occurrence, habitat types, and land ownership at a level of detail never achieved before. These reports inform decisions of the U.S. Fish & Wildlife Service and the U.S. Forest Service. The Nature Conservancy uses eBird data to identify which rice farmers in the Central Valley of California they should ask to flood their fields at just the right time for migrating waterfowl. Researchers have written more than 100 peer-reviewed publications using eBird.

The examples above can both be described as "citizen science." The first fits a use of the term introduced in the mid-1990s by British sociologist Alan Irwin (1995) to describe a more democratic, participatory science. The second fits a use of the term that can be traced back to Rick Bonney (1996), then a program director at the Cornell Laboratory of Ornithology, as he tried to describe projects where nonscientists contributed scientific data. Below we explain these two meanings of the phrase citizen science, give a brief account of how they emerged, and explore the sweet spot where the two overlap.

Alan Irwin: The Citizenship of Science

In the late 20th century, historians and sociologists of science increasingly understood that science is embedded in the fabric of society. Consequently, some aspects of science are shaped by major threads in that fabric. For example, institutional forces (such as military and corporate interests) may dominate scientific agendas, instead of the agendas representing the needs and desires of broader publics. One can see this in the way that interests of the pharmaceutical industry drive much research on cures for cancer, even though some public interest groups suggest that we need more research on the environmental causes of cancer. Irwin's work—in a 1995 book titled *Citizen Science*—addressed the varied social pressures shaping science by seeking to reclaim two dimensions of the relationship of citizens with science:

1. Science should address the needs and concerns of citizens, and seek to meet those needs.
2. The process of producing reliable knowledge could be developed and enacted by citizens themselves. People bring into science such things as local contextual knowledge and real-world geographic, political, and moral constraints generated outside of formal scientific institutions.

Though Irwin's idea of a more democratic science has been widely used by scholars in the sociology and politics of science, his use of the term "citizen science" did not itself acquire scholarly cachet. Instead, researchers came to use terms like "activist science" or "public engagement."

Rick Bonney: Contributing Observations to the Scientific Method

The second meaning of citizen science developed in ornithology, when Bonney used it to describe birdwatch-

ers' voluntary contributions of observations across North America. According to Bonney, the term came to him as he stared out the window while writing a grant proposal in 1994 to support collection of those contributions. He used the phrase publicly in a 1996 magazine article, not knowing about Irwin's work. "Citizen science" became widely used at the Cornell Lab of Ornithology; then, as the Lab of Ornithology developed new projects and connected with analogous volunteer efforts by other organizations, the term spread.

In 2014, the Oxford English Dictionary documented that the phrase citizen science was actually used before Irwin and Bonney. In 1989, the National Audubon Society used the term in a way similar to Bonney's use—in their case to describe a program where volunteers collected rain samples, tested the acidity levels, and sent results to Audubon headquarters. The OED defined citizen science as "the collection and analysis of data relating to the natural world by members of the general public, typically as part of a collaborative project with professional scientists."

Thus the earliest use of the term described projects in which a professional entity designed a scientific project and geographically dispersed volunteers contributed observations, usually in ways that aligned with their hobbies and interests. Because of the large number of these projects, the term has most frequently been equated with these top-down projects, with an emphasis on volunteer data contributions. More recently, the term has been used to describe a wide variety of styles in which the public helps carry out any of the steps of the scientific method, whether conceiving of the research questions, designing methods, collecting the data, and/or interpreting results. These other styles include projects that involve more collaboration between scientists and nonscientists in project design and even projects that emerge from community

needs with only advisory input from professional scientists.

The second usage of citizen science gained popularity with the media. By the early 21st century, a community of project developers sought to unite various public engagement practices into a professional field of practice. But in the process, these practitioners recognized drawbacks in the term citizen science. Some felt the word "citizen" excluded those not claiming citizenship in the country where they contributed to projects (such as migrant workers engaged in community-based forestry to sustainably harvest salal, a non-timber forest product used in the floral industry). Others felt the term only pertained to contributory style projects and therefore excluded community-based projects (such as projects monitoring polluted waste emerging from industrial plants). Still others felt the term required the abandonment of other terms with longer histories, such as participatory action research and community-based management.

Although each of these critiques raised issues similar to those addressed in Irwin's 1995 study, few people in the practitioner community knew of that scholarly work. In 2009, an effort was made to identify a broader term, renaming the field as public participation in scientific research, or PPSR (Bonney et al., 2009). But by the middle of the second decade of the 21st century, the term citizen science had become the most popular, with little recognition that the phrase unintentionally co-opted Irwin's original intent.

The History of Citizen Science

Although the term is relatively new, the practice is old. The professionalization of modern scientific practices occurred in the late 19th century. Before scientists were called scientists, they were called men of science and natural phi-

losophers. Before citizen science was called citizen science, the practice of gathering observations by enlisting the help of hundreds, even thousands, of ordinary people was not referred to by any particular term at all. Even relatively recently, when initiated by conservation organizations like the North Carolina Wildlife Resources Commission in 1982, the practice of enlisting the lay public in monitoring beaches and collecting data on turtle nesting was simply termed volunteer monitoring. The practice of what is now frequently called citizen science did not begin with the coining of the term. We can use the term citizen science with historic activities and see that leaders in science in the 18th and 19th century carried out citizen science.

In 1776, Thomas Jefferson made plans for the collection of weather data across the state of Virginia via what would today be called contributory citizen science. Beginning in the late 1840s, U.S. Naval officer Matthew Maury created maps of the seasonal distribution of whales and of ocean wind and currents by aggregating observations reported by thousands of military and merchant vessels. William Whewell, Master of Trinity College, won a Royal medal for work based on almost a million observations of the tides systematically, and synchronously, collected by lay people on both sides of the Atlantic Ocean in 1835. Denison Olmsted, professor at Yale, crowdsourced meteor observations in 1833.

So for more than 200 years, scientists have been crowdsourcing observations. Today citizen science is an umbrella term under which to describe a practice that is occurring in many disciplines in which volunteers collect and/or process data. Many whole fields have long histories of such a practice. For example, the longest-running meteorological records in the United States were collected by volunteers in the National Observers Network, which started in 1880. The longest running ornithological sur-

veys in the United States have been carried out by bird watchers in the Christmas Bird Count since 1900.

Other fields have shorter histories of such practices, with the speed and ubiquity of communication and information technologies assisting in creating new research frontiers. For example, volunteers in exclusively online projects solve three-dimensional puzzles of protein folding, individuals use automated sensors to detect earthquakes, and indigenous people in non-literate communities use smartphones to map important natural resources. Public and scientist collaborations continue to expand using a variety of labels: for example, community-based natural resource management, participatory action research, participatory forestry, and volunteer geographic information. Despite its limitations, citizen science provides a useful, catchall term for all contemporary activities in which the public is involved in the scientific method.

Yet there is still the question of how the "public participation" type of citizen science links with the "democratic action" idea introduced by Irwin. If the term has come to represent a multitude of ways that the public is involved in science, what distinguishes it from Irwin's initial intent? In the practitioner world, citizen science originally referred only to participation in data collection; it then expanded to practices that include the public in other aspects of the scientific method, such as formulating the question and interpreting data. Nonscientists, however, can engage in the production of reliable knowledge (also known as "science") in ways other than contributing data. Publics can pose original questions. They can identify relevant variables and sources of data that professional scientists would miss. They can shape the norms and practices established around the scientific enterprise of validating knowledge. Each of these contributes to a more democratic vision of science embedded in society. While the "participatory" version of citizen science describes

how people can serve as instruments in the scientific method, the "democratic" version shows how people can influence and transform the larger scientific enterprise.

The term is coming full circle. Increasingly, practitioners of the "participatory" citizen science see "democratic" citizen science as their goal. Particularly in projects that involve environmental monitoring and environmental justice, practitioners and participants seek to transform the power dynamics of local, regional, national, and even international communities. They seek to exercise power that challenges the interests of large government, corporate, or even academically-based research communities.

The technical details explored in the subsequent chapters of this book largely relate to crowdsourcing observations by the public (the participatory model). But ultimately, a larger reason for refining citizen science methods is to increase capacity for research agendas to align with public interests. Practitioners of citizen science seek a hybrid of the Bonney/OED and Irwin meanings: essentially, a gold standard for citizen science practice in which people do more than contribute data, and researchers do more than use the data. Together, a new relationship between scientists and the public will be created. Citizen science strives for designs that will achieve what Irwin envisioned with his original use of the term: scientists engaging with people in ways that deeply shape what we know about the world.

A Third Story of Citizen Science: Democratized and Contributory

With a phone call to Marc Edwards, an engineering professor at Virginia Tech in April 2015, LeeAnne Walters, a resident of Flint, Michigan, set in motion the development of the Flint Water Study, a citizen science project to measure lead levels in tap water. Walters was a stay-at-home mom who could not get

state or local officials to respond to her concerns about rusty orange tap water, thinning hair, and skin irritations in her home.

Edwards responded with citizen science. For preliminary data, he taught Walters to take tap water samples that he could test. Even though Edwards found exceedingly high levels of lead in Walters's water, he was initially ignored when he brought the findings to the U.S. Environmental Protection Agency. So Edwards created the Flint Water Study with his students, some funds from the U.S. National Science Foundation, and more funds from an online crowdfunding campaign. Participants in the Flint Water Study received special water vials, collected tap water according to a specific protocol, and mailed the samples for processing at Virginia Tech. Data were publicly available and displayed. Walters created the "Water Warriors" to collect samples and helped them use the data to support their political action.

The results of the project garnered national media attention and broader public pressure, forcing government actions (short-term provisioning of bottled water, testing of blood levels, movement towards long-term solutions) and inspiring community service (e.g., hundreds of union plumbers installed water filters for free). The project that began with data collection became a key element of a national political debate about social power in settings where technical expertise is necessary.

The third story of citizen science illustrates the achievement of "democratic" citizen science through the "contributory" style of citizen science. One way of understanding the relationship between the meanings of "citizen science" explored in this chapter is that the "democratic" definition represents a larger context in which the "contributory" style of citizen science resides. The lowest common denominator to citizen science projects is the collection and/or processing of data. From that focal point, the collaboration between scientists and non-scientists can expand. If the collaboration expands

enough, the resulting new relationship then takes on the vision presented by Irwin, characterized by new perspectives, collaborative action, trust, etc., leading ultimately to societal influence shaping scientific agendas and norms.

Further Reading

Ballard, H. L. & Belsky, J. M. (2010). "Participatory action research and environmental learning: implications for resilient forests and communities." *Environmental Education Research* 16: 611-627.

Bonney, R. (1996). "Citizen Science: A Lab Tradition." *Living Bird* 15(4): 7-15.

Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T. Shirk, J., & Wilderman, C. C. (2009). *Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education CAISE Inquiry Group Reports*. Washington, DC: Center for Advancement of Informal Science Education.

Conde, M. (2014). "Activism mobilizing science." *Ecological Economics* 105: 67-77.

Cooper, C. B., Dickinson, J., Phillips, T., & Bonney, R. (2007). "Citizen Science as a Tool for Conservation in Residential Ecosystems." *Ecology and Society* 12(2): 11. http://www.ecologyandsociety.org/ vol12/iss2/art11

Cornwall, M. L. & Campbell, L. M. (2012). "Co-producing conservation and knowledge: citizen-based sea turtle monitoring in North Carolina, USA." *Social Studies of Science* 42: 101-120.

Epstein, S. (1995). "The construction of lay expertise: AIDS activism and the forging of credibility in the reform of clinical trials." *Science, Technology, & Human Values* 20: 408-437.

Irwin, A. (1995). *Citizen Science: A Study of People, Expertise, and Sustainable Development*. New York, NY: Routledge.

Littman, M., & Suomela, T. (2014). "Crowdsourcing, the great meteor storm of 1833, and the founding of meteor science." *Endeavour* 38(2): 130-138.