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Citizen Science Initiatives: Engaging the Public and Demystifying Science

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The Internet and smart phone technologies have opened up new avenues for collaboration among scientists around the world. These technologies have also expanded citizen science opportunities and public participation in scientific research (PPSR). Here we discuss citizen science, what it is, who does it, and the variety of projects and methods used to increase scientific knowledge and scientific literacy. We describe a number of different types of citizen-science projects. These greatly increase the number of people involved, helping to speed the pace of data analysis and allowing science to advance more rapidly. As a result of the numerous advantages of citizen-science projects, these opportunities are likely to expand in the future and increase the rate of novel discoveries.

INTRODUCTION

Advances in technology have changed how science is conducted. Through the Internet and smart phones, we now have access to a great deal of information that, in the past, would have been inaccessible or would have taken a very long time and great effort to share worldwide. We use the Internet to search for information, to purchase products and reagents, to find employment opportunities, to seek training through webinars and online classes, as well as to socialize and keep up to date with family and friends. This highly accessible communication has also opened new avenues for collaboration among scientists across the globe, and research teams have expanded as a result. In addition, this unprecedented access to information has broadened citizen science opportunities, as well as public participation in scientific research (PPSR). Here, we discuss citizen science, what it is, who does it, and the variety of projects and methods that are used to increase scientific knowledge.

CITIZEN SCIENCE

Citizen science is defined as public participation in scientific research projects, usually by volunteers who collaborate with scientists and researchers to increase scientific knowledge (1, 13). The volunteers who participate in citizen science have varying levels of expertise. They may be children who are exposed to science through school projects, high school students who participate in science clubs, amateur scientists with little formal training, community groups organized around a science interest, educators, or naturalists. The earliest examples of citizen science were networks of local interest groups, such as birders who tracked local populations of birds, allowing migratory bird patterns to be established. In January 2016, the 116th year of The Audubon Society's Christmas Bird Count concluded—the longest running citizen-science project in the United States (www.audubon.org/conservation/science/christmas-bird-count. In this case, volunteers are grouped with at least one professional bird watcher per group to conduct the bird counts, which are done annually. Along with the Audubon Society, The Cornell Lab of Ornithology also hosts a citizen-science website, eBird (http://ebird.org/content/ebird/), where bird watchers can record the presence or absence of species in their region (14). This site is used to compile data from annual events such as The Great Backyard Bird Count (GBBC), which occurs in February. The Cornell Lab of Ornithology used the data from eBird to develop a smart phone app called Merlin Bird ID to aid bird counters in identifying birds in their region. In addition to this site, they also host NestWatch (http://nestwatch.org/), which provides online training to become a certified Nest Watch monitor, allowing the public to find nests, monitor them, and collect data and then report the data online to help track successes and failures of nesting birds. There are now a number of citizen-science projects that include wildlife-monitoring programs, where individuals share photos and observations of species in a particular area and share these online. Several examples of these types of projects are listed in Table 1.

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TABLE 1.
Citizen-science projects that document wildlife and biodiversity.

Program	Website	Description
BioBlitz	www.nationalgeographic.com/explorers/projects/bioblitz/	Find and identify as many species of plants, animals, microbes, fungi, and other organisms as possible in an area over a short period of time. Also known as a biological inventory or biological census. Occurs once a year, usually in a National Park, during a 24-hour period.
Project BudBurst	http://budburst.org/	Document the leafing, flowering, and fruiting of plants to monitor climate change and its impact on plants (6).
BugGuide	www.bugguide.net/node/view/15740	Share photos and observations about insects, spiders, and other related creatures.
Christmas Bird Count	www.audubon.org/conservation/science/christmas-bird-count	Conduct annual bird counts under the direction of at least one professional ornithologist. December event.
DiveBoard	www.diveboard.com/	Provides an online dive log where scuba divers can record their dive locations and marine life encountered to aid divers in selecting a dive site; also available as a smart phone app.
EarthDive	www.earthdive.com/	Recreational scuba divers and snorkelers record sightings of key indicator species in a global dive log to provide information about human-induced pressures in the world's oceans.
FrogWatch USA	https://www.aza.org/frogwatch/	Learn about wetlands in the community and report data on the calls of local frogs and toads. February through August.
Nature's Notebook	https://www.usanpn.org/natures_notebook	Online program for recording observations of plants and animals to generate long-term data sets used for scientific discovery and decision making. Tracking seasonal changes in plants and animals.
NestWatch	http://nestwatch.org/	Train online to become a certified Nest Watch monitor, then find nests, monitor them, collect data, and upload data online to help track successes and failures of nesting birds.
The Great Backyard Bird Count	www.audubon.org/content/about-great-backyard-bird-count	Count birds in your backyard or anywhere in the world during this four-day event, and report these sightings online to provide data on the bird population and the environment that we share.
The Great Nature Project	www.inaturalist.org/projects/national-geographic-great-nature-project	Project to document the Earth's biodiversity, where participants upload photos of organisms and these are identified and recorded.

There are a number of beneficial aspects to citizen-science projects: they showcase the scientific process and highlight the fact that science is all around us; they allow for large amounts of data collection around the world that would be very expensive to generate without the use of volunteers; they also can advance projects more rapidly due to the large number of people that are involved. Through these endeavors, the public learns and becomes more informed about a topic (2).

Sometimes citizen-science projects are designed to allow people to report when a specific event has occurred in their region. For example, honey bees that have been parasitized by the zombie fly, *Apocephalus borealis*, embark on a flight of the living dead. Infected bees abandon their hives and display disoriented zombie-like behavior, including congregating near lights at night, before dying (5). Infected bees, called Zombees, found in your area can be reported through the ZomBee Project (www.zombeewatch.org/); these bees are then tested to confirm whether or not they are infected. In a similar manner, as part of the Wildlife Health Monitoring Network, a website called the Wildlife Health Event Reporter (www.whmn.org/wher/) was established to allow members of the public to report dead or sick wild animals in their area. Monitoring these events can help

detect new emerging diseases and other problems that could affect wildlife, domestic animals, and human populations.

Occasionally, scientists would like to collect samples from multiple sites across the country. This can be very expensive, depending on the number of sites, and often the majority of the cost is for travel to the site where the sample will be collected. Citizen-science projects can allow for samples to be taken from a large geographic area in a short amount of time. One example of this type of project is Project MERCCURI (http://spacemicrobes.org/), which aims to examine the bacterial diversity of microbes on Earth and on the International Space Station. Thousands of citizen scientists were involved in collecting bacterial samples from sports events and sites of historical interest, such as the Liberty Bell. From these samples, a team of scientists selected 48 types of microbes to investigate, and these were sent to the International Space Station (ISS) to better understand how microbes grow in zero gravity. One goal of this project was to engage the public and get people interested in experiments both on the ISS and in microbiology, with the hope of encouraging more people to get involved in significant science. Other projects, intended to characterize human microbes by sequencing the microbial genomes from mouth, skin, or fecal samples, are ongoing (http://ubiome.com/pages/buynow, https://fundrazr.com/campaigns/4Tqx5). In these projects, samples are processed and the data provided to participants for a small fee. These data are also used collectively for a larger study, where they will be analyzed to identify the bacteria species that reside in the gut. Another project involving sample collection requires that citizen scientists send a sample of dirt to scientists who are interested in discovering novel fungi that perhaps can be used for medicinal purposes (http://npdg.ou.edu/citizenscience). The microorganisms in the samples of dirt will be tested to determine whether they possess natural products that can be used for medicinal purposes. The World Water Monitoring Project (www.monitorwater.org/default.aspx), requiring sampling of local bodies of water, is an outreach effort to engage citizens in monitoring their local water quality with a goal of increasing awareness of human activities and their effects on local water resources.

Some scientific research projects generate a large amount of data over relatively short time intervals. For example, projects that involve using video cameras to record animals in their natural environment, or projects where thousands of DNA sequences have been acquired and need to be analyzed. It would take a long time for scientists to evaluate all of this data. Tools are needed for data analysis, and one way to accomplish this is through the use of computer games that motivate participants to play, resulting in high-quality scientific data analysis. A group of tools, Citizen Sort (http://citizensort.org/), allows the public to participate in classifying images as part of several video games that were developed specifically for this purpose. Another group, which has collected thousands of hours of deep sea videos, has developed a game called Digital Fishers (www.oceannetworks.ca/learning/citizen-science/digital-fishers), where participants view video clips and identify ocean animals they see during the course of a 60-second video. In addition to these citizen-science games, a game called Phylo (http://phylo.cs.mcgill.ca/) has been developed to analyze genetic sequences (11). In the game, players align genetic sequences in a similar manner to the game Tetris, where building blocks of similar features are aligned. The results of this puzzle game contribute to genetic disease research by helping to identify where sequences align well from patients with particular genetic diseases and where they do not. A puzzle game called Fold it (http://fold.it/portal/info/science) has also been developed, in this case to predict how proteins fold (3, 4). Since the structure of proteins is key to understanding how they function, this game, by allowing players to evaluate the possible ways that a protein can fold, contributes to the development of novel proteins that could be useful in preventing or curing disease. A game called EyeWire (www.eyewire.org) has also been developed in the field of neuroscience. In this game, players are identifying specific cell types within the known classes of retinal cells to map the connections between neurons in the retina, which will help to determine how vision works (10, 12). In the online gaming environment, EyeWire holds regular competitions and challenges that allow players to compete for bonuses, profile icons, and even neuron naming rights. When converted into a game, data analysis is more fun, and, in the interest of advancing one's character and leveling up, players are motivated to continue to solve challenges. As they do so, they are contributing to important citizen neuroscience. Gaming citizen-science projects have resulted in scientific publications in high-level peer reviewed journals that included Foldit Players or EyeWire Players in the author lists (4, 7–10). This highlights the contribution and significant role that citizen science plays in these scientific research projects.

The learning outcomes associated with PPSR projects generally fall into three main categories: outcomes for research such as scientific findings, outcomes for individual participants in which new knowledge and skills are developed, and outcomes for social-ecological systems that may influence policies, build capacity in the community for decision making, or result in conservation action (1, 13). An online resource called SciStarter (http://scistarter.com) is a database of current and ongoing citizen-science projects where individuals, teachers, and scientists can search current citizen-science projects in which to participate. These projects have a high level of individual participation, the quality of participation is high, and, in the process of participating in these projects, a scientifically literate society is being developed.

One example of such a project is NASA's Soil Moisture Active Passive (SMAP) Satellite Mission. NASA has launched a satellite that monitors soil moisture and water availability. The data collected will be used to improve weather forecasts; detail water, energy, and carbon cycles; monitor droughts; predict floods; and assist with crop productivity.

Participants across the world are collecting and measuring soil samples in real time as the satellite is overhead to help calibrate the accuracy of NASA's satellite mission and to learn more about soil quality in the process. Participants log onto a website to determine when the satellite will be directly overhead at their location so that they can collect soil samples at that time. Next, participants determine the moisture content from their soil samples and upload their data to the GLOBE.gov database. GLOBE provides the ability to view data measured across the world and interact with other participants. During the process of collecting data and determining the soil moisture content, participants are validating satellite data for NASA and learning more about the goals of the scientific research. Using technology, through the website and mobile apps, participants can interact with others involved in the project, evaluate their data, and become part of a collaborative group. This is just one example of a citizen-science project in which public participation in science results in increasing science literacy. This project does not require sophisticated equipment or expensive materials. These types of projects are ideal to provide active learning opportunities for students. Students participating in these types of projects also may use these activities for science fair opportunities, where they present data and practice scientific communication of their results. Through this one citizen-science project, all three learning objectives, generation of scientific findings, individual acquisition of new knowledge and skills, and interest in social-ecological systems, are addressed.

CONCLUSION

Advances in technology have greatly expanded the number of ongoing citizen-science projects. Citizen-science projects enable extensive data collection worldwide. They contribute to sample collection over a wide geographic area without the high cost and time commitment required for scientists to travel to each individual site. More recently, after collecting large amounts of data, games have been developed to encourage citizen science and greatly increase the number of people involved. Citizen participation in these games helps to speed the pace of data analysis and allows science to advance more rapidly. Smart phone apps have been developed to support citizen-science projects, as well as websites for uploading data and communicating with others working on these projects. Due to the numerous advantages that come with citizen-science projects, these opportunities are likely to continue to expand in the future and increase the rate of novel discoveries.

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