CITIZEN SCIENCE

Next Steps for Citizen Science

Strategic investments and coordination are needed for citizen science to reach its full potential.

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Around the globe, thousands of research projects are engaging millions of individuals—many of whom are not trained as scientists—in collecting, categorizing, transcribing, or analyzing scientific data. These projects, known as citizen science, cover a breadth of topics from microbiomes to native bees to water quality to galaxies. Most projects obtain or manage scientific information at scales or resolutions unattainable by individual researchers or research teams, whether enrolling thousands of individuals collecting data across several continents, enlisting small armies of participants in categorizing vast quantities of online data, or organizing small groups of volunteers to tackle local problems.

Despite the wealth of information emerging from citizen science projects, the practice is not universally accepted as a valid method of scientific investigation. Scientific papers presenting volunteer-collected data sometimes have trouble getting reviewed and are often placed in outreach sections of journals or education tracks of scientific meetings. At the same time, opportunities to use citizen science to achieve positive outcomes for science and society are going unrealized. Here, we offer suggestions for strategic thinking by citizen science practitioners and their scientific peers—and for tactical investment by private funders and government agencies—to help the field reach its full potential.

Training for data-gathering. Women from Komo (Republic of the Congo) learning to map in the forest, as part of the Extreme Citizen Science (ExCiteS) Intelligent Maps project.

Transformed by Technology

Although citizen science is sometimes considered a recent phenomenon, amateur scientists have studied the world for most of recorded history (*1*). Much of our current understanding about our natural environment, including the effects of climate change, is derived from data that have been collected, transcribed, or processed by members of the public. During the past two decades, the number of citizen science projects, along with scientific reports and peer-reviewed articles resulting from their data, has expanded tremendously.

Much of this growth results from integration of the Internet into everyday life, which has substantially increased project visibility, functionality, and accessibility. People who are passionate about a subject can quickly locate a relevant citizen science project, follow its instructions, submit data directly to online databases, and join a community of peers. eBird, for example, engages the global birdwatching community to collect more than five million bird observations every month and to submit them to a central database where they can be analyzed to document the abundance and distribution of bird populations.

The Internet also has enabled citizen science projects that can be accomplished only online. Many are data-processing projects for which participants classify or interpret sound files, videos, or pictures, such as the millions of images of galaxies, moon craters, and seafloor organisms that have been categorized by participants in various projects operated through Zooniverse.

Citizen science also has been enhanced by statistical tools and computational techniques that remove many of the barriers to compiling and analyzing complex data sets. Computers and accessible interfaces have made participation possible for groups that previously were not reached or well served by citizen science, such as those with literacy or numeracy skills that are not text based (*2*).

Scientific Impact

Some people question the practice of citizen science citing concerns about data quality. With appropriate protocols, training, and oversight, volunteers can collect data of quality equal to those collected by experts (*3*). For large projects where training volunteers and assessing their skills can be challenging, new statistical and high-performance computing tools have addressed data-quality issues such as sampling bias, detection, measurement error, identification, and spatial clustering (*4*, *5*).

As an illustration of data quality, data from eBird have been used in at least 90 peer-reviewed articles and book chapters covering topics in ornithology, ecology, climate change, and statistical modeling (*6*). Zooniverse projects have yielded more than 50 peer-reviewed articles on topics ranging from galaxies to oceans (*7*). And many environmental protection agencies use volunteer water- and air-quality data to target streams and neighborhoods for protection.

Understanding the scientific impact of citizen science can be challenging because of the spectrum of projects that are referred to

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by that name. As the field matures, we hope that the term "citizen science" will be used to describe projects, regardless of size, that truly do science—that produce reliable data and information usable by anyone, including scientists, policy-makers, and the public, and that are open to the same system of peer-review that applies to conventional science. To ensure that critiques of citizen science efforts are based on merits of the research rather than unfounded assumptions about the practice, project developers must employ sound research or monitoring design, and reviewers should look for evidence of such practices in their appraisals (*8*).

Those who seek to build capacity in the citizen science field can help by developing and improving open-source data management technologies, data analysis tools, professional development opportunities, and project evaluation services similar to those already available in other fields of science. These services would help to address skepticism about data quality. Many guides, tools, and templates are available to support citizen science project planning, testing, maintenance, and evaluation; formal data policies; and data management and quality-control plans (e.g., citizenscience.org, citizensciencealliance.org, and citsci.org).

Social and Environmental Impact

Although citizen science projects should have authentic scientific objectives, they also can realize significant social outcomes. The sea turtle monitoring network Grupo Tortuguero supports a body of hypothesis-driven scientific work, including investigations into turtle diet, distribution, and disease, at sites throughout northwestern Mexico (*9*). This collaboration between biologists, agencies, and communities has helped to establish marine protected areas and sustainable fisheries practices that are sensitive to the well-being of both turtle populations and local livelihoods. The West Oakland Environmental Indicators Project empowered individuals living in a very poor neighborhood to collect air-quality and health data documenting the degree to which air pollution affects local residents (*10*). And in the Congo, scientists from University College London are leveraging the data-capture capabilities of smartphones to work with nonliterate individuals to document environmental impacts, such as poaching and illegal logging (*2*) (see the photo).

These examples demonstrate how citizen science can provide opportunities for people of many backgrounds and cultures to use science to address community-driven questions. Creating projects to achieve social and scientific objectives requires deliberate design that is attentive to diverse interests, including why and how members of the public would even want to be involved (*11*). Investments in infrastructure and partnerships that help to create more local projects with both science and social components could leverage under-appreciated knowledge sources, including local and traditional knowledge. Such efforts could also inform the questions and issues pursued through citizen science, leading to new research and a stronger science-society relationship.

Organizing to Maximize Impact

The growing number of citizen science projects around the world is inspiring. On the other hand, a lot of new projects are not really "new." Many different projects collect similar data in similar locations, which confuses the pool of potential participants and results in numerous patchy data sets rather than a few large and truly useful ones. One solution to reduce project redundancy is for scientists and project developers to adopt, adapt, or collaborate with already-proven projects and to fit them to their area or topic of interest. This approach also reduces the expense of design, testing, and implementation when a project is started "from scratch." eBird, for example, has developed "portals" that allow partners to customize the program for specific regions or data-collection processes, while still channeling all program data into one accessible repository.

Project developers could also look for opportunities to gather truly important information in ways that are currently going unrealized. For example, citizen science could play a stronger role when natural or human-caused disasters or other unique data-collection opportunities occur. In 2009, the Jamaican Water Resource Authority required data on water levels from remote sites that could not be monitored readily by automatic equipment. The authority enlisted and trained volunteers to read river gauges at assigned locations, gathering data needed to implement protective measures before floods (*12*). As another example, the Famine Early Warnings Systems Network enlists local monitors to report data, such as rainfall and staple food prices, around the world for use in ensuring food security (*13*). Many existing citizen science projects could be enhanced by preparing protocols and volunteer infrastructure to enable scientifically sound data collection during and after recurring disaster situations (e.g., oil spills, wildfires, or earthquakes).

To help facilitate development, organization, and innovation of the field, a consortium of individuals and organizations has created an international Citizen Science Association (CSA; www.citizenscienceassociation.org). The group's goals are to promote and support citizen science best practices in such areas as data management, scientific rigor, ethics, and project evaluation. The CSA is also working closely with regional organizations such as the newly formed European Citizen Science Association. Input from a wide range of scientists and educators and investment in the CSA's infrastructure by a variety of funding agencies would meet a critical need.

Going beyond the networking and tool development activities of the CSA, citizen science projects could be coordinated around the world to synthesize and analyze their diverse data sets to better understand significant scientific and socially relevant issues such as climate change. Most citizen science projects work independently, and many citizen science data sets containing a wealth of information are unknown or unavailable to decision-makers. The process of making these data accessible and usable as a tool for meeting some of science and society's grand challenges would be facilitated by organizing around citizen science centers.

Centers for citizen science could create, organize, and synthesize centralized repositories of volunteer-collected data on topics such as water quality, phenology, biodiversity, astronomy, precipitation, and human health. Centers also could help to coordinate questions being asked of citizen science data, methods of answering those questions, and techniques for achieving educational and community-development goals for participants. As such, centers for citizen science would be excellent strategic investments for both private and government foundations.

References and Notes

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10.1126/science.1251554