KOSMOS

The Journal for Global Citizens Creating the New Civilization

CUTTING EDGE LAW, JUSTICE, POWER AND PEACE

PHOTO TAO | FRONTIER OF SCIENCE AND LIFE
TOWARD A COMMON THEORY OF VALUE
21st CENTURY COLLECTIVE SPIRITUALITY
NEW PARADIGM FOR DEVELOPMENT AND GOVERNANCE

fall | winter 2013
$10 US | $11 Canada

The Rise of Citizen Science

by Kathleen D. Toerpe

Imagine yourself discovering another Earth. Or identifying an unknown underwater species. Helping the blind to see. Finding a cure for cancer. Proving the existence of extraterrestrial intelligent life. Such visions motivate hundreds of thousands of ordinary people—of all ages, from around the world and all walks of life—to participate in the phenomenon known as citizen science.

Also called crowd-sourced science—or, more formally, public participation in scientific research—citizen science is "the systematic collection and analysis of data; development of technology; testing of natural phenomena; and the dissemination of these activities by researchers on a primarily avocational basis," according to OpenScientist.org. It has evolved from hobby to serious science and is on its way to becoming the favored twenty-first-century model for conducting large-scale scientific research.

First and foremost, citizen science answers the scientific community's need for more researchers. Academic scientists get an army of motivated and dedicated volunteers who are trained in basic data identification, collection, interpretation and analysis. Historically, this data collection has been local and done in person, as in the popular Audubon Society's annual Christmas Bird Count or the highly successful Wells Cook study of seasonal bird migrations—a 50-year project that yielded an impressive six million individual records dating back to the 1880s.

Backyard bird studies are still a core interest of many citizen scientists, and Cornell University's Ornithology Lab has been a leader in shaping modern citizen science proposal, training, reporting and evaluation protocols. However, contemporary projects are decidedly more digital.

SETI@home, one of the first digital citizen science projects, taps into individual users' computer down time to run data searching for radio signals of extraterrestrial communications. This type of 'distributed computing' has largely been replaced by more interactive projects.

Tapping into the Science Crowd

The entire citizen science movement has taken on a rather entrepreneurial feel, with the focus on science as crowd-centered and open-sourced. A university or academic institute, frequently in collaboration with a hosting platform that serves as a gateway to individual projects, sponsors most of the citizen science research programs. Yale University's partnership with the Zooniverse platform is one of the major models here: Zooniverse handles login, authentication, project promotion and visitor tracking for Yale's Planet Hunters. Many of today's most popular projects are conducted start-to-finish online, with volunteers acting as gamers who 'win' by finding patterns hidden in the data sets. These massive amounts of aggregate raw data are the product of data-generator behemoths like NASA's Kepler Mission, the Sloan Digital Sky Survey and University of California at Santa Cruz's Genome Browser.

Locale-based projects might involve research at a local lake or wildlife sanctuary, one's workplace, backyard or even one's own home. These projects are more heterogeneous and closed-ended, while mass online research projects, such as astronomy-based GalaxyZoo, SETI Live, and Planet Hunters, and biological projects, such as Foldit and Phylo, are ongoing with an increasingly standard and predictable format. In those projects, volunteers are offered a short tutorial and then shown a series of data sets to evaluate.

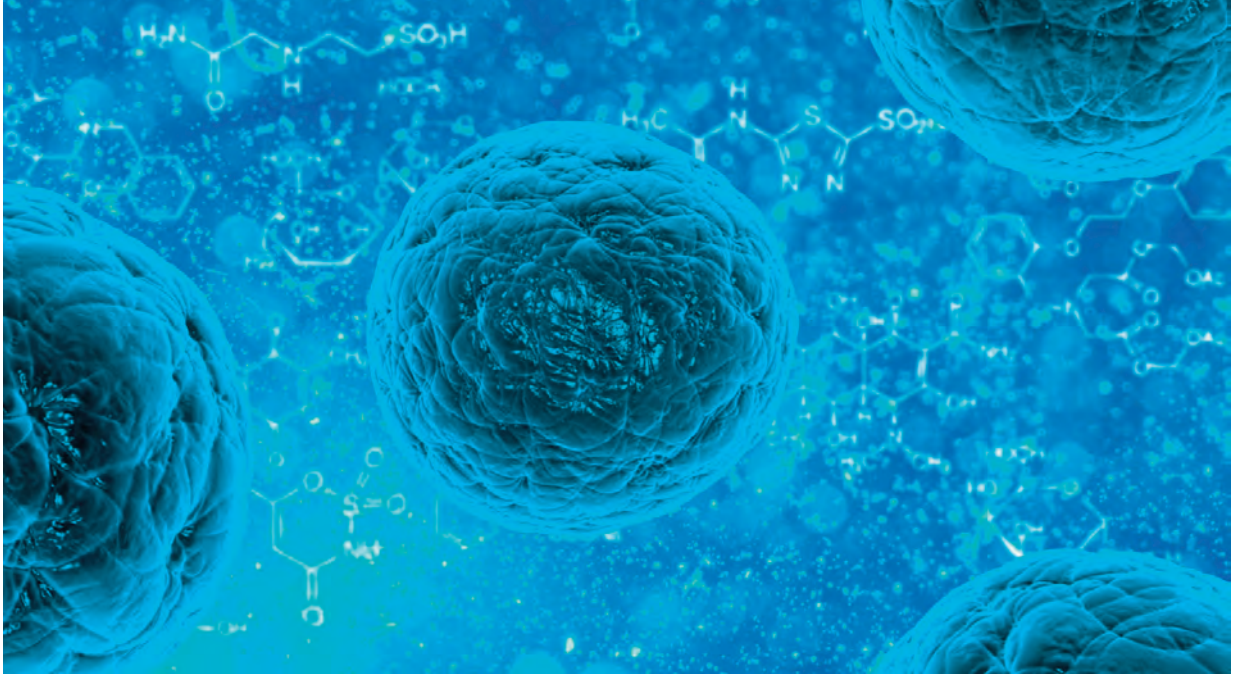
It seems we humans are uniquely suited to these tasks. Our brains can discern patterns in raw data sets that are not picked up by computer algorithms, especially novel patterns or multiple, complex ones. A data set might consist of radio frequency signals picked up by SETI Live's Allen Telescope Array, searching for signs of extraterrestrial life, or of variations in starlight, recorded by the Kepler telescope on Planet Hunters, that are produced when an extrasolar planet, or exoplanet, passes in front of its star. Volunteers tag the pattern or anomaly; it is then farmed out to other volunteers for verification and comment, with academic scientists reviewing and interpreting the final results. Collaboration is facilitated through online forums in which participants report unusual findings and speculate on their significance.

Adding elements of gaming to the projects, such as tokens, awards and points, reinforces motivation, as does recognizing individual effort both on the project websites and in the formal papers that announce the discoveries to the academic community for peer review.

But this is all more than fun and games. For research scientists, who are increasingly long on data and research agenda but short on grant funding and paid degreed assistants, motivating and utilizing citizen scientists has proven to be both an efficient and pragmatic strategy.

What Citizen Scientists Get from Doing Science

Citizen scientists benefit from knowing they've helped advance scientific research and knowledge in a field they are passionate about. Plus, they get to be part of the thrill of discovery. Galaxy Zoo, which uses volunteers to classify the shapes and characteristics of galaxies, surveyed its members in 2010 and



Cell Slider is the first citizen scientist project whose goal is to speed up cancer research by enlisting citizen scientists to analyze real tumor samples, such as that above. Computers can pick up obvious trends but only the human eye can spot subtleties that have led to important serendipitous discoveries. By giving just a few minutes of your time and a few clicks of your mouse, you can help accelerate the research. www.scistarter.com

determined that they were motivated by an interest in astronomy, the personal gratification of doing original research, and a sense of awe at the vastness of space.

The contributions of these citizen scientist volunteers can both make a difference and make headlines, as journalist Michael Belfiore recently found when he profiled Jaime Nomen, a Spanish dental surgeon. Nomen used telescopic cameras at the La Sagra Observatory to identify the now famous asteroid 2012 DA14, which glided to within 17,300 miles of Earth on February 15, 2013. With only a scant 1% of the nearly one million Near Earth Objects identified and tracked, there is an all-too-obvious need for more eyes on the skies.

Closer to Earth, there is a citizen science project for every appetite. The diverse range of projects vying for volunteers is impressive and shows the extent to which the academic community has embraced citizen science. Activities include:

- Documenting the number of ducks shot by hunters
- Measuring levels of industrial pollutants in local water supplies
- Monitoring individual microorganisms inhabiting one's own body
- Recording seismic activity in individual homes and offices
- Classifying unidentified underwater seafloor organisms
- Monitoring local automobile traffic patterns
- Mapping retinal connections to understand the mechanisms behind human sight
- Recording the number of local outdoor ice rinks to corroborate climate data with observable ice freeze

Even such subjective projects as monitoring your baby's laughter or the intelligence of your dog are available.

Late to the party but not to be left out, the humanities are testing the waters of volunteer research assistance. For example, the Ancient Lives project is cataloging and transcribing ancient Egyptian papyri scanned into an online database. Zooniverse is collaborating with the Imperial War Museum in London for a World War I project. Thus, for the citizen scientist, whether teenager or retiree or anywhere in between, citizen science offers a cafeteria of choices and the tantalizing hope of discovery.

Society, too, benefits from this partnership between professional scientists and dedicated amateurs. There is a global demand for increased proficiency in the STEM disciplines (science, technology, engineering and mathematics). Not surprisingly, these are the precise fields that are most active in recruiting citizen scientists. With website links for volunteers to go deeper into the science behind the games, the projects provide hands-on STEM opportunities in tune with academia's advocacy of lifelong learning for everyone.

Culturally, these projects tap into the themes of our everyday life. For instance, Cancer Research UK's Cell Slider project is mapping patterns in archived cancer cells, making the race for the cure everyone's race. Politically, a more scientifically literate electorate might, in democratic countries, result in more vocal support for science initiatives and science-minded candidates at the ballot box.

Overall, from its humble beginnings in bird-watching and environmental activism, citizen science has proven itself to be a win-win-win formula for society, scientists and the volunteers themselves.

Managing Scientific Conduct and Methodology

Significant challenges lay ahead, however, if citizen science is to reach its full potential in academia and extend eventually to the private sector. Concerns about standards of competency, ethics, assessment and oversight have emerged. Locale-based projects especially are difficult to monitor for accuracy and integrity of data. Don't we all think our baby or dog is cuter and smarter than the average? Subjectivity

The Grassroots Mapping project began in 2010 when the Public Laboratory for Open Technology and Science (PLOTS) began documenting the BP oil spill on the American Gulf Coast using balloon mapping—an accessible and low-cost alternative to satellite imaging. Recognizing the power of community satellites to subvert the power dynamics associated with cartography, the project has expanded to nine environmentally compromised sites. GrassrootsMapping.org

in data collection can derail the best of scientific studies and can be difficult to avoid, even for veteran researchers.

These concerns cut across project lines, and the most efficient solutions may be ones that train and certify volunteers in the overall conduct and methodology of science rather than in specific project content. Two-year community and technical colleges could have a prominent role here, creating Citizen Science 101 mini-courses that could teach the scientific method and the ethical practice of scientific inquiry through participation in specific citizen science projects. Coursera, Udacity and edX, emerging leaders in designing massive open online courses (MOOCs), could also contract with gateway sites to provide online certification training that would be simultaneously accessible to tens of thousands of people.

Beyond training scientists, recruitment and retention continue to be problems. Zooniverse's portal has hosted more than 740,000 citizen science visitors from 196 countries since its inaugural in 2007, but half of those volunteers completed only a few data sets before moving on.

That disappointing retention rate from one of the movement's largest stakeholders may mean that visitors are more curious than committed, or that they are merely sampling different projects to find a perfect fit. Not a bad thing, necessarily, but it does mean professional staff needs to focus much of their time on attracting and retaining volunteers, instead of analyzing data results, formulating conclusions and disseminating research for review.

Interestingly, ornithology's citizen scientists are a committed lot; volunteers in the Breeding Bird Survey averaged eight years of involvement, with 10% still active after 25 years. This likely reflects the more established nature of these projects, the central role of organizations like the Audubon Society, and ornithology's long-time success in attracting backyard bird-watchers. If that is the case, then the retention numbers in other projects may stabilize after visitors each find their niche, settle down, get to work (or start playing!) and as the overall movement matures.

Recruiting and retention, however, would be easier if project designers had a firmer understanding of the average, or even ideal, citizen scientist to attract. Preliminary—and admittedly incomplete and anecdotal—demographic profiling shows citizen scientists to be predominantly middle income and having completed some college. Excluding students who complete citizen science projects as part of classroom assignments, a significant number of volunteers are middle-aged or older, with college degrees in fields unrelated to the projects they are involved in. In the United States, the demographic bubble of baby-boom retirees, many now active as citizen scientists, will continue to pad the numbers, but as this cohort thins, participants may be harder to find. The gaming platform of newer projects may help attract younger participants.

Compounding the problem is the fact that some citizen scientists volunteer on multiple projects concurrently, so a marked reduction in total participants will have a ripple effect across multiple projects. And, of course, since most projects are accessed and reported online—and many completely conducted online—on-demand computer access, basic Internet savvy, and high-speed availability are prerequisites. This effectively shrinks the number of potential volunteers from lower socioeconomic strata, whose work commitments may also leave limited free time.

Still left out of the picture are interested recruits from developing countries where limitations in high-speed access may make online projects difficult—not to mention more underlying social and economic impediments. While the latter challenge is beyond the reach of citizen science, current experiments in creating mobile phone app-based projects may increase access in countries with established cellular networks.

The increasing complexity of the research projects themselves poses its own challenges. Phylo, which has volunteers look for patterns in human gene sequencing, requires more than the cursory background information provided, since terms like 'heuristic' are not part of most people's everyday vocabulary. While MOOC providers can provide basic instruction in scientific methodology, training specific to each project will still be required.

As the movement gropes its way to consolidation, expect to see more projects come under the banner of fewer gateway providers who provide simplified authentication and login protocols, upgraded user interfaces and standardized online reporting forms. This will streamline administrative functions and provide a seamless 'entry to exit' experience for volunteers. This, in itself, may help boost retention numbers.

Photography | Britts Ricker

The New Collaborative Relationship

The most vexing challenge facing citizen science, however, may be forging a new model of collaboration between scientists and volunteers. At what point do highly trained amateurs become dissatisfied with tallying and collecting data or discerning patterns in data sets and demand a more vocal role in project creation, administration, funding and even final published output?

The Public Laboratory for Open Technology and Science (PLOTS) is already creating open source 'communities of shared interest' in which participants can create their own local environmental projects, *sans* scientists. CitSci also encourages individuals to create their own projects or to join the projects designed by other citizen scientists. And at what point are degreed scientists reduced to caretakers, displaced by people who, to be honest, are still comparative amateurs? Is there a pushback scenario to be avoided?

One solution is to invite citizen scientists into the inner circle. Historically, citizen science projects have been informally classed according to the objects, subjects or locales studied. Projects were critter-based, environment-based, interaction-based, document-based or space-based, depending on focus.

The Center for the Advancement of Informal Science Education (CAISE) has suggested an alternate ranking based on the depth of scientist-volunteer collaboration:

• *Contributory* projects limit citizen scientists to more passive roles in data collection and identification. This represents the majority of available projects today.

• *Collaborative* and *co-created* projects, on the other hand, allow for increasingly autonomous roles for volunteers to define hypotheses, set research protocols, interpret findings and disseminate conclusions.

This is what CitSci is doing. This is where passive citizen science becomes Citizen Science 2.0. Remember Jaime Nomen, the dentist-turned-astronomer who discovered asteroid 2012 DA14? He is a team leader at La Sagra Observatory, writing and receiving grant money from The Planetary Society for upgraded equipment, and now spends more time hunting asteroids than pulling teeth.

So while collaborative and co-created projects may require more up-front preparation, training and oversight, the payoff to citizen, scientist and society is tangible and lasting.

What's Ahead for Citizen Science

Future opportunities await citizen science as the private sphere—e.g., pharmaceuticals, agribusiness, information technology and energy industries—taps into public concerns over shortages of resources, health and privacy. The challenge will be whether for-profit corporations can inspire volunteers to donate the time and effort required to launch and sustain projects that immediately benefit shareholders rather than society at large. Private corporations will likely take a more proactive role in providing the standardized interfaces, reporting protocols and project design templates currently lacking.

Moving forward, expect citizen scientists to openly advocate for their positions on science and technology issues, as individuals or through coordinated political action. Signs abound that citizen science is here to stay. The inaugural Public Participation in Scientific Research academic conference was held in August 2012, and the movement has debuted an online journal, the *Citizen Science Quarterly*.

These are important benchmarks of institutional legitimacy. Citizen scientists have earned a seat at the table and will want a voice as their research is translated into public policy, integrating the roles of researcher, beneficiary and taxpayer.

The ultimate thrill may still await. The United States Rocket Academy, a private space enterprise that has purchased ten suborbital flights from XCOR Aerospace, has founded 'Citizens in Space.' It is recruiting citizen scientists to create their own research experiments, or payloads, to be conducted in space. Better yet, they will be training ten citizen astronauts to conduct those payloads.

From citizen to scientist to astronaut, all from the humble beginnings of backyard bird-watching! Citizen science has proven that there is power in numbers and in commitment. If two heads are better than one, and four heads are better than two, then the exploding phenomenon of citizen science has shown that hundreds of thousands are by far the best yet. And, who knows? You may even be the first to find ET!

Selected Resources for Citizen Scientists

WEB. Center for Advancement of Informal Science Education, www.caise.insci.org; Cellslider, www.cellslider.net; CitizenSci, www.citizensci.com; Citizen Science Central, The Cornell Lab of Ornithology, Cornell University, www.citizenscience.org; *Citizen Science Quarterly*, www.citizensciencequarterly.com; CitSci, www.citsci.org; Foldit, www.fold.it/portal; Galaxy Zoo, www.galaxyzoo.org; Open Scientist, www.openscientist.org; Phylo, www.phylo.cs.mcgill.ca; Planet Hunters, www.planethunters.org; Public Laboratory for Open Technology and Science, www.publiclaboratory.org/home; SciStarter, www.scistarter.com; SETILive, www.setilive.org; United States Rocket Academy, Citizens in Space, www.citizensinspace.org; Zooniverse, www.zooniverse.org.

BOOKS. *Citizen Science: Public Participation in Environmental Research,* edited by Rick Bonney and Janis L. Dickinson (Comstock Publishing Associates/Cornell University Press, 2012); *Reinventing Discovery: The New Era of Networked Science* by Michael Nielsen (Princeton University Press, 2011).

Note: This article was presented in July 2013 at World Future 2013: Exploring the Next Horizon, a conference of the World Future Society and was published in the July-August 2013 edition of the society's publication, *The Futurist*. Some minor edits have been made by *Kosmos*.

***Kathleen Toerpe, PhD** is a social and cultural historian who researches the human dimension of outer space through an emerging field called astrosociology. She is the Deputy CEO for Public Outreach and Education with the Astrosociology Research Institute, volunteers as a NASA/JPL Solar System Ambassador and is active with the 100 Year Starship effort to lay the groundwork for future interstellar travel. She teaches social sciences at Northeast Wisconsin Technical College. She can be found on Twitter at @ktoerpe.*