Final Workshop Report

NSF Grants
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Design for Citizen Science

PI:
Dr. Kevin Crowston
348 Hinds Hall
Syracuse, NY 13244
crowston@syr.edu

Compiled by:
Andrea Wiggins
337 Hinds Hall
Syracuse, NY 13244
awiggins@syr.edu

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Executive Summary

Citizen science research projects involve "organized research in which members of the public engage in the processes of scientific investigations: asking questions, collecting data, and/or interpreting results," (from Citizen Science Central `http://www.citizenscience.org`.) While there are many successful variations on these participatory science projects, the dominant forms involve participants in collecting observational data or completing analysis or processing tasks that are best accomplished by humans rather than machines. The Internet and related technologies now permit greater levels of public participation in scientific research than was previously imaginable, leading to fast-paced growth of such projects and the emergence of new issues related to increasing scope and scale.

From May 24–27, 2011, a workshop on design for citizen science brought together a diverse group of citizen science practitioners from academia, museums, and nonprofit organizations. A variety of scientific domains were represented, including several strands of research in ecology along with paleontology, climatology, and water quality. It also included experts in social computing, such as computer scientists who focus on online communities, human computation, and design for participation. The workshop goals included promoting networking among practitioners and generating insight into the design considerations relevant to citizen science, both for best practices and supporting technologies.

The workshop discussions brought up a variety of practical and research questions that have yet to be addressed. Many of these questions relate to the interactions between motivation and rewards for participation. The need to build contributor confidence was identified across multiple discussions as a barrier to more fully engaging the public in research. A related need for more development of scaffolded or progressive participation opportunities was also singled out several times in cross-cutting discussions. Participation design is sufficiently well established for some types of citizen science that advances in the complexity of overall project design, e.g. including multiple levels of participation, may yield beneficial outcomes.

Other discussions highlighted the citizen science practitioner community's needs for simple, easy to use tools that support effective data management, due in part to the expectations for feedback to contributors and visibility of contributions as a potential motivation for continued engagement. As data management needs change throughout the life of a project, so too do the issues related to project growth, participant retention, and effective project planning. Several points of advice were generated for new projects and growing projects, many of which focus on relationship development and management, and the necessity of maintaining a "big picture" perspective that involves elements more commonly associated with organizational management. On the whole, the group identified a number of areas for development of citizen science that serve as a reminder that "free" data collection or analysis comes at the cost of volunteer management, a nontrivial undertaking for which many domain researchers are not prepared through formal training or professional experience.

1 Introduction

From May 24–27, 2011, a group of 27 individuals with expertise in the areas of citizen science and computer science assembled for intensive discussions at Minnowbrook Lodge in Blue Mountain Lake Village, NY. The goal of the workshop was to promote networking among practitioners, while generating insight into the current state of, and needs for, information technologies that support citizen science. This workshop was supported by two NSF grants (09-43049 & 11-11107), and served the goals of each by engaging experts in knowledge exchange and focused discussions on topics related to best practices and technologies for citizen science.

There are many variations on the model of participatory science in which the public assists in data collection or data reduction. The workshop opened with brief overview presentations from a panel of project organizers to demonstrate the diversity of the projects represented. A second set of talks on the first day focused on the needs of long-term projects, and led to a brainstorming session for setting an agenda for breakout group discussions that continued into the evening.

The second day began with presentations of the prior day's breakout group discussions, followed by a panel focusing on projects that use mobile technologies in citizen science. The day continued with another round of intensive discussions in the same breakout groups, and ended with a series of presentations from each breakout group, summarizing their findings. Finally, PI Kevin Crowston wrapped up the workshop with a review of the highlights of the prior two days.

Workshop Participants

- Rick Bonney, Cornell Lab of Ornithology
- Mark Chandler, EarthWatch
- Dan Cosley, Cornell University
- Kevin Crowston, Syracuse University
- Andy Farke, Raymond M. Alf Museum of Paleontology
- Mathieu Gerbush, Office of the New Jersey State Climatologist & Rutgers University
- Eric Graham, Center for Embedded Network Sensing, University of California Los Angeles
- Jen Hammock, Smithsonian Institution & Encyclopedia of Life
- Kay Havens, Chicago Botanic Garden
- Sandra Henderson, National Ecological Observatory Network
- Rebecca Jordan, Rutgers University
- Steve Kelling, Cornell Lab of Ornithology
- Robert Kraut, Carnegie Mellon University
- Edith Law, Carnegie Mellon University
- Gretchen LeBuhn, San Francisco State University
- Bill Michener, University of New Mexico & DataONE
- Greg Newman, Natural Resource Ecology Laboratory, Colorado State University
- Karen Oberhauser, University of Minnesota
- Eric Paulos, Carnegie Mellon University
- Tina Phillips, Cornell Lab of Ornithology
- Nathan Prestopnik, Syracuse University
- Gongying Pu, Syracuse University
- Christine Robson, IBM Research Almaden & University of California Berkeley
- Eric Russell, National Geographic Society
- Charlie Schweik, University of Massachusetts Amherst
- Jennifer Shirk, Cornell Lab of Ornithology
- Robert D Stevenson, University of Massachusetts Boston
- Julie Vastine, Alliance for Aquatic Resource Monitoring & Dickinson College
- Andrea Wiggins, Syracuse University
- Xueqing Xuan, Syracuse University
- Shu Zhang, Syracuse University

2 Presentations

Several workshop participants provided descriptions of their projects during three thematic panels. These panels were organized to highlight the diversity of the projects, while also surfacing their commonalities. The three panels included an overview panel, a panel on long-term projects, and another on mobile technologies.

2.1 Overview Panel

We asked four panelists to briefly present their projects to give everyone a taste of the diversity of citizen science projects represented at the meeting. The projects they presented were in the areas of pollinator service, paleontology, water quality, and human computation. Several involve data collection, others focus on analysis, or balance a variety of scientific research tasks.

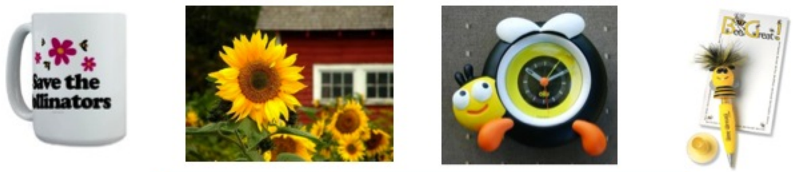
The Great Sunflower Project

Gretchen LeBuhn discussed the Great Sunflower Project (`http://greatsunflower.org`) which has the goal of accelerating the pace of pollinator conservation through citizen science. Additional project goals include general outreach and education.

Participation in this project involves growing flowers and counting the number of bees that visit designated flower species; some participants also take photos. The primary measure is "bees per hour," which is assessed through a simple data collection protocol. In designing the project, she chose sunflowers because other taxa (besides bees) rarely visit them. The project goals include creating a detailed map of pollinator service and identifying areas that don't have enough pollinators. The reason for creating digital records of pollinators visiting sunflowers is to see if native bees are replacing honeybees where they have declined.

The biggest challenge that the Great Sunflower Project has encountered is growth; in the first year, people signed up at an unexpectedly high rate, and continue to do so as the project matures. In response to the overwhelming public interest in the project, she moved all communication online to better accommodate the volume, but even keeping up with email was difficult. Instead, she has promoted the use of online forums, and has found that people take notice and answer others' questions. But with this kind of growth, it is hard to do much to support participants.

Another challenge is figuring out how to better engage participants with a limited budget. About 5–10% of those who register end up submitting data, and they would like to increase the proportion of people who report data while still operating on a small budget to help keep the project sustainable. Opportunities have arisen to expand participation through partnerships with the American Museum of Natural History, DiscoverLife, National Phenology Network, and Cornell. Partnerships have generated mixed success; some have spawned competing programs, while others have allowed people to engage in the project more fully throughout the growing cycle. A major step in determining how to do partnerships well is figuring out how to integrate partners' contributions appropriately. The project's future plans include improving the website, mobile data entry, and identifying and establishing new partnerships. Known challenges with using technology to support the project includes



Bee number	Type of bee	Time
1	Don't know	10:02 am
2	Honey bee	10:07
3	Bumble bee	10:08
4	Green bee	10:15
5	Bumble bee	10:15

Figure 1: LeBuhn showed example data for the Great Sunflower Project.

evidence to date that participants are not very "tech savvy," for example, many older participants have a hard time remembering their passwords, so a lot of direct support has been required to keep the project broadly accessible.

The Open Dinosaur Project

Andy Farke presented an overview of the unique design of The Open Dinosaur Project (`http://opendino.wordpress.com`), which is focused on understanding the evolution of limb anatomy in ornithischian dinosaurs. To answer their questions, they need a database of measurements, so the public are contributing to research through as open a fashion as possible. While the measurements of dinosaur limb bones have already been made, they are published across a range of journals and have not been summarized. The project's focus is on plant-eaters, which are scientifically interesting due to diverse anatomy, and the ODP is focusing on mobility due to interesting evolution of limb anatomy. A secondary project goal is setting a precedent for open science in paleontology, and they have been able to do this because dinosaurs are very popular, and so-called "paleo-junkies" already collect scholarly articles in the thousands.

The project's participants range from high school students to paleontologists to computer scientists; they go through the literature to pick out measurements, enter them into a spreadsheet, and the data are verified by receiving the reference twice and cross-checking. The verified data go into public spreadsheet, and in fact, everything the project does is

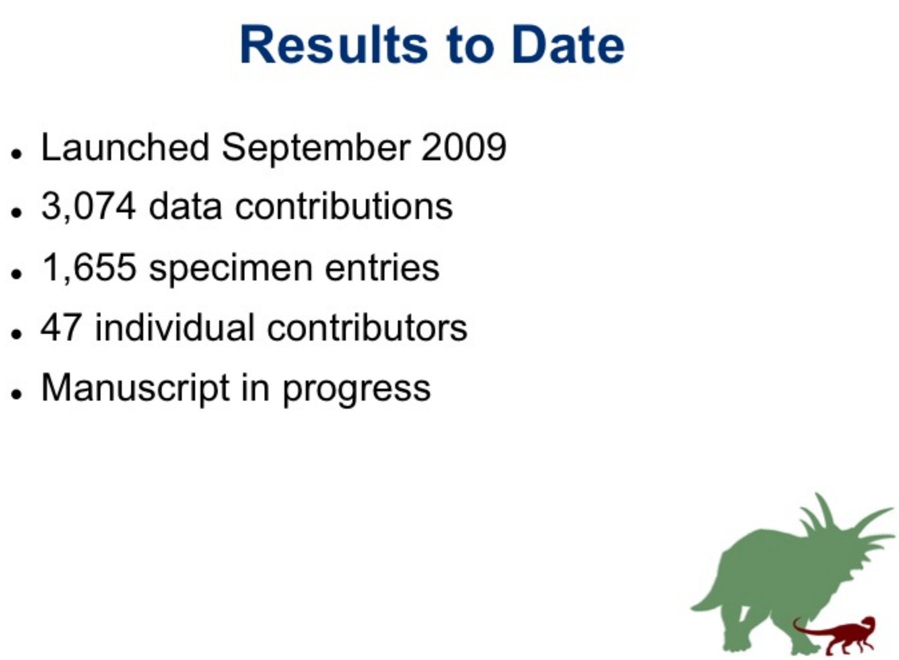


Figure 2: Farke described the Open Dinosaur Project's outcomes to date.

public, with much of the communication occurring on a very active project blog.

The ODP launched in September 2009, and has accumulated over 3,000 contributions for over 1,600 specimens, contributed by 47 participants. The researchers are currently working on a manuscript, and many contributors will be co-authors because they have contributed to the intellectual content. The ODP's biggest challenges are coordinating data submissions with zero budget, and keeping up project momentum after the data collection stage. The project's opportunities have included the high degree of interest from amateur and professional paleontologists, and their future plans include submitting a paper for publication and using the project as a model for other projects in paleontology.

Alliance for Aquatic Resource Monitoring

Julie Vastine represented ALLARM (`http://www.dickinson.edu/about/sustainability/allarm`), which has been working with water quality volunteer monitors, which is the typical term used to refer to participants in citizen science projects that are concerned with water quality. The project is supported by the Pennsylvania State Department of Environmental Protection, with some support from Dickinson College and fundraising from small foundations. Their model of engagement focuses on capacity building through empowering communities with tools to carry out studies by themselves. They build on a rich history of volunteer monitoring in PA, which has more stream miles per land area than any other state, so communities are very concerned with protecting this resource.

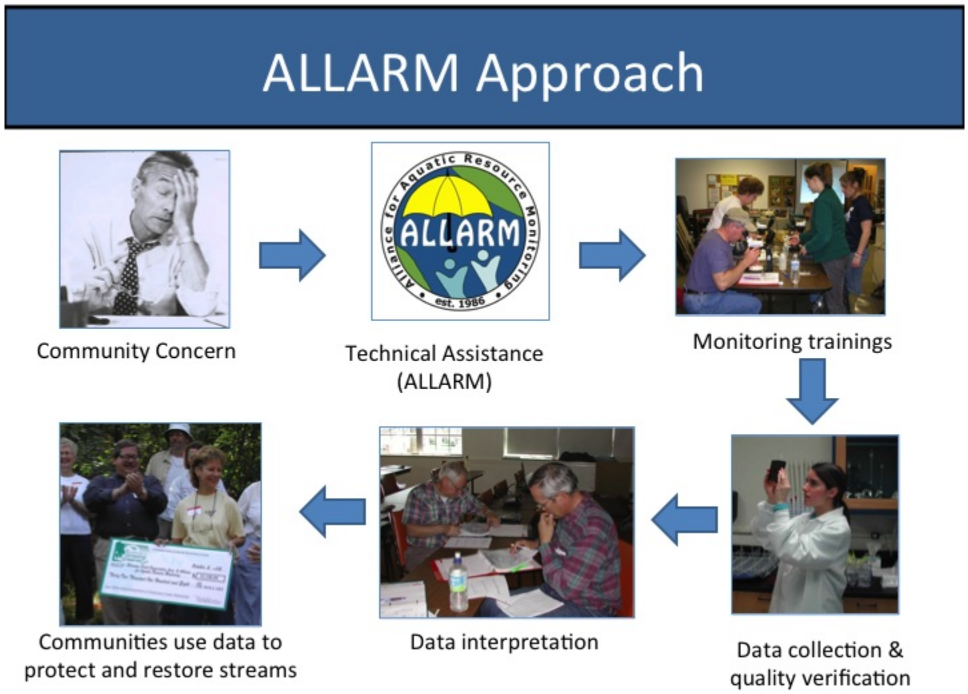


Figure 3: Vastine shared ALLARM's approach to community engagement.

They have worked with several participation models, such as acid rain monitoring to address the scientists' research questions and a traditional model of capacity building and leading people through the scientific process. The research approaches are traditional water quality evaluation techniques, and are fairly technical. They are now working on a community-driven approach based on local questions and concerns, specifically around natural gas drilling. The ALLARM capacity building approach starts with a community concern which often leads to a watershed association. The local community members decide to do monitoring to address their concerns, and contact a technical assistance provider like ALLARM. These organizations help with training and QA/QC, provide training in interpretation, and then communities are able use the data on a local level. Training is provided by the project director and students.

The main drawback of the capacity-building model is that it is very time intensive. As a result, they can only work with 15 groups at a time, and they must be located within a 3-hour drive. Another challenge is that because volunteers own and manage their own data, there is a lot of siloed data which could be integrated but are not; they are currently waiting for statewide database to be established for data storage and integration.

Human Computation

Edith Law described human computation as the process of having people do tasks that computers don't do well, like object recognition. For example, the ESP game, in which a pair of participants are shown the same image and receive points for the way they tag its contents, has garnered millions of online gamers, and the data it generates are being used to power Google Image Search. Another example is reCaptcha, which is digitizing books by turning images into text. It builds on Project Gutenberg concept, using two words to check whether you're a bot while also digitizing a word from a book. 200 million reCaptchas are filled in every day, which is quickly digitizing books.

One challenge of designing these games is applying the game concept in other scientific domains, and it doesn't always work as well. For example, getting participants to give matching tags on music can be very hard, due to vocabulary issues. Maybe the motivation is better in citizen science, but for most of their work, they are trying to prevent spamming, which involves both collecting data and ensuring accuracy. Related to citizen science, she is working on a new game to extract attributes for specific species. The game uses a complementary agreement mechanism, having one person select a positive attribute and the other select negative attribute.

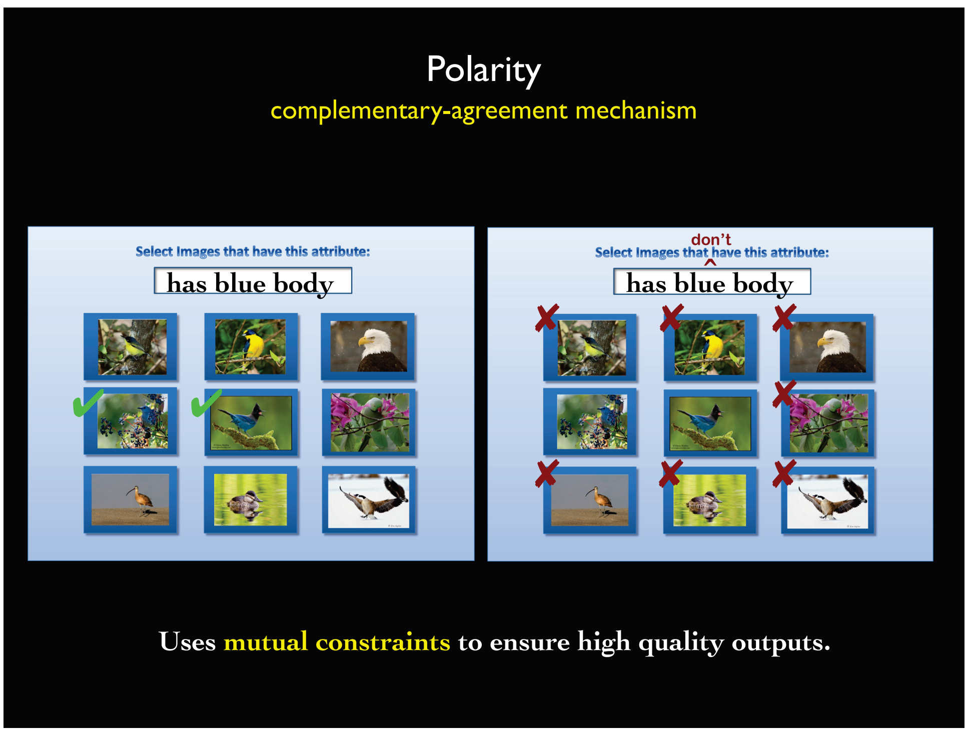


Figure 4: Law described a human computation game mechanism for identifying species.

2.2 Long-term Projects

This panel included presentations focusing on the needs and challenges of long-term projects. Many citizen science projects are designed for long-term monitoring and data collection, and these panelists provided their perspectives on project development and sustainability.

Monarch Larvae Monitoring Project

Karen Oberhauser presented MLMP (`http://www.mlmp.org`), a long-term project that is monitoring egg and larva abundance and milkweed habitat. This project is both long-term and complicated, and among other things, they are interested in volunteers' chosen monitoring sites' characteristics, such as location and natural features. Contributors can enter the data for several different aspects of the project, providing a series of related optional activities that allows volunteers some choice of how to contribute. In the main study, volunteers at individual sites record different life stages of monarch butterflies, but training volunteers to recognize the different stages of development has presented challenges. Volunteers bring a new element to the study; for example, they have had problems measuring mortality because volunteers wanted to intervene to save the monarchs' lives, which is contrary to the standard scientific protocols. The data interpretation must take these issues into consideration and so they have to use data differently than initially expected, and they ask people about rearing the eggs indoors.

Currently, they have about 1,000 sites being monitored, and many contributors have multiple sites. About a third of volunteers never submit data, and the Western states have lower participation for this project because monarch density is low in the West. They have more volunteers in places where participation is fun because there are more monarchs. They have also found that volunteers often fail to report negative data because they do not think it valuable. To quantify the data collected, 1500 "volunteer years" have added up to 15K events recorded about monarchs.

MLMP recently added a way to enter anecdotal observations, where volunteers record the location where they see the monarch, and in the future, they are hoping to have that involve photo uploads to permit verification. The project has encountered some structural challenges, primarily with respect to resource constraints and volunteer retention. They found that they can maintain the project on a lower budget than the initial level needed to get the project started. The funding they have received is focused on education rather than the science, which is their main interest as researchers. This can create a tension between education and science.

Another challenge for engaging a larger contributor base is that participation in this project requires a lot of time and the protocols are fairly detailed. Related issues included human resources constraints: frequently changing personnel (grad students) and also retention of volunteers, particularly with the "difficulty" of volunteering; nonetheless, the project has about 70% year-to-year retention, which is fairly high.

The project has also encountered challenges with data management; for example, they don't clean the data that is publicly available, so people who download the data may get erroneous data. This situation is a result of a decision to put the data up on the website as people enter it, although they know there are errors; they make no corrections to the data because contributors get upset if their data get removed. The scientific data issues include

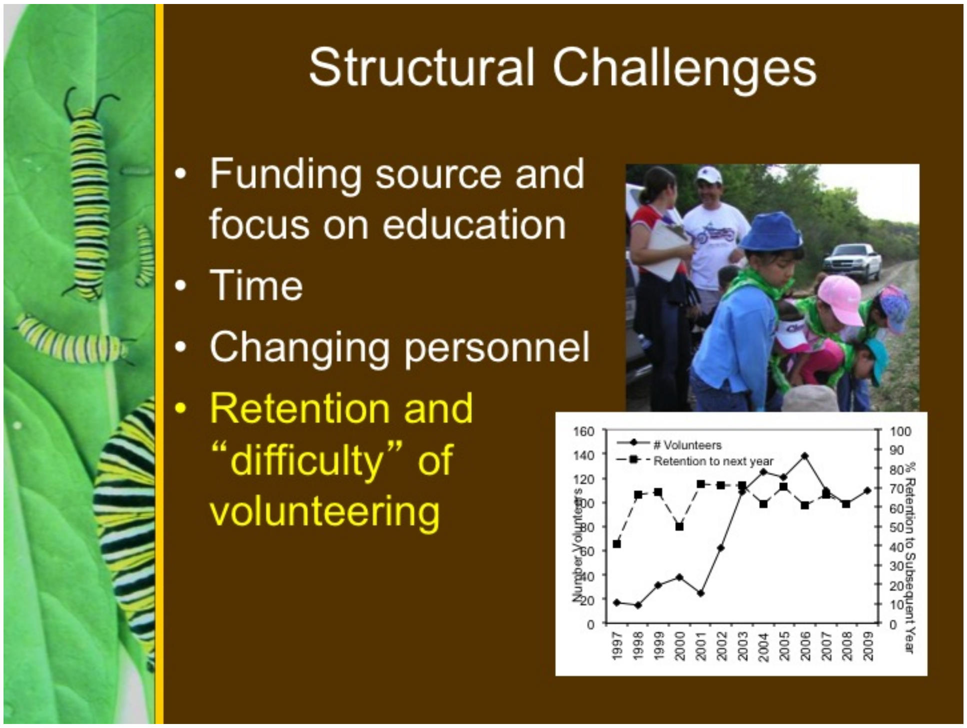


Figure 5: Oberhauser discussed structural challenges for the MLMP.

inaccuracies from identification errors, and non-random sampling. MLMP has found that the volunteers tend not to monitor a site if monarchs are rare or absent, or they seek high quality plants and oversample plants that are more likely to bear monarchs. Because the sampling procedures are important to this project, they have really had to work on training volunteers about random sampling. Another important point for early consideration is how to handle exceptional observations that may still be realistic. Oberhauser described an example of a photo substantiating a seemingly impossible data point reported by a volunteer. As a result of this incident, they are working more and more on finding ways to enable photo verification as part of the participation process.

Further opportunities for this project's development include coordination with related monarch projects as well as getting into large-scale data analysis and synthesis. With respect to generating scientific knowledge, the project has yielded a number of academic papers and they are sharing data with many other people, so it is considered successful from this perspective.

Community Collaboratory for Rain, Hail, and Snow

Mat Gerbush, who co-coordinates a small statewide chapter of CoCoRaHS (`http://www.cocorahs.org`) in NJ, drew on the organization's national coordinators' perspectives for the big picture. CoCoRaHS can be described as a grassroots, high density, precipitation monitoring network. They have over 15,500 currently active volunteers who take daily precipitation measurements in their yards each morning. As in many projects, a lot more people sign up than actually participate.

The project addresses skill needs through in-person training sessions, but also provide online training materials for those who cannot attend in-person trainings; they believe that the majority of project participants receive their only training through these online materials. In-person trainings are coordinated through statewide chapters, some of which provide low-cost measurement tools to volunteers, but most observers pay $25 for their rain gauges, which is a relatively low cost for participation in a weather monitoring project. Additional tools that participants must learn to use accurately include rulers and "hail pads" that are styrofoam covered with foil to collect indents of falling hail.

Demographically, they find that most participants are older, but the project is designed so that no experience is necessary and there are no limitations on location. Both from scientific and management standpoints, the ideal would be better distribution and density, but their policy is that all data are welcome. The project makes both data and learning materials open to everyone, and their website provides real-time data feedback in both map and tabular formats, with different methods to obtain data from the project to make it more accessible.

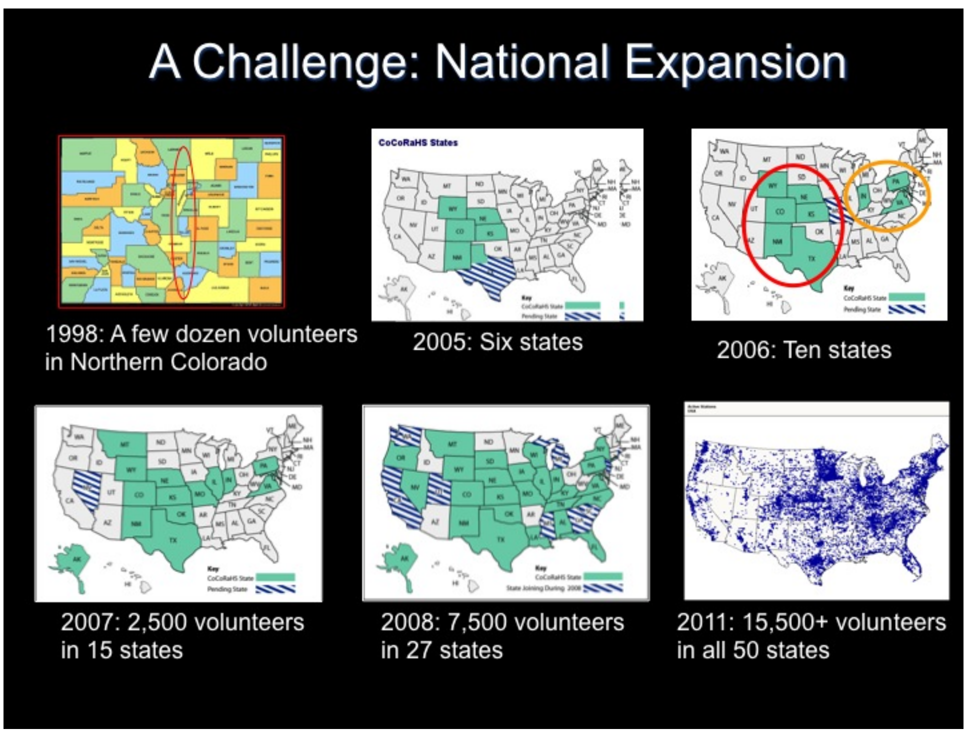


Figure 6: Gerbush described CoCoRaHS's strategic response to the challenge of national expansion.

Gerbush discussed the challenges involved in national expansion. Since 1998, CoCoRaHS has expanded from a few dozen volunteers in Northern Colorado. Major expansion really started in 2005 with six states in the Midwest; the project continued spreading at a rate of about 10 states per year, and is now active nationwide. Throughout this process, they made sure they had a dependable state coordinator and other organizing materials before launching the project in each state. As the project grew, eventually they had to find suppliers for rain gauges because the CoCoRaHS national headquarters couldn't handle the volume of orders from participants. In addition to state-wide coordination, some states have localized coordination, but in general, have fewer observers in Western states that have lower population densities, a geographical sampling challenge that faces a variety of projects that aspire to continental-scale observation networks.

One of the project's opportunities for development came from involvement with the National Weather Service; some offices volunteered staff or interns to coordinate in their states' CoCoRaHS networks, and subsequently started using CoCoRaHS data in their data outputs. The project is now the largest source of precipitation data in the country, and their Significant Weather Reports can be used for severe weather warnings, demonstrating that it is trusted data for a variety of purposes.

Their future plans include embracing new audiences with social media such as Flickr and YouTube, which may also provide ways to incorporate contributions of photos and movies with reports (e.g., for Significant Weather Reports), new recruitment targeting strategies to address sampling concerns, and improving training materials. Technology-wise, this year's undertakings will include working on redesign of their website, utilizing cloud server technologies, and arranging Open Data Protocol support for better user querying. The organizers' current participation goal is to have 30,000–40,000 active observers by the end of 2013.

eBird

Steve Kelling provided an overview of the eBird project (`http://ebird.org`), which collects data on bird distribution and abundance. He notes that there are many kinds of citizen science, and he is particularly interested in crowdsourcing, a term he uses with a very specific meaning, referring to the use of humans to do things that machines cannot do. For example, no computers or sensor networks can identify organisms, and until they can, we must rely on the people who can be drawn into participation.

The focus for the eBird project has always been on maximizing number of observers and number of observations to generate a large dataset that can be used for a variety of scientific and other purposes. There is a long history of monitoring in a few specific communities, especially birds; every country has a major bird monitoring project. The project collected over 2 million observations in its first two years, which is impressive by most standards, but for their scientific goals, this volume of data was a drop in the bucket compared to what is needed for the kind of species distribution models they wanted to generate.

To improve contribution levels, instead of redesigning their data input processes, they brought in experts who were identified as serious birders within the community, and worked with them to redesign all the data output tools. This ensured that the project created data products that birders would enjoy, as well as giving the project further credibility through the association with the accomplished birders. In the process of revamping the tools, they built acknowledgment and competition into the project.

This strategy has worked so well that contributions continue to increase in volume, and in May of 2011 they expected to collect three million observations. The project currently has about 60,000 contributors, and around 15,000–20,000 people who submit a lot of data. Volunteers contributed 1.3 million hours of observation to the project in 2010, and that doesn't include any data entry time, which does add up.

After the initial funding for the project, subsequent grant funding proposals have been in computer science, focusing on how to use the data that lets them look at species distributions anywhere in the year, anywhere in the US. Having collected this data is providing the first opportunities for researchers to track species movements throughout their whole lifecycle. Successes in gaining funding for these developments means that eBird can now fund a secondary group to do research and analysis that advances computing research.

The outcomes of the project are an international data source, probably exceeding 100 million records of birds in the Avian Knowledge Network, all of which is provided free and open access. In terms of scientific knowledge production, researchers have gotten 80 publications from this data source in the last three years, mostly by people who are not involved in running the project. Other new initiatives that have come out of eBird are data modeling projects that have them working with ecoinformatics groups, involvement with DataONE (a network for ecological data management) in several areas, primarily with experts in visualization, data processing, and data modeling. The focus of the project's research efforts have been moving into data-intensive science and linking observations with other variables to produce very accurate models.

2.3 Mobile Technologies

Mobile technologies are an area of increasing interest for citizen science projects, particularly because smartphones are capable of capturing photos that can be used for verification and automatically capturing location information and other data, potentially reducing data entry effort and improving accuracy. Several participants who had experience working with mobile technologies to engage the public discussed their experiences with these approaches to citizen science.

BudBurst

Sandra Henderson provided an introduction to Project BudBurst (`http://neoninc.org/budburst`), which has been adopted by the National Environmental Observatory Network (NEON). BudBurst is a national citizen science field campaign that focuses on plant phenology. It engages the public in collecting data about the timing of leafing, flowering and fruiting of plants. The project is rapidly expanding as part of a national network engaging with a variety of collaborators and partners. BudBursts's education goals include increasing awareness of the impacts of changing climates, increasing science understanding and appreciation through participation, and getting people outside.

BudBurst recently released a mobile app for Android, developed with the UCLA Center for Embedded Network Sensing. The topic of mobile devices in citizen science was the focus of a workshop in fall of 2010, and gathered representatives from education, science and technology perspectives. They expect to organize a larger meeting on this topic in the spring of 2012.

Henderson reviewed some key take-aways that Project BudBurst learned from working on developing a mobile app. First, it is important to establish communication between institutions and programs interested in utilizing mobile technologies, to maximize benefits from interdisciplinary collaboration. It is strategically valuable to establish communication among developers and programmers of these apps to determine common functionality that is needed to support citizen science projects with mobile apps. A project can then plan to adopt a compatible set of methods and approaches for the functionality to support the specifics of the scientific protocols. Setting expectations is important to prepare projects for dealing with future changes in the mobile platforms that can be used for citizen science data collection. Best practices already exist for app development, so take care to consult this knowledge base while defining the user interface elements and functionality.

Mobile Apps for Citizen Science from CENS

Eric Graham gave an overview of the new developments in mobile apps for citizen science from the UCLA's Center for Embedded Network Sensing (`http://http://research.cens.ucla.edu/urban/`). CENS is a collaborative group of computer science and electrical engineering faculty and students building technologies, systems, and applications for programmable, distributed, multi-modal, multi-scale observatories to address compelling science and engineering issues. What's Invasive! and Project BudBurst Mobile are two examples of recent work.

What's Invasive! leverages millions of visitors to National Parks to help combat the spread of invasive species. In collaboration with the National Park Service, they have developed a smartphone and website system that allows participants to geo-tag invasive species observations so that NPS staff have access to up-to-the-minute weed and pest location information.

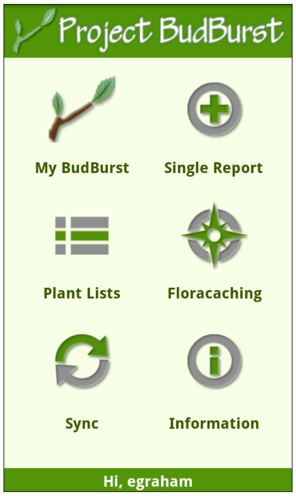


Figure 7: Graham presented citizen science mobile apps for What's Invasive (left) and Project BudBurst Mobile (right).

BudBurst Mobile is intended to support Project BudBurst, the project Henderson described. The mobile app for Android allows users to capture and upload data in the eld using a mobile phone. The data are automatically geotagged and photos help with data quality control. It also implements some Web 2.0 social networking features. They are also developing a method of displaying shared "community" plants that multiple people can monitor to add a layer of social activity to participation. A new project CENS is working on for BudBurst Mobile is a game, Floracaching, which is like geocaching except that participants look for plants and capture phenology data.

Some next steps for advancing mobile citizen science include data sharing among systems in an environmental network, and back-end data analysis for real-time models within games. Both of these areas would enable more sophisticated ways to engage users through "pervasive" games. The CENS projects are working with networks for data sharing from What's Invasive!, and are combining BudBurst Mobile data with external data sources to create daily, real-time feedback and predictions.

mCrowd

Charlie Schweick introduced mCrowd (`http://crowd.cs.umass.edu/`), a task market for mobile sensing. This provides a general framework following the crowdsourcing model of data collection, with the option to offer compensation for completing portions of the task. The tool lets task designers select sensors for the smartphone, including 3G, Wifi, accelerometer, audio, and GPS, using these data streams to create route-based or spatial sensing tasks, among others. Example tasks included sensing a route using accelerometer information and Wifi hotspots, or gathering EKG data from individuals running through on-body sensor data collection that uses cell phones to report data to a remote server. The mCrowd client creates an interface for both creating and completing these tasks, using a website and web services, so that anyone can create a crowdsourcing task that utilizes smartphones, and anyone with the app can participate in the tasks, which can be searched and filtered according to distance and compensation type.

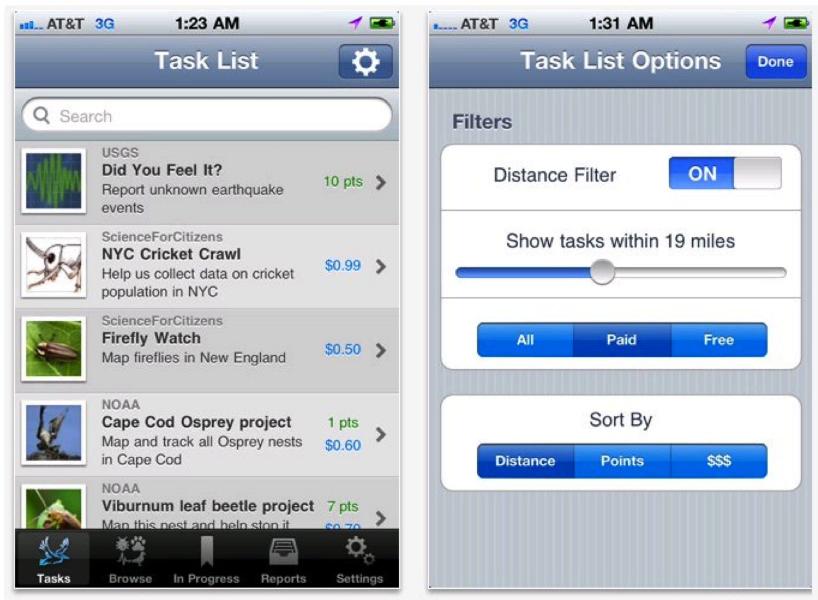


Figure 8: Schweick described mCrowd's mobile sensing "task market" app.

The goal of this type of market is to get as many people engaged as possible, while lowering the barriers to entry for people who want to utilize crowdsourcing to gather data from mobile phones and other individual-based sensors. Another part of the system architecture is the ability to have a "domain expert" review and accept or reject data; this is especially useful for paid tasks.

CreekWatch

Christine Robson briefly discussed CreekWatch (`http://creekwatch.researchlabs.ibm.com/`), a project that collects data on water quality in creeks and streams. This project was created from a user-centered design perspective, with the goal of creating a way to participate via smartphones that fits into ordinary lifestyles and minimizes the complexity and expectations of contributors. The practical use case was to create a smartphone app that was so simple and straightforward it could be used to report the condition of a stream during a daily dog walk without pausing.

The design of the CreekWatch app requires answers to two simple questions, each with only 3 options, minimizing the number of interactions required to contribute data. This simplicity was intended to get as many people engaged as possible. For example, in order to evaluate the level of pollution in creaks and streams, they ask how much trash is visible. The design process involved interviewing people to improve the app, and they started a social media campaign well before the app was available. This was important to the project's success; they made sure people were aware of the project and built up hype so that there was a recruited contributor base waiting when the app was ready for use. The word about CreekWatch got out quickly, and they had 30,000 people who were Facebook fans and were getting project updates. Starting this effort in advance was key to the project's success upon launch.

Living Environments Lab Projects

Eric Paulos made a *pecha kucha*[1] presentation on his work on mobile sensing and novel ways of engaging people through technologies (`http://www.living-environments.net/`). Among the highlights of this fast-paced introduction to a wide range of projects from the Living Environments Lab, Paulos shared stories about air sensors on garbage trucks causing police run-ins and the intersection of grassroots data collection with public expression and activism through community sensing. Paulos also discussed projects around treating energy as a material object, and "spectacle computing" that uses novel technologies in public spaces to provoke engagement, such as balloons that change color in response to the surrounding air quality.

Figure 9: Paulos gave an example of spectacle computing with balloons that react to air quality.

[1]Pecha kucha is a presentation style where 20 slides are shown for 20 seconds each, adding up to six minutes and 40 seconds.

2.4 Discussion

Following the presentations of current work and projects represented by the workshop participants, an open discussion touched on a variety of issues. Many of the discussion topics revolved around volunteer management, motivation for participation, and ways to improve participation rates.

Law kicked off the conversation by asking, how do you find participants? Oberhauser's project advertises with groups that have natural affiliations, while also focusing on specific geographic areas where there are not a lot of people participating, since this affects the sampling for the scientific research.

Bonney brought up Wiggins's research and the notion of taking a hobby and building it into science, versus taking science and turning it into a hobby. This approach meant that eBird could really understand the motivations that would get hobbyists to provide data. Everyone accepted that birders are a unique lot, and Bonney said that there are likely to be very different motivations for participation in projects focused on other taxa, or altogether different tasks. At the same time, he noted that there is currently almost no up-front research on motivations to participate, even in the big NSF projects; they are taken on faith, and citizen science has never done the market research. Kelling mentioned that motivations vary by participant roles as well; since about 4% of records get flagged in eBird, it's a huge time commitment to be an expert reviewer of these data.

Bonney responded that this highlights the need to consider the goals of both researchers and participants in order to design the project. Newman, whose work has put him in contact with numerous projects, has observed a common thread of passion among those participating, which may be connected to a hobbyist interest. This brings up the question of what areas have genuine interest already existing?

Schweik identified another motivation for participation: a user-centered need. For example, water quality monitoring may be driven by concern on the part of residents, in addition to scientists asking for research data. Vastine, who works in water quality monitoring, verified that this issue arises in a conflict of retention versus threat; after people win their battles, they may question what to do next and whether to continue the project or their participation in it. More recently, fracking has revitalized water quality monitoring interest, and a whole new set of people are now becoming involved.

Gerbush said that CoCoRaHS appeals primarily to weather enthusiasts rather than people who are just looking for something to do. The amount of time it takes to do precipitation observations, with the exception of snow, is a lot shorter than other projects, but the daily frequency of participation is higher than most other projects.

Returning to the motivation question, Phillips pointed out Kelling's observation from eBird of the effects of changing focus away from an altruistic endeavor. While some people participate because they value science, desire to contribute, and so on, if you give them rewards it helps with retention and encouraging submission, though that may not work as well for casual birders. LeBuhn mentioned that she is trying a reward system, focusing on learning about your own backyard. This year when participants enter data they will get an email summary telling them what their bees-per-hour is compared to the national average. She hopes that this will help motivate more repeat data submissions.

Kraut noted that there is a great deal of evidence from volunteerism in other contexts

Figure 10: Listening to participant presentations led to lively discussion.

that in any project, there is a wide range of initial motivations for participation, and those motivations change over time. For example, people start volunteering in a soup kitchen to help the needy, but they stay because they like the social engagement or cooking. Rather than taking a simplistic view of motivation, projects will do better if they acknowledge the variety of motivations for different participants and try to speak to them. Crowston also pointed out that a lot of citizen science is not designed to be social.

Paulos suggested that even symbolic rewards such as icon badges or mayorships can be a huge motivator for belongingness. Participation varies significantly for different time scales of 15 minutes versus 5 minutes, and Paulos sees huge opportunity in shorter time scales that might be valuable. In addition to hobby-science issues and motivation issues, playful curiosity can also be valuable, so building in scaffolding is a strategy to further involve people who come to a project out of pure curiosity.

Building on Paulos's point about the amount of time required for participation, Schweik brought up Benkler, who talks about task granularity, presenting the notion that very small amounts of time from a large number of contributors can be as valuable as a lot of time from just a few people. Schweik also mentioned the work of Nathan Eagle, who claimed to have the "largest workforce in the world" with text messaging work in Africa. After many attempts with pay-based incentives, the most successful effort was a blood bank in Nigeria, which created a just-in-time blood supply system with text messages and cell phones. The project was a huge hit at the start but immediately stopped working because nurses were being charged for the text messages. They solved the problem by putting up money for cell providers, so that nurses were reimbursed for the message plus a little extra cell time, and participation took off again. The nurses and people submitting data were doing it for public good (blood supply), but also getting reimbursement for cost of participation. This brought up the issue of compound incentives, and Schweik observed that providing multiple participation incentives may help drive more participation.

3 Breakout Groups

The primary focus of the workshop was on intensive discussions around several themes, with an aim to produce brief topical reports and recommendations for funders and citizen science project organizers. These themes were derived through group discussion on the first day of the workshop, after which additional topic development was done by the workshop organizers. Based on the themes identified by the workshop participants, four breakout groups were formed to address the issues of 1) data management, 2) participation life cycles, 3) working with contributor motivations to encourage participation, and 4) leveraging communities for growth, sustainability, and scalability. Breakout groups met twice, once to explore their topic more generally, and once with a specific focus on technologies. The breakout groups reported back after each discussion; the summaries below incorporate the discussion from both breakout session reports for each group.

Figure 11: Greg Newman and Rebecca Jordan discuss the finer points of citizen science.

3.1 Breakout Group 1: Data Management

The data management breakout group was composed of members of the DataONE working group on public participation in scientific research, who took advantage of the time at this meeting to work on developing goals for advancing data management practices in citizen science.

The usual representation of the scientific data management cycle includes several steps: collect, analyze, describe, deposit, preserve, discover, integrate, analyze, and return to the beginning (see Figure 12).

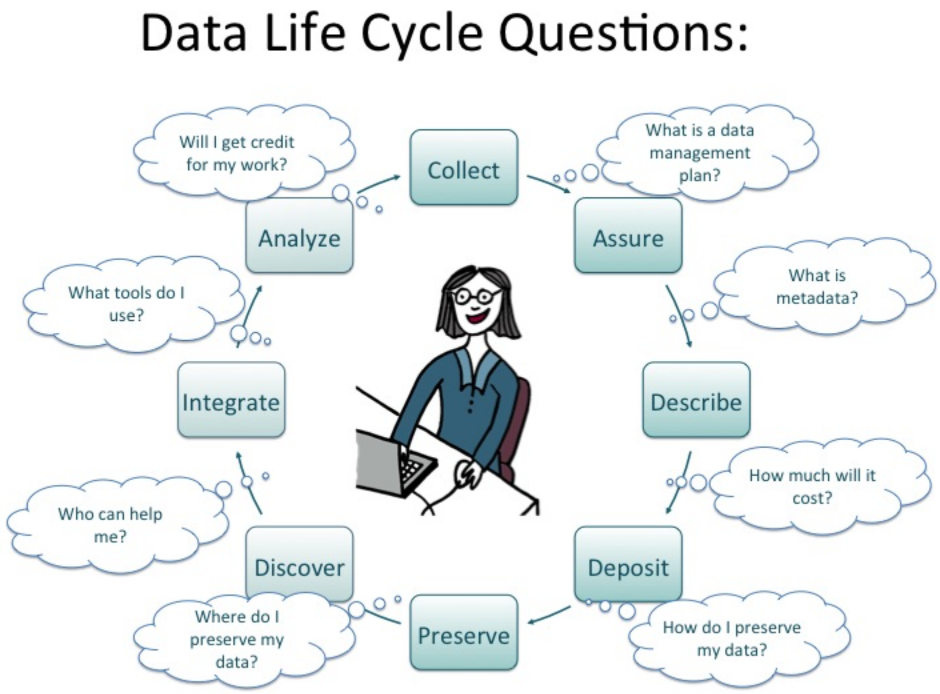


Figure 12: Typical scientific data management cycle model.

It is clear to those involved in citizen science that there are some different needs for data management when volunteers become involved. Additional consideration is needed to better define the differences between citizen science and conventional science data, as this impacts the types of services, guidelines, and recommendations that could be useful to project organizers. One potential difference is that because participants are offering data, there is more need to think about what they are good at providing and what they are not good at providing; LeBuhn gave an example of self-reported urban/suburban/rural categories for participants' gardens that yielded nonsensical results in analysis because participants made relative judgments of how urban their living space may be.

The group discussed what advice could be helpful for project organizers, such as outlining some of the needs of researchers who might use PPSR data for their own research. Three specific areas where project organizers could benefit from advice are in validation and privacy: access to common validation techniques with examples, common strategies for handling location privacy concerns, and strategies for addressing other privacy concerns. These needs are not entirely unique to citizen science but are substantially magnified due to public involvement, and more so as the scale of project participation increases. The group identified potential value in providing easy-to-access resources for metadata standards, controlled vocabularies, and even templates to make it easier for projects to engage in better data management practices.

In discussion with the other workshop participants, Kelling raised the point that there is a sense that large citizen science projects may in fact do a better job of data management than conventional science, because issues such as providing feedback to contributors and visibility of contributions to motivate ongoing participation means that there is more attention to persistent architectures than is typical for an academic scientist. In Kelling's experience, projects like eBird, the USA National Phenology Network's Nature's Notebook, and other larger projects in the UK and Australia, typically have more extensive data management than he has observed in individual or small-team research. Other participants noted, however, that it is important to ensure that there is not an assumption of a generous budget, since many projects produce scientifically valuable results without much staffing or tools to support them. Nonetheless, there was a general sentiment that data management practices could be much improved if the needed resources were more accessible and less expensive.

The breakout group's subsequent discussion focused on the primary issues that need to be addressed with respect to citizen science data management, and the resources needed to support these goals. The areas in which projects need more support that were identified by the group included basic data entry functionality, data quality, data usability, contributor confidence, and training for project organizers. To better address these issues, a number of ideas for technologies and related services emerged:

- Configurable tools for easy data entry
- Tools for performing data validation, particularly identifying outliers in large data sets
- Tools that support second order data management workflows to help deal with these outliers
- Sandboxes and demo modes to help participants with technology training and build contributor confidence
- Checklist configuration tools for enabling collection of absence data (e.g., as seen in eBird)
- Identification and customization of existing tools that can support project needs
- Training on data management for citizen science project managers, in formats such as workshops or online courses

3.2 Breakout Group 2: Participation Life Cycles

The breakout group focusing on participation life cycles identified several modes of participation based on different roles (see Figure 13), and a set of characteristics of project participants that influence their involvement in citizen science.

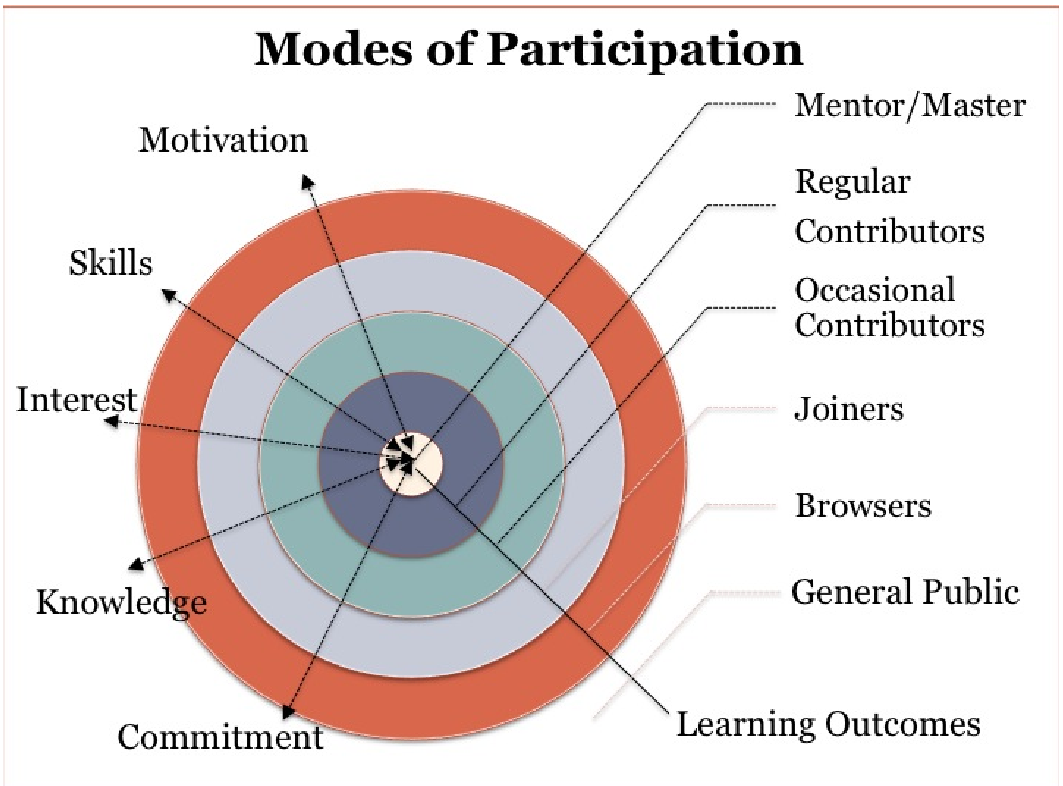


Figure 13: The "bullseye" or "onion" model of participation, illustrating roles and attributes of participants.

In addition to participant roles, however, the group also identified a variety of relevant factors to consider when examining modes of participation, including participant commitment, experience, interest, skills, motivation, and learning outcomes. The relationships between these roles are not linear, because people can move in and out of these different levels. Linking project goals to participant audiences is a key consideration that raises several questions: What is participation? Who is a participant? Is it just signing up, knowing about the project, or contributing data? The collective wisdom suggests that if a project's goal is getting as many people engaged as possible, the main strategy is to minimize barriers to engagement, while if the goal is high quality data, it may conversely be valuable to create a system of checks and balances that help improve data quality.

Successful projects match participant skills, motivations and commitment to activities early on. Assessing participant expectations can offer ways to better accomplish this; some suggested mechanisms to gather information include virtually monitoring behavior and administering voluntary surveys, or perhaps implementing a virtual "suggestion box." A useful strategy to support ownership of tasks is to permit self-selected interests, while trying to help match the participants to activities.

In addition, the group noted that it is important to consider participant development, and a number of strategies help support long-term engagement. Projects can support ongoing participation by providing scaffolding of activities, a process that gradually introduces more complex tasks so that participants can graduate to greater involvement and skill. Scaffolding supports those who want more depth to their engagement and to avoid boredom from repetition that may arise in some projects. More generally, it is valuable to acknowledge and respect all levels of participation, facilitate mentoring opportunities (creating a win-win situation for participant mentors and mentees) and provide social networking opportunities.

While it may seem self-evident, it is also important to recognize participant contributions, and check in with participants to ask whether motivations are being met and if people are satisfied with their participation opportunities. Projects can also help address participant confidence in data quality and using tools, to help ensure that participants don't lapse in participation because they second-guess the value of their work.

When it comes to training and instruction, motivation is strong. Projects can ask volunteers to help write documentation for newcomers, which is good resource utilization and development. Additional tools include certification levels and badges, practice tutorials with feedback on performance, and where appropriate, embedded or mandatory quizzes or games can help increase participant confidence. A cross-cutting issue is a need to experiment with different training and testing of models, promotions, and incentives, since "best practices" are still uncertain in this area.

The group also identified some remaining questions:

- What are the outcomes during various stages of participation?
- How do we increase confidence of volunteers' data collection abilities?
- How do we follow up with one-off participation (e.g., students)?
- How do we best harness passion or concern to retain participants.?

With respect to technologies to support the participant lifecycle, the group felt that most of the needed elements are available; for example, mobile technologies, cloud services, and functionality to submit data such as the Open Data Kit (`http://opendatakit.org/`).

3.3 Breakout Group 3: Making Participation Rewarding

The breakout group focusing on how to create engaging, rewarding participation experiences started with a series of questions about motivating participation:

- What determines motivation after novelty wears off?
- What characterizes a good transient/short term user experience and a good long-term experience?
- What are important categories of users?
- What incentives are important for each?
- What effects do specific functionalities have on user experience? E.g. visualization of their data, games, reputation?

In considering these questions, the group identified a long list of types of users, and thought about different motivation strategies that can be matched to the user types. Type of users included students, retirees, nerds, geocachers, hikers, birder, gamers, activists, eco-conscious, stargazers, environmental scientists, policymakers, land managers, and civic governments. The motivation strategies that they identified were equally diverse: badges and points, recognition of substantive contributions, display of data, reputation, interaction and debate, academic credit, monetary, co-authorship or formal acknowledgements, narrative, freshness, and scaffolding. The group noted that "fictional" or symbolic rewards (such as virtual badges or titles) are not useless, and virtual avatars motivate people.

From these brainstormed lists, they identified two camps of motivations: fictional (virtual) or nonfictional (real). This brought up the question, how do people understand the recognition that they are getting? For example, participants might receive notifications about downloads of the data they contributed, or data users could be offered a way to notify the contributors of the outcomes or publications from the data. Participants often seem to enjoy having access to their own data, e.g. with visualization tools, making the data publicly accessible so citizens can explore their own questions, allowing citizens to suggest research questions for researchers to pursue. Narrative is motivating, and is often missing from citizen science projects with lots of repetitive work over long periods of time.

There are different ways of acknowledging the contributions, and the question of what kinds of recognition are appreciated. Reputation can be purely symbolic, or can produce concrete changes like authority or data quality in the project. Showing leaderboards and contribution levels raises an issue of disincentive at the start of participation, in which an individual may feel that everyone else is an expert and they cannot catch up, but this is easily overcome by having leaderboards reset (e.g. monthly or weekly totals) so they can actually "score" and feel that they have accomplished a new participation level.

This ties into the idea of scaffolding, not just in terms of task difficulty, but starting with a playful experience and then moving toward deeper engagement. This is rare in citizen science, but can be accomplished with either within-project scaffolding or between-project scaffolding, with related projects partnering to offer participation opportunities that span a range of levels of complexity.

Finally, the group discussed games as a way to motivate participation. Real world interactive games where communication goes through mobile devices, e.g. geocaching, could be adapted for field data collection, offering an opportunity to tap into an audience who would not participate for the sake of "citizen science."

The primary suggestion was to take your problem to the experts by talking to game designers. Game design can address some of the motivation challenges many projects face. A concrete recommendation was to hold a competition for game designers to produce a game based on a citizen science dataset, e.g. pervasive games with explore mode (based on contributed data) and author mode (contribution of data). The group also noted that there are many unexplored directions for integrating game-like qualities into citizen science participation.

Figure 14: Eric Russell and Greg Newman chat about data management for citizen science

3.4 Breakout Group 4: Communities, Growth, Sustainability & Scalability

This breakout group's initial conversations started by generating advice for designing new projects:

1. Identify your goals/outcomes and what you want to do.
2. Know the group that you are going to work with.
3. Know who or what your project is benefitting.
4. Need incentives and to remove barriers to motivation.
5. Think about what you are doing for science and what you are doing for yourself (just because you want to grow a dataset is not sufficient).
6. Build into your protocol a way to get feedback from your participants.
7. There are different kinds/types of work to be done, embed this into your project if exists.
8. Establish good leaders particularly those who know your community.
9. Develop a clear understanding of data use and layers of learning outcomes for volunteers.
10. Think about how technology needs will change as a project grows, as well as the additional costs and efforts that may be involved.
11. Hire project managers who are members of contributor communities.

This discussion lead to the identification of some gaps in knowledge and open questions for research. We need to think about what individuals are doing, according to role, e.g. contributors versus data users. Ask questions like, Is this related to expertise? How participants view themselves? Think about contributions and reason to participate, and remove barriers that may discourage participation. What value do individuals provide, compared to the resources provided to them? Do we fully understand our constituents?

In addition, the individual needs to feel motivated (autonomous, valuable, interested). Is there a way to scaffold participation by facilitating multiple portals of entry, allowing for practice? Are we thinking about comfort level, reputation, or other relevant factors, like incentives? The notion of incentive versus motivation warrants distinction, as does the notion of participation on the part of individuals or groups. Participants are heterogeneous and understanding distinctions between groups is important. From the perspective of organizing projects, have we studied the structure of governance or institutional design in these projects? Have we adequately explored partnerships or technology? Ways to bring together diverse interests, e.g., merging corporate interests with conservation interests? Collaboratories are distributed science projects with similar concerns for managing access and structuring governance, so are there parallels for citizen science?

These discussions highlighted two important points. First, a shift in focus from contribution to participation, with ultimate goal of contributing for the future, may be a more useful view. Very different levels of contributions are possible, but how do we structure projects to support this? Different needs and targets for participants bring up the question of how to think about motivating participation when we work with both transient and long term participants. Second, a community has its own level of expertise that needs to be considered; community-driven science projects focus resources to support and facilitate community ownership, which suggests lessons for projects that aren't strongly community-based.

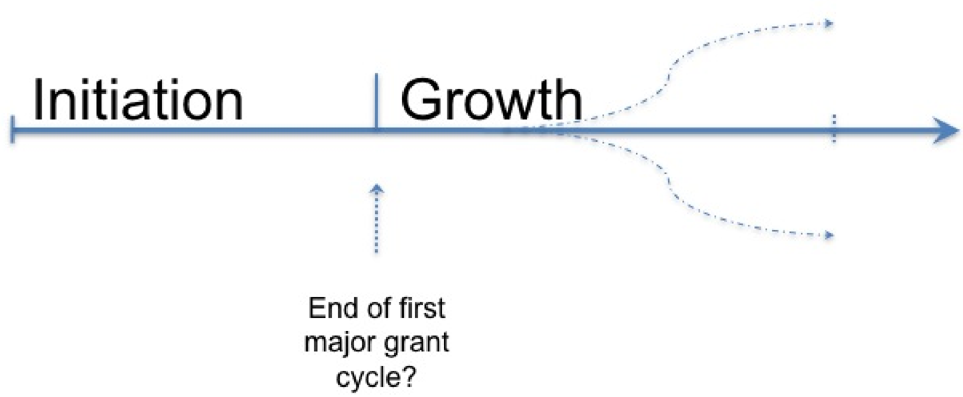


Figure 15: The discussion of project sustainability and scalability focused on the transition between initiation and growth.

The group's subsequent discussion focused on program growth, scale, and sustainability. Again, collective advice for growers or sustainers was generated by the group:

1. Similar to knowing your audience, you should know your funders or potential funders; think broadly about sustainability through such mechanisms as endowments and sale of services.

2. Understand the necessary tensions that arise when you have multiple stakeholders.

3. Leadership is important and is related to knowing your community.

4. Plan for major stages of project development: first website, first grant, first grant ending. Think about funding before your first grant funding has run out.

5. Plan for growth, relative to your own community's size and needs.

6. Growth and planning involve not just getting bigger: it includes turnover, phases, targets, and handling unplanned events.

7. Be strategic in how you partner with other groups. Empower your partners, and be prepared to "lose control" as others implement and disseminate the project/s.

8. In planning for growth, think also about planning for shrinking and/or legacy planning. Think about how to hand over your project to someone else to manage—permanently.

9. Plan to develop ways to bring new life to the project over time, which may mean targeting multiple partners.

10. It is important to understand the differences between the metrics of success of the project versus the things that contribute to the success of the project.

11. Plan for changing technologies.

These points of advice highlighted additional gaps in knowledge and potential research questions, such as, are there general principles to be studied as projects mature? Do new partnerships change the structure of the programs? In a related context, open source software development, there was an initiation stage, then this moved into growth stage; factors that lead to success in initiation stage are different to those for the growth stage. Might this change be reflected at the time your first grant runs out? Are there frameworks of scale that could used to understand these projects more as we compare across projects? Something like the principles of social capital may not operate the same way on smaller versus larger scales. As projects grow and evolve, how does the project change from face-to-face contexts versus participation primarily via online tools? How do you plan for projects that grow to international scale? What are the barriers and opportunities in working with different cultures, e.g., indigenous communities, or dealing with a culture of mistrust about research? How do you deal with different views of technology or language barriers?

A following meta-level discussion covered the topics of goals, engaging community, and multiple tiers of participation and the appropriate types of incentives. The notion of a citizen science project as an online community is not necessarily commonplace; do we think in terms of community or is important to differentiate between participant communities and open collaborative communities? As a community, are we pushing ourselves enough? Are we providing the proper support to follow these best practices? Does our sense of immediacy cause us to short circuit the important elements? The group felt that there are more or less best practices, but perhaps what we have are really principles. How do we move from principles to practices? We may think we are following a best practice, but in moments of failure, do we realize that maybe we aren't following the practice?

4 Conclusion

After three days of learning about the state of citizen science and engaging in intensive dialogue, workshop participants highlighted some similar themes in their breakout group discussions. Small group discussions and free time allowed for more informal dialogues to develop as well.

The data management group focused on the importance of quality management, adoption of standards for interoperability, and need for training for both organizers who have little background in data management, and for participants, who may lack in confidence in their ability to contribute useful data. The participation life cycles group also noted that participant confidence is an important consideration; they identified a variety of modes of participation analogous to similar models from other online peer production phenomena, and noted the value of engaging participants in a variety of ways, carefully aligning project goals with participant interests, and providing acknowledgement and recognition. The group that focused on making participation rewarding discussed motivation, acknowledgement and recognition extensively as well. They noted the utility of scaffolded participant experiences for participant retention, and gave substantial thought to the role that games can play in supporting participation. Finally, the group discussing leveraging communities for growth, sustainability, and scalability brought up numerous questions for further consideration and research. They noted that project life cycles are an important consideration as well, and that moving from an initiation phase to a growth mode brings with it a new set of challenges.

These discussions focused on recurring issues that may be fruitful for further research, particularly motivation, incentives, participation structures for building participant confidence and ongoing engagement, and balancing recruitment and retention of participants. Many were excited by the potential offered by mobile technologies and games to support participation by new audiences. Others noted the challenges of keeping up with new technological developments, particularly given resource constraints. Discussions of the life cycles of both participants and projects highlighted a number of practical needs, and brought up questions about how well projects are implementing known project design principles and best practices.

Participants returned home from the workshop with new friends, new ideas, and new collaborations. The workshop organizers thank all the participants for sharing their expertise, enthusiasm, and insights; we look forward to continuing these discussions in the future!