# SciStarter 2.0:
## A Digital Platform to Foster and Study Sustained Engagement in Citizen Science

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## ABSTRACT
*In this chapter, the authors focus on how SciStarter has developed a new digital infrastructure to support sustained engagement in citizen science, and research into the behaviors and motivations of participants. The new digital infrastructure of SciStarter includes integrated registration and contribution tracking tools to make it easier to participate in multiple projects, enhanced GIS information to promote locally relevant projects, an online personal dashboard to keep track of contributions, and the use of these tools (integrated registration, GIS, dashboard) by project owners and researchers to better understand and respond to the needs and interests of citizen-science participants. In this chapter, the authors explore how these new tools build pathways to participatory policymaking, expand access to informal STEM experiences, and lower barriers to citizen science. The chapter concludes with a design for a citizen-science future with increased access to tools, trackable participation, and integrated competencies.*

*Keywords: STEM, Participatory Policymaking, Competencies, Informal Science, GIS, Contribution Tracking*

## INTRODUCTION
Individuals come to citizen science from different perspectives and preferences, and engage in a wide range of projects from data collection to public policy (Irwin, 1995; Bonney et al. 2009). Many participate exclusively online in crowdsourcing projects such as Galaxy Zoo, Fold-It, and Eyewire. Hundreds of thousands gather data on-the-ground for academic and community research projects led by scientists at universities, government agencies/NGOs, and nonprofits. Untold others initiate their own projects in response to local environmental and health issues. All types of citizen science endeavors face challenges around data access and management, around access to tools, around relationships with scientists and project managers, and around making their scientific accomplishments visible as they accumulate over time. Among the most universal and ongoing challenges for all types of citizen science according to Crowston & Prestopnik (2013), however, "is attracting and retaining enough participants to make achievement of project goals possible" (p. 3). One known reason for this issue is the reality that individual projects and project types exist in "silos" –as self-segregated groups with particular shared interests (Dickinson, Zuckerberg, & Botner, 2010). SciStarter, an online citizen science "hotspot" and a research entity of Arizona State University (ASU), is building an innovative new platform to address these prolific issues in the field of citizen science.

As a research entity of ASU, SciStarter is helping researchers at the university's Center for Engagement & Training in Science & Society (CENTSS) address fundamental questions about citizen scientists and their motivations. The Center is structured to develop and implement new

modes of engaging audiences in conversations about how science and society interact, while maintaining a robust research platform about these interactions.

SciStarter features more than 1,600 searchable citizen science projects and events from across the globe, added by researchers and project owners, serving an engaged community of more than 50,000 citizen scientists. SciStarter selects projects from its database to promote on its site, and to share with Discover Magazine, Astronomy Magazine, Philadelphia Inquirer, NPR, PBS, the United Nations, the National Science Teachers Association and others through open APIs that allow the database of projects to be shared with other sites. SciStarter also brings these projects to life through its syndicated blog network on the Public Library of Science and DiscoverMagazine.com, as well as in the pages of Discover magazine each month.

While SciStarter has demonstrated success in promoting projects and attracting potential participants for those projects, its development team can attest to the challenge of attracting and retaining participants over time. The next iteration of the site, known as SciStarter 2.0, supports the theory and practice of citizen science by (1) helping expand, deepen, and sustain public engagement in science and (2) serving as an aggregating platform to enable research on the motivations and behaviors of participants across the enormous range of variation in citizen science experiences.

## BACKGROUND

The design of SciStarter 2.0 is based on the premise that ownership of information and resources and the ability to organize and display contributions, combined with greater access to projects and opportunities to connect socially with fellow citizen scientists and professional researchers, can lead to the deep and sustained engagement in citizen science. Research will be done to understand which platform features motivate increased engagement, either deeper involvement in individual activities or broader participation in many activities, and what the differential impact of those features are across demographic categories, such as age, education, income, location, and project styles (contributory, community-based, etc.). SciStarter 2.0 will also enable researchers to explore and evaluate how varying types of scientific contextual content, such as humanizing profiles of scientists, historical narratives on research topics, and direct interaction with scientists impact interest, engagement, motivation, and behavior in terms of participation in science activities. Of the digital citizen science platforms in the field, SciStarter is the most suited to answer these crucial questions because of its large and growing community. The backbone of SciStarter is the community of 50,000+ citizen scientists that are ready to find new ways to engage in citizen science.

In 2013, the Sloan Foundation supported SciStarter's exploration of cloud-based mobile and web platforms for citizen science, which resulted in a widely used report (Cavalier et al. 2014) and in the development of wireframes for user profiles and dashboards. Also with support from Sloan, in February 2014, SciStarter organized a workshop in London at the Citizen CyberScience Summit where a design process was prototyped and participants were categorized and storylined into eight “personas” based on varying engagement level and motivation, from “dabblers” to “educators” to the most dedicated “super-users” involved in many projects. These personas are

key to understanding how different people participate in citizen science projects and how different digital tools enhance their participation across projects and platforms. Additionally, the Knight Foundation supported a prototype tool that connected people to projects based on their location. This proof-of-concept tool provided the basis for the geographic matching tools implemented in SciStarter 2.0.

To further inform the design of SciStarter 2.0, a survey of more than 200 participants in the SciStarter community provided information to inform a baseline understanding of their engagement in citizen science. The results of the survey broadly supported the theory that participant engagement will be enhanced by integrated registration and a dashboard with associated portfolios, data access, project suggestion, and social engagement:

- 50% of respondents were active in more than one citizen science project
- 74% of those who participate in multiple projects are involved in projects on different topics
- 87% of respondents said they would use a dashboard on the site.
- 64% of respondents store their data independently as well as share it with a citizen science projects
- 57% of respondents don't know how to access their data once they submit it to a citizen science
- project, and 84% of respondents would like to know how

These reports and surveys informed the design of SciStarter 2.0. The new platform includes:

1. An integrated registration and data transfer system for participants to more easily engage in one or multiple citizen science projects, across platforms
2. GIS implementation for project owners to define the geographic boundaries of projects so people can find them more easily
3. An online, personal dashboard for participants to track their projects, participation, and contributions to science, record interests in projects, create profiles, and find people and projects of interest to them
4. Use of these tools (integrated registration, GIS, dashboard) by project owners and researchers to better understand and respond to the needs and interests of citizen science participants.

SciStarter 2.0, with its contribution tracking and related programming, will enable the unprecedented ability to implement and study online practices that support and retain diverse types of citizen science participation. It is a smart collection of web components, including a dashboard and contribution tracking, designed to extend, enhance, and enrich participant experiences while at the same time supporting STEM research and enabling research on motivations and learning outcomes of participants. SciStarter currently includes blogs, newsletters, emails, project searching, project sharing, project information and promotional partnerships. Added to the existing system will be components that support participation in, and management of, multiple projects; continuity in, and sharing of, a broad and accessible citizen science community; and social components. Community and stakeholder

research will ensure the development of a smoothly functioning system that will benefit thousands of citizen science projects, and hundreds of thousands of participants. In turn, this will allow better definition of the participant community to learn who is doing what and where, as well as what data, experiences, and interests they have. Previously, this has not been studied efficiently across research disciplines in a manner that enables researchers and practitioners to understand, and effectively respond to, the needs of their communities.

There is currently a broad base of work on what motivates a person to contribute to a single citizen science project, but little work on how a rewarding experience with one project motivates involvement in more citizen science projects and science experiences. By bringing the 1600+ citizen science projects on SciStarter together in one place, participants' efforts will no longer be siloed among the different projects, but can be examined together. SciStarter is the best place to answer questions about how participation in one project motivates participation in more or different projects.

## Building pathways to participatory policymaking and expanding access to informal STEM experiences.

In its strongest form, the citizen science movement (alongside related efforts, like the open movement and other forms of public engagement) has the potential to radically transform how society makes decisions. From the particulars of how a municipality manages a park to high level decisions about where federal investments should be made, experiences in citizen science make clear that the public has a much more powerful role to play. This influence can occur in a variety of forms, including providing new and richer data, speaking on behalf of affected people and communities, and challenging traditional norms about who ought to be invited to the decision making table (Kennedy, 2016).

This optimistic vision, however – of citizens actively engaged in making decisions about science, technology, and society – requires a citizenry that has access to data, tools, peers, and expertise. It isn't enough to simply offer a pathway by which to access decision makers. Formal education has a role to play, but learning must be larger than the classroom. Informal science experiences are fundamental to the current state of science literacy in the U.S. (Lundh, Stanford, & Shear, 2014). A growing body of evidence demonstrates that Americans spend less than 5% of their lives in classrooms and learn most science outside of school, especially on the Internet (Falk & Dierking, 2010). In the words of Falk & Dierking (2010):

> *But is better schooling really the solution? …the most important sources of scientific knowledge are not schools; [and] the informal infrastructure of museums, aquariums, broadcast programming and other sources of science exposure… is a far more potent source of public understanding of science than has been previously acknowledged.* (p. 486)

To advance citizen science, therefore, requires developing a robust set of pathways through which citizens can think constructively and reflectively about the impact of science on their life and the

lives of those around them; and feel empowered to contribute to these conversations and debates in productive ways. With respect to the first, SciStarter 2.0 can link interested members of the public with opportunities to learn and contribute more through direct engagement in citizen science. It also affords a venue wherein project participants can work through both practical challenges (e.g., ownership of information and access to resources, among others) and these more hefty reflections (including evaluating their impact, weighing the aims and objectives of varying projects, and contrasting their experiences during and after). More pragmatically, SciStarter 2.0 also expands access to STEM-related citizen science projects in the areas of biology, environmental science, astronomy, meteorology, ecology, and microbiology, making it easier to link these existing citizen science projects with informal learning opportunities.

## Broadening participation in STEM through citizen science

SciStarter begins to identify the elements required to engage citizen scientists in new or multiple projects, and to feel empowered in the process of citizen science. SciStarter 2.0 sets the stage for greater inclusion of previously marginalized groups in citizen science activities and will extend to all forms of public engagement in science in future iterations. To date, research suggests that participation in citizen science, while inspiring participant learning (Jordan, Gray, Howe, Brooks & Ehrenfeld, 2011; Price & Lee, 2013) and value to researchers (Cooper, Shirk, & Zuckerberg, 2014), is limited both relative to participant diversity (Pandya, 2012) and intensity and duration of engagement (Chu, Leonard, & Stevenson, 2012). The SciStarter 2.0 system addresses barriers to participation identified by Pandya (2012), Chu et al. (2012), and Rotman et al. (2014), including issues of local relevance (by adding much-needed GIS data), community bonds, and diverse channels of communication. Motivations of participants change over time, initially based strongly on personal interest and, for sustained participation, based on external factors such as attribution, acknowledgement, and relationships (Rotman et al. 2012; 2014). Pandya (2012) suggested that effective programs extend participant engagement beyond data collection to other aspects of the scientific process. SciStarter 2.0 will have the tools and standards to make it possible to begin to explore the relationships between inclusion, participation, and outcomes. A small, but growing body of research addresses participant motivation in relation to the sustainability of online citizen science projects (data analysis rather than data acquisition and sharing). SciStarter 2.0 will explore the importance of collective motives, norm-oriented motives, reputation, and intrinsic motives (Nov, Arazy, Lotts, & Naberhaus, 2013; Nov, Arazy, & Anderson, 2014), and will examine their efficacy when applied to a set of on-the-ground citizen science projects, unified in the technology-mediated SciStarter community. Studies of motivations of participation in on-the-ground citizen science projects tend to be focused on single projects, with a few exceptions, and they also find a variety of motivations, including motives of altruism, achievement, social, and esteem-building (Jacobson, Carlton, & Monroe, 2012; Nov, Arazy, & Anderson, 2011; Ryan, Kaplan, & Grese, 2001).

## Building pathways between science, citizenship and decision-making

Citizen science can create alternative co-evolutionary pathways from civics to science and from science to civics. For the civics to science pathway, SciStarter 2.0 can provide an on-ramp for lay citizens who participate in citizen panels, public forums and similar deliberative processes to move from participatory problem identification to participatory problem solving. Most

specifically, SciStarter can take the output from participatory Technology Assessment (pTA), a process of engagement that seeks to improve the outcomes of science and technology decision-making through informed dialog with lay citizens (Sclove, 2010). The process specifically targets non-expert representative of the general population who—unlike political, academic, industry and organized interests—are routinely underrepresented in technology related policymaking. It has three steps (i) Issue selection and problem framing, (ii) Peer to peer deliberation, (iii) Reporting and dissemination. These processes identify data gaps (in addition to policy and participation gaps), which can be used by SciStarter to design, develop and seed, use-inspired citizen science connected with community priorities and concerns in a variety of areas from environmental hazards to public health concerns to emerging technologies. The pathway need not end there. In fact, this special class of community priority inspired citizen science can actually help frame the problems and issues taken up in a pTA exercise. Once set in motion, the iterative pTA to SciStarter and SciStarter to pTA process (Figure 1) could generate a broad range of benefits for the participants and their community. It would increase and deepen scientific and civic literacy, broaden citizen science participation in disadvantaged and marginalized communities and forge beneficial partnerships between citizen and the public, private and nonprofit entities designed to serve them.

The pathways between science and civics are possible with SciStarter as it serves as a place for these communities to work together. By identifying the 1600+ projects and events in the database by location, people can find projects with local relevance that they are invested in to see through to the end goals. In their personal dashboard, citizen scientists can track their contributions to projects and to other participatory decision-making, building a full profile of experiences. As discussed later, the breadth of experience tracked in the dashboard can soon be used to develop contribution rewards.

*Figure 1. SciStarter and possible pathway from Civics to Science and Science to Civics*

## Flipping the world of citizen science

The current structure of science has highly centralized control that makes it an elite, closed system of knowledge production in which scientists are authorities in making new knowledge which is produced in academia, industry, and government, and it is influenced by commercial and academic forces. A reformed structure has decentralized control that makes it an egalitarian, inclusive system that involves ordinary people in the process of knowledge production governed in ways that serve the public good via influence of public interests. In short, reforming science would mean the adoption of three pillars of public science by the scientific enterprise as a whole: open science practices, dialogue-based science communication, and participatory methods of citizen science.

SciStarter 2.0 develops a system for volunteer contributors that empowers them to participate more broadly, more deeply, and more meaningfully in science activities, while simultaneously enabling project owners to better study and manage (recruit, retain, and enhance experiences of) their contributors. Tools that give contributors control and power over their participation are transformational not only to the field of citizen science, but to public engagement in science

overall (Overdevest & Mayer, 2008; Ottinger, 2010; Cooper, 2012). Technologies that can be used to address ethical and privacy challenges related to the sharing of location-based information, confidentiality, data ownership, and data submissions that cross legal jurisdictions are also needed for citizen science (Scassa & Sattler, 2011; Quigley & Roy, 2012; Bowser, Wiggins, Shanley, Preece, & Henderson, 2014). Tools that increase the capacity of project owners is predicated on the observation that projects are often coordinated by teams that include people with expertise in multiple fields from informal science education to informatics, whether from contributory-style projects or community-based efforts. It is difficult for any single project to have full capacity in all the disciplines that provide support for practice of citizen science. SciStarter 2.0 can help meet the communication and engagement needs of projects, thereby freeing resources for projects, big and small, to build capacity and sustainability in other areas. SciStarter 2.0 will provide technical components that research projects require for their "system assemblage," as described by Prestopnik and Crowston (2012), such as registration, sign-in, and collecting participant information. Researchers have only begun to explore the possibilities of citizen science as a tool for STEM engagement and learning. The nature of SciStarter 2.0 is such that, once the standards are developed, tested, and refined with partner projects, it will be possible to quickly expand a final product to a very wide range of citizen science participants and project owners and create a large and vibrant informal science learning community.

As a whole, these advances allow the pursuit of research questions about citizen scientists, questions about the subgroup of practitioners who are project owners and administrators, and questions about the role of this digital infrastructure as an intervention in the relationships among participants and project owners and how these components decentralize scientific knowledge.

## Designing a future with low-barriers, trackable participation, and integrated competencies.

SciStarter 2.0 provides the tools, services, and research platform to enhance the citizen science community of participants, project owners, and researchers. The project vision includes the following goals:

1. Allow project owners to use the participant tools (sign-on, dashboard, GIS, and, soon the ability to loan or sell instruments through SciStarter) for the purposes of learning about if and how their current contributors move between projects, interact with citizen scientists in other projects, use the new online tools, access/use instruments, and strategically reaching out to potential contributors among the broad SciStarter community with related interests.
2. Improve researcher access to citizen science data by disseminating data from participants to researchers with related topics of interest.
3. Encourage growth of citizen science participation through software driven outreach (recommending projects with similar goals, in local areas, recommending appropriate instruments, etc).
4. Enhance citizen scientists' self-identification as stakeholders in the research process by making their research data available and shareable.

5. Evaluate how recognition and feedback, such as "information about where, how and to what extent the data [was] used," as recommended by Rotman et al. (2014), influence participants' behavior.
6. Provide contributors with (optional) information about others who have similar interests and/or are geographically nearby, thereby providing ongoing opportunities for the informal science community and the research community to reach out to, engage with, involve, and teach contributors.
7. Offer teachers turnkey tools for involving students in appropriate citizen science topics (and thus provide informal educators with aggregate info about students in the citizen science world).
8. Enable collaborative relationships among and between project owners and citizen science portals and providers.

## Lowering barriers to participation

There are still significant logistical barriers to participating in citizen science projects including quick access to the required tools. SciStarter has the capacity to build lending libraries of tools by re-purposing the database as a searchable inventory of tools. Since many project owners, organizations, and agencies cannot recommend or sell products, SciStarter is in the unique role to provide this service to the broader community. The forthcoming “Build, Borrow, and Buy” system will make it easy for participants to get involved in projects right away with the necessary materials at their fingertips in the SciStarter system. Links directly on project pages will show which materials are needed and where to buy them, including from the SciStarter store.

The focus on the “Build” aspect integrates citizen science more deeply into the maker, hacker, and DIY science community, opening access to not only data collection, but tool development. SciStarter 2.0 has the capacity to host product ratings and reviews from participants that can be used as the Maker/Hacker/DIY community builds and refines tools. To further this effort, SciStarter is helping to co-organize the Makers Meet Citizen Science symposium at Arizona State University. This event and related projects will both advance the experience for citizen scientists and provide a necessary service, through ratings and reviews, to the “Build” community.

The “Borrow” aspect will be piloted with a lending library at the NC Museum of Natural Sciences, including with partner projects eMammal and Sparrow Swap. SciStarter is looking at software to provide the inventory tracking service. This service will be piloted through equipment loans for NC Candid Critters (a project of eMammal), Cat Tracker, Sparrow Swap, and project launching in fall with National Parks Service to record soundscapes, and will ideally be scaled up to a national level over time.

SciStarter is investigating partners to manage the retail sales of citizen science equipment so new participants can “outfit a project” in just a few clicks. These experimental activities, while incremental and timely, represent an important step forward to build sustainable revenue streams that will move SciStarter away from a dependency on grants.

By making citizen tools easier to build, borrow, and buy, one of the major barriers to participating in citizen science is significantly lowered. Furthermore, the contribution tracking system will allow us to measure the effect of accessible tools on citizen science participation across the broad spectrum of SciStarter projects.

### Rewarding contributions with SciStarter's digital infrastructure.

As the community of citizen scientist builds and the skills that they develop grows, it is important to recognize their accomplishments. In a SciStarter online poll, 60% of the community says they completed college in a STEM major while 30% completed college but in a non-STEM major. Therefore, building acknowledgement for the skills and competencies developed in citizen science project must be beneficial for these two groups. First, participants that already have content knowledge in STEM can gain recognition for the new information and skills they acquire, possibly leading to advances in their own career. Second, participants without STEM backgrounds can build a reputation for their diverse knowledge and experiences outside of their current career. For example, competencies for citizen science projects could lead to credit in continuing education courses at community college, badges on career profiles like LinkedIn, or simply extrinsic motivations like free rewards from local businesses. SciStarter will work with experts to identify and map competencies to experiences and ultimately to projects and dashboards on SciStarter.

## CONCLUSION

The SciStarter digital infrastructure radically changes the way people participate in citizen science and how researchers study those contributions. The platform allows participants to deepen and enhance their experience in citizen science while allowing researchers to track entry into citizen, movement among citizen science projects, and the spillover effects into participatory policy-making and additional STEM experiences. As the community of 50,000+ citizen scientists on SciStarter continues to grow in tandem with the 1600+ projects and events on the site, the opportunities to study public participation in scientific research will expand.

## REFERENCES


Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., & Wilderman, C.C. (2009). Public participation in scientific research: Defining the field and assessing its potential for informal science education. *A CAISE Inquiry Group Report*. Washington, DC: Center for Advancement of Informal Science Education (CAISE).

Bowser, A., Wiggins, A., Shanley, L., Preece, J., & Henderson, S. (2014). Sharing data while protecting privacy in citizen science. *Interactions, 21(1)*, 70–73.

Cavalier, D., Cheetham, R., Emanuele, R., Frankl, J., Johnson, M., Manik-Perlman, R., Marcus, J. & Redeschi, M. (2014). Citizen Science Data Factory. Retrieved from http://scistarter.com/research

Chu, M., Leonard, P., & Stevenson, F. (2012). Growing the base for citizen science: Recruiting and Engaging Participants. In Dickinson, J.L. & Bonney, R. (Eds.), *Citizen Science: Public Participation in Environmental Research* (pp 69–81). Ithaca: Cornell University Press.

Cooper, C. B. (2012). Links and Distinctions Among Citizenship, Science, and Citizen Science. A Response to "The Future of Citizen Science". *Democracy and Education, 20 (2),* Article 13.

Cooper, C.B., Shirk, J., & Zuckerberg, B. (2014). The Invisible Prevalence of Citizen Science in Global Research: Migratory Birds and Climate Change. *PLoS ONE, 9(9),* e106508

Crowston, K. & Prestopnik, N. R. (2013). Motivation and data quality in a citizen science game: A design science evaluation. In *Forty-sixth Hawai'i International Conference on System Sciences (HICSS-46),* Wailea, HI.

Dickinson, J.L., Zuckerberg, B., & Bonter, D.N. (2010). Citizen Science as an Ecological Research Tool: Challenges and Benefits. *Annual Reviews of Ecology, Evolution, and Systematics, 41,* 149–172.

Falk, J. H., & Dierking, L. D. (2010). The 95 Percent Solution School is not where most Americans learn most of their science. *American Scientist, 98*(6), 486-493.

Irwin, A. (1995). *Citizen science: a study of people, expertise and sustainable development.* London: Routledge.

Jacobson, S. K., Carlton, J. S., & Monroe, M. C. (2012). Motivation and satisfaction of volunteers at a Florida natural resource agency. *Journal of Park and Recreation Administration, 30(1).*

Jordan, R. C., Gray, S.A., Howe, D.V., Brooks, W.R., & Ehrenfeld, J.G. (2011). Knowledge gain and behavioral change in citizen-science programs. *Conservation Biology, 25(6),*1148–1154.

Kennedy, E. B. (2016). When Citizen Science Meets Science Policy. In *The Rightful Place of Science: Citizen Science*, Cavalier, D. & Kennedy, E. B. (Eds). Tempe, USA: Arizona State University.

Lundh, P., Stanford, T., & Shear, L. (2014). Nano and Society: Case Study of a Research-to Practice Partnership between University Scientists and Museum Professionals. Menlo Park, CA: SRI International.

Nov, O., Arazy, O., & Anderson, D. (2011). Dusting for science: motivation and participation of digital citizen science volunteers. *Proceedings of the 2011 iConference*. New York: ACM

Nov, O., Arazy, O., Lotts, K., & Naberhaus, T. (2013). Motivation-targeted personalized UI design: a novel approach to enhancing citizen science participation. *ECSCW 2013: Proceedings of the 13th European Conference on Computer Supported Cooperative Work*. London: Springer.

Nov, O., Arazy, O., & Anderson, D. (2014). Scientists@ Home: what drives the quantity and quality of online citizen science participation?. *PloS one, 9(4),* e90375.

Ottinger, G. (2010). Buckets of Resistance: Standards and the Effectiveness of Citizen Science. *Science, Technology, and Human Values, 35(2*), 244 – 270.

Overdevest, C., & Mayer, B. (2008). Harnessing the power of information through community monitoring: Insights from social science. *Texas Law Review, 86,* 1493–1526.

Pandya, R.E. (2012). A framework for engaging diverse communities in citizen science in the US. *Frontiers in Ecology and the Environment, 10*(6), 314-317.

Prestopnik, N. R., & Crowston, K. (2012). Citizen science system assemblages: understanding the technologies that support crowdsourced science. In *Proceedings of the 2012 iConference*. New York: ACM.

Price, C.A., & Lee, H.S. (2013). Changes in participants' scientific attitudes and epistemological beliefs during an astronomical citizen science project. *Journal of Research in Science Teaching, 50(7)*, 773–801.

Quigley, K., & Roy, J. (2012). Cyber-Security and Risk Management in an Interoperable World An Examination of Governmental Action in North America. *Social Science Computer Review, 30(1)*, 83-94.

Rotman, D., Preece, J., Hammock, J., Procita, K., Hansen, D., Parr, C., Lewis, D., & Jacobs, D. (2012). Dynamic changes in motivation in collaborative citizen-science projects. In *Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work*. London: ACM

Rotman, D., Hammock, J., Preece, J., Hansen, D., Boston, C., Bowser, A., & He, Y. (2014). Motivations affecting initial and long-term participation in citizen science projects in three countries. In *iConference 2014 Proceedings*. London: ACM.

Ryan, R. L., Kaplan, R. and Grese, R. E. (2001). Predicting Volunteer Commitment in Environmental Stewardship Programmes. *Journal of Environmental Planning and Management, 44 (5)*, 629–648.

Scassa, T., & Sattler, A. (2011). Location-based services and privacy. *Canadian Journal of Law and Technology, 9(1 & 2)*.

Sclove, R. (2010). Reinventing technology assessment: A 21st Century model. Woodrow Wilson International Center for Scholars. Washington, DC.

## KEY TERMS AND DEFINITIONS

**Competency:** Skills that may be acquired through participating in citizen science projects.
**Contribution Tracking:** A digital system to record contributor activity in citizen science projects including data collection, data input, analysis of images/photos, etc.
**Dashboard:** A digital place to visualize a contributor's interests, skills, location, past participation, and contributions to themselves as well as the rest of the citizen science community.
**Digital Infrastructure:** The network, data, devices, and software that provides a service or product to an online community.
**Integrated Registration:** A digital system that makes it easier for contributors to login to different citizen science projects. This may include registering with oAuth providers like

Facebook or Google or it may send information like name, email, and zip code to projects a contributor is joining.

**Participatory Policymaking:** A way of informing government policy by engaging citizens in the complete process of developing new policies.