ABSTRACT

SHAROVA, MARIA VASILIEVNA. Next Steps in Shared Management of Citizen Scientists: Understanding Project Owner Perspectives and Volunteer Connections to Science (Under the direction of Dr. Caren Cooper)

Citizen science is a powerful tool that harnesses the efforts of non-scientists who contribute to active research projects. Long-term, impactful research questions about environmental change, invasive species, the spread of disease, and machine learning require many data points from many different places. Citizen science can both advance research and empower volunteers with skills and knowledge. Furthermore, by participating in citizen science projects, volunteers can gain an appreciation, understanding, and trust for science.

This thesis explores the ways in which the dual goals of citizen science, to advance research and to increase public engagement with science, can be better achieved with the help of "third-party organizations." In citizen science, third-party organizations refer to online aggregates of individual citizen science projects that volunteers can search and join through the convenience of a single website, thereby fostering multi-project engagement. The full potential of these emerging organizations, with regard to potential impacts on volunteer participation and learning, has not yet been explored. I explore their potential impacts on volunteer participation and learning through the third-party organization SciStarter.org, which is an online repository of over two thousand citizen science projects. I examine project owners' attitudes about volunteer management and the impact this has on volunteers. By better understanding these attitudes, we can better understand how to foster citizen science experiences that bolster a project's research and learning goals.

In Chapter 1, I examine the existing beliefs that individual project managers have about volunteer behavior and volunteer management using a mixed-methods study involving

interviews and survey with project managers. Results reveal that many project managers currently embrace a unitary perspective regarding “their” volunteers (i.e., dedication to one project at a time). However, a shared management perspective that acknowledges and supports simultaneous, multi-project engagement, typically through third-party organizations, may be more realistic and productive. Basing management practices on actual volunteer participation patterns is more likely to enhance the broader outcomes and benefits associated with citizen science as a field.

In Chapter 2, I investigate the extent to which multi-project engagement through a third-party platform can facilitate and evaluate volunteers’ connection to science, including science affinity (interest in science), science efficacy (knowledge of and confidence in scientific skills), and science agency (having the knowledge to perform pro-science behaviors). We surveyed volunteers participating in SciStarter.org projects and explored associations between volunteer activity using digital trace data from the website and these different dimensions of connection to science. We found very high average scores across all constructs regardless of project participation, suggesting that (a) many citizen scientists have inherently high levels of science affinity, efficacy, and agency, and (b) citizen science participation reinforces those attitudes and behaviors. Future research could explore how different groups of volunteers (e.g., those who are not self-selected) might change and learn as citizen science engagement increases. Using third-party organizations like SciStarter.org, we can better understand project managers’ volunteer management beliefs and practices and develop tools and strategies for evaluating volunteer learning outcomes. The ultimate goal might be a shared volunteer management system that creates a community of citizen science volunteers whose expertise and interactions within and outside of specific projects can affect social and environmental change.

Next Steps in Shared Management of Citizen Scientists: Understanding Project Owner Perspectives and Volunteer Connections to Science

by
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DEDICATION

To the citizen scientists who are changing the world.

BIOGRAPHY

Maria Sharova was born in Moscow, Russia, into a family of scientists, researchers, and musicians. Her family immigrated to the United States shortly after she was born, and she grew up in North Potomac, MD.

Before coming to North Carolina State University, Maria earned a Bachelor of Arts in Anthropology and a minor in Russian Studies at the University of Maryland, College Park. After completing her bachelor's degree, she worked on the citizen science and education programs at the Smithsonian Environmental Research Center.

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EXECUTIVE SUMMARY

Citizen science is a unique tool in which volunteers and scientists work together to answer real-world questions (Bonney et al., 2009). Citizen science is a type of specialized volunteering because it is for achieving goals that require scientific research, rather than volunteering to help the mission of an organization. Throughout the history of citizen science, the organization that is responsible for developing a citizen science project has typically been the only organization to manage volunteers for that given project. Management by an organization involves activities like recruiting volunteers, training volunteers, providing updates about the project to volunteers, and sharing collective data with volunteers. More recently, organizations that are not responsible for creating a given citizen science project are increasingly involved in managing volunteers in that project. Motivated by interests such as environmental education, STEM education, or conservation, these third-party organizations may also recruit, train, and give updates to volunteers. Notable third-party organizations managing citizen science volunteers include the Girl Scouts, K12 teachers, museums, corporate volunteers, and online platforms such as SciStarter and Zooniverse.

One example of a third-party organization within citizen science is SciStarter. SciStarter is an online aggregate of citizen science projects that connects volunteers to individual projects. Through SciStarter, project managers can find volunteers in specific locations, specify skillsets they need, and communicate with volunteers. Project managers also learn about how many and the number of contributions volunteers make to their projects. Volunteers can search for projects by location, topic, and tasks. Volunteers can also join or save projects directly through the website and track their participation on their individual account profile pages (called "User

Dashboards”). SciStarter offers tools and data to inform volunteer managers about volunteers on their projects, which is useful for managers who monitor volunteer participation.

From analyzing SciStarter data, our research team learned that volunteers participate in multiple projects (Allf, et al., In Prep 2020). This participation can be sequential: volunteers participating in one project at a time. Participation could also be simultaneous, for volunteers who participate in multiple projects at the same time. Sequential or simultaneous participation might arise even if not encouraged by traditional volunteer management; for example, if facilitated by third-party volunteer management. Furthermore, project participation can occur across mode (online vs. offline) and across discipline and could be motivated entirely by the volunteer without the influence of the project manager. However, project managers can also have an impact on volunteers.

Most existing best management practices both within and outside of citizen science are based on individual projects (Gallo & Waitt, 2011; Prysby & Supec, 2007; Cornell Lab of Ornithology Toolkit, Federal Crowdsourcing and Citizen Science Toolkit). We adopted terms proposed in nonprofit volunteer management to describe a spectrum of attitudes adopted by nonprofit management best practices (Brudney et al., 2019). Shared beliefs describe those who manage volunteers beyond one specific project or project type. Unitary beliefs refer to managers who manage volunteers with a focus on their one project without the context of a larger third-party organization. We adopt these terms to expand beyond the practices of management to include the beliefs managers hold with regard to volunteers who participate in their projects. What do these beliefs mean for third-party organizations like SciStarter? How do the management attitudes of project managers impact volunteers? What does this mean for a volunteer participating in multiple projects? What does this mean for the larger field of citizen science?

This thesis focuses on understanding both citizen science project manager's attitudes about volunteers and volunteers' science affinity, efficacy, and agency associated with single and multiple project participation. We first wanted to learn about whether project managers consider and account for the movement of volunteers across multiple projects in the management of their individual projects. Do project managers know if or what other projects their volunteers participate in? Do managers believe that volunteers are participating in multiple projects across the broader field of citizen science – and do they think this is a good thing?

We characterized a range of volunteer management beliefs (unitary vs. shared) and found that management beliefs were related to four factors. Project managers who held beliefs favoring shared volunteer management in their own projects were linked to shared beliefs across citizen science more broadly. A second factor was related to participation patterns in projects. Shared management perspectives were defined by beliefs that volunteers participate in projects simultaneously. This indicates that, perhaps not surprisingly, managers holding shared management perspectives also support volunteers' participation in other projects. On the other hand, managers espousing unitary perspectives valued volunteer loyalty and expressed concerns about competition and volunteers shifting to other projects. A third factor was related to volunteer involvement in an organization. While managers expressing both unitary and shared perspectives valued volunteers, those that held shared management perspectives also involved volunteers in their program plans and structure. The fourth factor was related to perceptions of the broader impacts generated by citizen science project. Project managers that held shared management perspectives were more likely to report that their organization promotes broader impacts like individual learning, building community, and empowering action. Managers adopting unitary perspectives were less likely to acknowledge these outcomes. Identifying these beliefs helps us understand the motivations and barriers that might influence project managers' decisions to adopt third-party management platforms and tools.

One way to inspire managers to adopt shared beliefs about third-party organizations like SciStarter is to understand the impacts of multi-project participation on volunteers. Throughout the first chapter of this thesis, we found that managers who adopt shared management practices were more likely to acknowledge the broader impacts citizen science projects, which includes individual learning. We wanted to learn more about volunteer learning across multiple projects centered on a third-party platform. If volunteers report clear benefits from participating in multiple projects, managers may be more likely to adopt shared beliefs and therefore engage in management practices that support third-party organizations. Consequently, the second chapter of this thesis examines volunteer characteristics associated with discipline and mode spanning patterns of volunteering.

The second chapter attempts to look for associations between citizen science activity and volunteer connections to science, which we define as science affinity, self-efficacy for science, and science agency. These are constructs that have been measured in individual citizen science projects (Cooper, 2016; McKinley et al., 2017; Bonney, Phillips, Ballard, & Enck, et al., 2016; Ballard, Dixon, & Harris, et al., 2017), but it's not yet clear the outcomes are affected by different types of projects. We therefore sought to investigate patterns in these science connection variables that might be attributed to different project attributes such as mode, (online vs. offline) and discipline, as well as overall patterns of volunteer's citizen science activity. By understanding the potential effects of participating in multiple different types of projects on volunteer connections to science, we could further argue for the benefits of shared management of volunteers via third-party organizations like SciStarter. We did not observe connections between connections to science and either breadth (e.g., projects spanning multiple disciplines) or depth (e.g., number and time of data contributions) of participation, potentially because the participants in our sample possessed a very strong baseline connection to science. However, participating in citizen science projects may promote stronger connections to science in the form of science affinity, self-efficacy for science, and science agency for those already have strong connections. There is a large spectrum of volunteer participation in citizen science, and we know that people who participate in many and to higher levels of projects have high levels of connections to science. However, our study could not determine causality. While it is possible that citizen science can attract participants who have higher levels of connection to science, it is also possible these constructs are precursors to participating in citizen science. Citizen science experiences across mode and discipline were the most likely to be associated with higher scores in connections to science, though these patterns were not statistically significant. Because third-party organizations provide volunteer experiences across mode and discipline, adopting shared management practices might therefore help to promote (or reinforce) science affinity, efficacy, and agency among volunteers. If citizen science can bolster connections to science and third parties can provide the opportunity for volunteers to span project modes and disciplines, there is great value in adopting shared management practices. Future research using social network analysis (SNA) will help to identify the extent of connections between volunteer participation and different types of projects. We also plan to assess causal relationships between citizen science and learning outcomes by conducing pre and post-participation assessments with certain subgroups of volunteers on SciStarter.

We recognize that many citizen science project managers may be reluctant to adopt shared management practices due to concerns funding, staffing, and wavering volunteer commitment. However, adopting shared management beliefs that account for realistic participation patterns of volunteers can help managers better support their volunteers and increase the sustainability of their own projects. Furthermore, there is evidence to suggest that third-party management may have an impact on the connections volunteers have to science, indicating that citizen science is a powerful tool to help increase those connections. Citizen science is still a relatively new field, so enhancing volunteer management practices as new information emerges can help grow and support this field (Jordan et al., 2016). If citizen science and third-party organizations are committed to advancing volunteer connections to science, including the development of science efficacy and agency, there is tremendous value in embracing and adopting a shared management mindset.

CHAPTER 1

CITIZEN SCIENCE PROJECT MANAGERS' PERSPECTIVES REGARDING VOLUNTEER MANAGEMENT: THE VALUE OF THINKING ACROSS PROJECTS

ABSTRACT

Citizen science volunteering has grown over the last 20 years, in part due to the emergence of third-party organizations that help connect volunteers to citizen science projects. Third-party organizations are uniquely positioned to facilitate and study changes in volunteers across the multiple projects in which they participate. However, to maximize this potential, individual project managers must also adopt beliefs and employ volunteer management practices that support this process and meet the needs and motivations of these volunteers.

We conducted a mixed methods study to understand project managers' beliefs and actions with respect to management of citizen science volunteers both within and outside the scope of their project. We first interviewed managers from a variety of projects to understand the range of perceptions regarding volunteer behavior and management practices. We discovered a plurality of beliefs: some managers embraced "unitary" or proprietary views of volunteers, while others adopted "shared" or collaborative beliefs toward volunteer management. Themes indicative of a unitary perspective included uncertainty surrounding the quality of volunteer management, a preference for long-term engagement and deeper involvement of volunteers, perceived ownership of volunteers, and concerns about competition between projects.

Based on interview responses, we implemented a survey of project managers on SciStarter.org to characterize the distribution of these perspectives across a broader range of citizen science projects. Results suggested that many managers recognized the value of shared volunteer management. Compared to unitary perspectives, shared management orientations

within a project were associated with shared orientations across citizen science more broadly, perception of simultaneous participation in multiple projects, stronger volunteer involvement in an organization and broader project impacts. The shared approach is also conducive for most project management practices including growing volunteer populations, recognizing and measuring volunteer contributions, and coordinating volunteers. For all of these reasons, shared volunteer management practices, supported by third-party organizations and platforms, can help create a more engaged and productive citizen science community.

INTRODUCTION

Citizen science is a research approach that draws on volunteer interest and participation to help collect or analyze data that can be used to answer scientific questions (Bonney et al., 2009). It is a powerful tool that can generate valuable data for the benefit of scientific research. At the same time, it can benefit the volunteers themselves by promoting learning and engagement outcomes (McKinley et al., 2016). For example, scholars have demonstrated that participating in a citizen science project can help increase knowledge of scientific facts (Brossard, Lewenstein, & Bonney, 2005; Trumbull, Bonney, & Grudens-Schuck, 2005), increase ecological literacy (Jordan, Singer, Vaughan, & Berkowitz, 2009), and generate broader educational impacts (reviewed in Bonney, Phillips, Ballard, & Enck, 2016). Other scholars have noted that citizen science may help people understand and trust the process of science, thus building trust between the public and scientists (Bonney et al., 2014; Jordan, Ballard, & Phillips, 2012). Therefore, as an approach capable of advancing science as well as helping the public better engage with and appreciate the scientific process, citizen science projects or programs should be designed and implemented to achieve both goals.

Volunteers are foundational to citizen science, and effective volunteer management is an essential aspect to its overall success. However, citizen science projects vary widely in terms of size and mode of interaction. The smallest projects, for example, engage just a handful of volunteers a year, while larger platforms such as iNaturalist support over 150,000 users (iNaturalist Statistics). Project size in terms of volunteer numbers is an important consideration for appropriate volunteer management. A project's mode, or how it is conceived and implemented (e.g., online vs. offline), also matters. For example, managers of an online citizen science project may spend more time developing online resources (such as tutorials), while managers of an in-person project may dedicate more time to developing in-person training activities. Different interfaces require different volunteer interactions and management practices. Given the expansion of citizen science over the last 20 years (Parrish et al., 2018), it is important that practitioners understand the nature of their projects and their views regarding volunteer engagement because both have implications on volunteer recruitment, management, retention, outcomes.

Volunteer management in citizen science is not well studied, but much can be learned from volunteer management literature in other disciplines. The origin of nonprofit volunteer management has largely grown out of the Human Resources Management (HRM) perspective (Howlett, 2010). This approach views volunteers as employees of an organization and presents a linear volunteer trajectory from recruitment of a new volunteer, to strategies to retain the volunteer including reports about performance, ending with volunteer separation (Studer & Von Schnurbein, 2013). Few studies have measured the efficacy of this management framework, but criticisms include differences in how organizations view volunteers (for example, either as lay people or experts) (Merrell, 2000; Netting, O'Connor, Thomas, & Yancy 2005). Organizational views and philosophies regarding volunteer management can greatly affect the volunteer experience. For example, negative experiences in one project can affect volunteer entry into other projects; this depletes the "volunteer commons," which represent a conceptual idea of the pool of volunteers at any given time (Brudney and Meijs, 2009). Brudney and Meijs (2009) suggested conceptualizing volunteers as a natural resource that can be grown, recycled, and regenerated to help manage volunteers in a more sustainable way. This idea is similar to Ostrom et al.'s (1994) concept of a common-pool resource. Volunteer managers that neglect this "commons" perspective and do not treat participants as valued members of a larger pool typically lead to more negative outcomes, including loss of participants (Brudney and Meijs, 2009).

Given this research and evidence, it is important to understand best practices for managing volunteers and identify how project manager's beliefs toward and interactions with their own volunteers might influence broader citizen science goals. We addressed the question of volunteer management in citizen science by first drawing on nonprofit literature to illustrate effective volunteer management practices, then conducting a mixed methods study of project managers on SciStarter, a multi-project platform and repository for a wide-range of citizen science projects, to characterize existing volunteer management beliefs and practices in citizen science.

Volunteer Management Best Practices

Literature in the nonprofit sector has shown that organizations or projects that employ volunteer management best practices report less difficulty with recruitment and retention (Hager 2004, Cuskelly et al. 2006). Key themes in volunteer management from the nonprofit literature include supporting a growing volunteer population, measuring the impact of volunteers on an organization, and an emphasis on volunteer coordination (Cuskelly et al., 2006; Hager 2004; Studer and von Schnurbein 2013; Strauss 2017). Furthermore, Hager et al. (2004) reported that organizations with greater organizational capacity (such as more staff dedicated to managing volunteers) implement more best management practices. A closer examination of these best management practices in could help inform citizen science volunteer management.

Growing a Volunteer Population

Growing a volunteer population focuses on best practices for recruiting volunteers and understanding their motivations for contributing as a volunteer in the first place (Strauss, 2017). In many cases, nonprofit volunteers leave organizations not because of a lack of motivation but because of a failure to bridge the gap between preferred and actual volunteer experience and satisfaction (Yanay & Yanay, 2008). Consequently, before working with volunteers, nonprofit organizations are advised to thoroughly outline programmatic goals, anticipate how volunteer involvement can help meet those goals, identify tasks appropriate for volunteers, and recruit accordingly (Strauss, 2017; Renz & Herman 2016). Recruiting for clearly specified tasks helps establish mutually shared expectations between volunteers and project staff. Similar research has shown that recruiting volunteers for clearly defined roles that feed the mission of an organization perceived fewer problems in overall retention (Cuskelly, 2006).

In addition to understanding volunteer motivations, some citizen science initiatives have recommended matching volunteer skill sets with appropriate assignments. Citizen science management resources such as the Cornell Toolkit and the Federal Crowdsourcing Toolkit offer strategies and resources for project managers to ensure projects meet volunteer needs and achieve the research goals of a project (Cornell Lab of Ornithology Citizen Science Toolkit, Federal Crowdsourcing and Citizen Science Toolkit). In fact, a growing body of research has explored the diverse motivations of citizen scientists and how knowledge of these motivations could be used to inform project recruitment and management (Larson, et al., 2019, in press; Tiago et al., 2017). Current practice suggests that recruiting volunteers for specific skills leads to higher data quality. By taking time to understand volunteer motivations across projects and anticipate how volunteers will be integrated into a program, a citizen science approach can more effectively recruit, then retain, participants.

Recognizing and Measuring Volunteer Impact on an Organization

Recognizing and measuring volunteer impacts on an organization is another key factor that can help to motivate and support volunteers (Renz & Herman, 2016). For example, charity organizations that meet volunteer needs through activities such as recognition events and training have the highest rate of retention (Hager, 2004). Further, recognition of volunteers should be organizationally appropriate. Organizations that work primarily with long-term volunteers who are involved in many aspects of a project may choose to recognize volunteers through an in-person recognition event (such as a catered dinner or picnic). On the other hand, organizations that work primarily with episodic volunteers may elect to provide external validation such as public recognition of volunteers through social media or in the press (Hager, 2004). Volunteer management literature also focuses on volunteers as a unique organizational resource, making measuring their impact an important aspect of organizational success (Studer & von Scnurbein, 2013). Activities such as broader advertising about the collective impact volunteers on an organization can help to maintain volunteers. Stirling & Bull (2011), for example, found that after distributing newsletters to volunteers about their impacts, the organization leadership realized the value of volunteers.

Volunteer recognition has been incorporated, and can be more consistently incorporated, in citizen science practices. One specific way that citizen science projects can recognize volunteer efforts is through report-backs, which are unique to data-collection projects. After data analysis, practitioners can disseminate the results back to the volunteers who were vital to the data collection process. The Cornell Lab of Ornithology Toolkit recommends disseminating results, or report-backs, as soon as possible after data are collected and analyzed. Within a citizen science project, recognizing volunteer contributions helps maintain interest in research and help retain volunteers (Domroese, 2017). Recognizing volunteer efforts within individual projects is important, but impacts could also be measured across projects to better assess total volunteer contribution among projects of similar disciplines, locations, or other attributes.

Coordinating Volunteers

Coordination of volunteers as a unique contributor to an organization is another key element of best management practices. Many scholars have recommended intentionally distinguishing volunteers from paid staff in order to identify their unique contribution in a nonprofit organizational setting (Howlett, 2010; Studer & von Schnurbein, 2013; Studer, 2016; Renz & Herman, 2016). Common practices for onboarding and maintaining volunteers (which grew out of HRM) have included providing a job description, training, placement, and evaluation (Smith, 1996; Gaskin, 2003; Macduff, Netting, & O'Connor 2009). Despite the emphasis of supporting and providing training to volunteers, many nonprofit and charity organizations dedicate only part time staff (if any staff at all) to such tasks (Howlett, 2010). Furthermore, staff members in nonprofit organizations often do not have specific training (such as opportunities to attend workshops or conferences) in volunteer management (Eisner et al., 2009).

Similar to nonprofit literature, there is a strong focus on providing training and support to volunteers in citizen science projects. However, there are not existing studies about volunteer managers, and their background and training with regard to citizen science projects. The coordination of citizen scientists is largely centered on training for data collection, which can take place in person or online depending on the mode of the project. These workshops can be resource intensive, requiring trained paid staff and extensive infrastructures to support citizen science activities (Gallo & Waitt, 2011). Technology can help facilitate long distance training, and networks of skilled volunteers (i.e. “Train the Trainers”) are frequently used by citizen science projects. Training sessions are a result of an emphasis on data quality within all citizen science projects, a feature that is not shared by non-profit organizations. While participating in a citizen science project has been shown to help volunteers build skills (Becker-Klein, Peterman, & Stylinski 2016), formal professional development opportunities for volunteers are not extensively documented in citizen science best management practices. Furthermore, helping citizen science volunteers develop appropriate skills can require significant organizational time investment. A staff person dedicated to managing volunteers is important for troubleshooting problems as well as communicating expectations and disseminating results to volunteers (Gallo & Waitt, 2011). Projects without dedicated staff who manage volunteers require more staff to carry out the scientific activities of the project (Gallo & Waitt, 2011). There is a need to distinguish between paid and unpaid staff in both nonprofit organizations and citizen science organizations, as well as provide adequate support to volunteers within and across individual organizations. In such cases, coordinated volunteer management offers a solution.

A Shift Toward Coordinated Volunteer Management

Despite general knowledge of volunteer best management practices within nonprofit management, adoption of these activities is not widespread (Hager, 2004, Howlett, 2010). Brudney and Mejis (2019) argued for a Volunteer Stewardship Framework, which draws on the concepts of unitary or shared guidance for volunteers. Unitary guidance is provided by a single organization, while shared guidance operates under a shared responsibility of guidance between an organization and a partner. This framework further distinguishes between private and common pool energy. In this sense, private access refers to pools of volunteers such as school groups or corporate volunteers. Brudney and Mejis (2019) described private access as a form of "third-party involvement" or a host organization. Alternatively, common pool energy refers to volunteers not associated with a larger host organization. While citizen science has historically relied on common pool energy (i.e., the general public) to advance project goals, there has been a recent emergence of host organizations – like SciStarter.org, Anecdata, and CitSci.org which serve as host to thousands of projects – to facilitate private access and coordinate management. Accounting for and integrating these host organizations when developing volunteer management best practices is a critical consideration when recruiting, retaining, and coordinating different types of volunteers.

Despite these advances, however, both nonprofit and citizen science volunteer management has typically focused on individual projects rather than considering the larger landscape of volunteer opportunities. When considering this broader landscape, it may be possible to view the various opportunities to join multiple projects as a competition between projects for volunteer resources. We adopt the vocabulary proposed by Brudney and Mejis (2019), who describe a singular group managing volunteers as a "unitary attitude" toward volunteer management. This conceptualization can help researchers productively explore how and why project managers may view their volunteers in a more competitive or collaborative way. For example, managers who embrace unitary beliefs might tend to view volunteers as participants of a single project or one type of project. In these cases, managers might tend to work with volunteers in a way that assumes a singular commitment to their project, and thus prioritizes their own project's training, data collection, dissemination and evaluation. In reality, however, most citizen volunteers participate in multiple projects across multiple topics (Allf et al., 2019, in prep). This reality might render the unitary approach somewhat irrelevant and counterproductive. By adopting a regenerative approach initially suggested by Brudney and Mejis (2009) that incorporates cross-project best management practices, managers could help accommodate and respond to realistic volunteering patterns across projects. We refer to these collaborative practices and this overall mindset as shared management. Managers who embrace shared beliefs tend to view volunteers as moving between projects and understand the value of volunteer trajectories that span many projects.

Under all volunteer management frameworks (e.g., traditional HRM, regenerative, and volunteer stewardship approaches), project managers might display a range of orientations from unitary to shared. However, the prevalence of these different beliefs, and their implications for volunteer management, are largely unexplored. Whether managing projects unitarily or shared, project managers make choices that have broader implications for citizen science. The emergence of third party organizations that host volunteers (e.g., platforms such as SciStarter) needs to be incorporated into management structures for individual projects. These third party organizations facilitate the multi-project participation tendencies of many volunteers, which can help to advance the field.

Within this context, however, there is a growing need to assess the beliefs that individual project managers have about volunteers and the kinds of management practices they employ to accommodate (or perhaps inadvertently restrict) movement across projects. This study extends best practices in volunteer management and applies them to advance understanding of current volunteer management in citizen science. Our mixed methods approach sought to understand the diverse perspectives regarding citizen science volunteer management, the personal and project-related factors associated with those beliefs, and broader implications for project management. The primary objectives of our study were to:

1. Characterize the range of unitary to shared volunteer management orientations held by citizen science project managers
2. Identify factors associated with unitary to shared project management orientations including links to perceptions of sequential or simultaneous participation, volunteer involvement, and broader project impacts

METHODS

For this study we chose a sequential exploratory design (Creswell & Clark, 2011), which first involves a qualitative component that informs a quantitative component (Teddlie & Tashakkori, 2003). This design is ideal for explorations of new phenomena because it allows researchers to first understand the variety of viewpoints that exist, and subsequently to assess how widespread viewpoints are. Using this design, we first sought to understand existing perceptions about volunteer behavior and management through interviews with a strategically selected subset of project managers. Next, we assessed the prevalence of these beliefs across a broader range of SciStarter project managers using a survey.

Qualitative Methods: Interviews

To address research goal 1, we used qualitative methods to explore project managers beliefs about their volunteers and challenges associated with managing citizen science volunteers. We reached data saturation (no new statements or themes emerged) after 15 interviews. We intentionally selected 15 managers representing a range of projects across different disciplines, locations, number of volunteers, and modes of interactions – both within and outside of the SciStarter database (Table 1.1). We selected these attributes because they capture a variety of citizen science projects and may influence citizen science volunteer management approaches.

The fifteen projects we selected were grouped by discipline based on a citizen science project classification system described by Allf et al. (2019). For example, eleven project managers reported supervising ecology and environment projects, two supervised pollution projects, one supervised a health and medicine project, and one supervised a transportation and infrastructure project. In terms of locations, four of these projects could be conducted anywhere in the world, seven could be conducted anywhere in the United States, two could be carried out anywhere in a specific state, and two were within a specific watershed area. Regarding the mode of interaction, twelve projects included elements that involved physically being outdoors to participate and therefore were classified as “outdoor,” while the other three projects could be completed entirely “indoor.” Finally, three projects required participants to be present in person at a specific location to participate in the project. The remaining 12 projects could happen on an online platform, mobile application, or through email. Project location and or scope generally corresponded to the number of volunteers an organization worked with. For example, a project within a specific watershed generally worked with fewer volunteers than an online project that could be conducted anywhere in the world.

The qualitative interviews were semi-structured and featured two questions and additional prompts as needed (Table 1.2) (Bryman, 2012). Each interview was conducted via phone or Skype call and lasted between 20-35 minutes. During interviews, we asked each individual open-ended questions about how they viewed the movement of the participants in their specific program or project and how they viewed the movement of participants between citizen science projects as a whole (Table 1.2). We also asked open-ended prompts about volunteer numbers, volunteer data quality, ease of recruitment, opinions about volunteer recruitment from other projects, and the resources required to recruit and retain participants (Table 1.2).

Qualitative data were analyzed using the constant comparative method to identify recurring themes and classify responses to support emerging trends (Dey, 1993; Kolb, 2012). Themes were developed using open and axial coding. Themes were based on common words or phrases used by respondents, which indicated a structure of experiences or processes, which were evident in the raw data. Words or phrases that were similar and numerous were grouped and resulted in themes presented. Themes that emerged during qualitative data analysis were used to inform survey development during the second phase of the research (Creswell & Clark, 2011). Emergent themes were integrated into two sets of survey questions which mirrored interview questions asked with regard to volunteer movement within a project, and across the broader field of citizen science (Appendix 1.1). For example, statements regarding volunteer loyalty and preference for depth of participation during interviews were captured by a survey item "The best volunteers are dedicated to one project at a time," (Appendix 1.1). We identified five overarching themes or areas of interest which represented all key statements made by interview subjects.

Quantitative Methods: Surveys

To address research goal 2, we built on themes from the analysis of interviews. We surveyed additional citizen science project managers to determine how themes applied across a broader range of people and projects. Our initial targeted population was project managers on SciStarter, however, we expanded the invitation to members of the Citizen Science Association (CSA) listserv and several smaller water quality monitoring listservs to generate a larger and more diverse sample. Because of the nature of our distribution technique, it was not possible to estimate a response rate for participants given the uncertainties regarding the scope of the distribution. For example, we do not know how many participants saw the emails and were able to respond. Despite this limitation, our results suggested that survey responses included a variety of managers and projects.

We developed the survey by combining questions about project management structure as well as questions derived from interview themes. Each interview theme was broken down into a series of statements that were framed in both positive and negative terms to measure the relative agreement and disagreement of respondents (Table 1.3). We also included items to define project attributes adapted from existing scales (Hager, 2004), such as the number of volunteers managed, whether volunteers were managed by paid or unpaid staff, volunteer inclusion in a project, practices for recognizing volunteer contribution, volunteer involvement in an organization, and reported difficulty recruiting and retaining volunteers (Appendix 1.1). These questions were included in order to assess whether volunteers studied by nonprofit management researchers were different from citizen science volunteers or managers. Questions about project managers' beliefs regarding volunteer behavior and management were developed based on key themes derived from interviews (Table 1.3).

We sent the survey to project leaders with SciStarter accounts on November 15, 2018, and we sent a reminder on November 27, 2018. We also sent out the survey to the CSA listserv on November 27, 2018. At our request, a stream monitoring coordinator sent the survey invitation to two water-monitoring groups on December 6, 2018. We received a total of 138 responses to the survey, of which 59 were incomplete and therefore not included in analyses. This resulted in an effective sample size of 79 survey participants. We did not record any personally identifiable information from the surveys and did not collect demographic information about project managers.

For scales with multiple items, we averaged score responses and conducted oblique rotation of factor loadings to simplify the data structure and assessed the reliability of constructs using Cronbach's alpha. We verified content validity by ensuring that items within each factor were logical and interpretable. We retained factors that had factor loadings ≥ 0.400 (Table 1.4).

Factor Analyses for Volunteer Interactions and Values Scales

We conducted separate factor analyses for scales about volunteer involvement, difficulty recruiting volunteers, and difficulty retaining volunteers, all adapted from Hager (2004) surveys. We also created a new scale to measure perceived broader impacts of citizen science projects. These scales captured project managers' beliefs and behaviors regarding the way they perceive volunteers, volunteers' contributions to their project, and the overall impact of their project on citizen science more broadly.

How volunteers are involved in an organization can inform the way a project manager or organization values and acts upon volunteer input. The scale for volunteer involvement consisted of five items (Cronbach's α = 0.774) such as "the views of volunteers have a big effect on how my program develops" and "the leadership or senior management in this organization is in touch with the feelings of volunteers." This scale, which was adopted from Hager (2004) indicated the importance of volunteers to an organization (Table 1.4).

Recruiting and retaining volunteers can affect the beliefs of project managers. If a manager perceives difficulty with getting and keeping volunteers, they may be less likely to adopt shared beliefs. Two factors emerged in our analysis for these items. The first assessed difficulty with recruitment and was comprised of two items (Table 1.6): "recruiting enough volunteers," and "recruiting volunteers with the skills needed," (Cronbach's α = 0.571). The second assessed difficulty with retention and was comprised of two items (Table 1.7): "retaining enough volunteers," and "retaining volunteers with the skills needed," (Cronbach's α = 0.746).

A project manager's perception of the broader impacts of their citizen science project was defined by a single factor comprised of three items (Cronbach's α = 0.774, Table 1.8): which asked project managers the extent to which their project, empowers action, supports individual learning and, "[Builds] community (connecting fellow citizens, sharing information across networks, cultivating social capital)." This scale indicates the value a manager sees their project as a whole having on the world.

Factor Analyses about Volunteer Participation and Management Beliefs

We found two dimensions across two different scales with regards to beliefs about volunteer behavior and beliefs toward volunteer management. Both dimensions were measured in a project-specific and a general way to gather opinions about what people think volunteers are doing in their individual projects, and what project managers think about volunteers across the broader field of citizen science. The first dimension focused on beliefs about volunteer participation ranging from simultaneous to sequential project participation. Simultaneous participation in projects refers to the perception project managers have for their volunteers participating in multiple projects at the same time. This factor included three total items (Cronbach's $\alpha = 0.819$) such as "I help my volunteers find other opportunities when they leave my project." Sequential project participation refers to the perception that volunteers across the broader field participate in one project at a time, indicating the existence of an end-date for volunteers. The sequential factor included three items (Cronbach's $\alpha = 0.723$) such as "volunteers prefer to pick one project over another," and "the best volunteers are dedicated to one project at a time," (Table 1.4).

The second dimension focused on volunteer management beliefs, capturing both unitary to shared perspectives with regard to project-specific survey items as well as across the broader field of citizen science. Unitary beliefs refer to ownership-oriented perceptions regarding volunteers in their specific project. There were four total items (Cronbach's $\alpha = 0.729$) for this factor, including "I value loyalty in my volunteers." Shared beliefs refer to more collaborative perceptions of volunteer management across the broader field of citizen science. This factor included four items (Cronbach's $\alpha = 0.608$) and included items like "An abundance of exciting citizen science projects is good for volunteer recruitment," and "Competition for volunteers across different types of citizen science projects is not a problem,"(Table 1.4).

Linear Regression

We ran a linear regression model in two steps to evaluate the relative influence of project attributes (step 1) and manager beliefs and beliefs about volunteers (step 2), with shared volunteer management orientations within a project as the dependent variable for both.

Focusing on project attributes as the independent variables could identify structural influences on manager beliefs about volunteers. Variables about project attributes included variables about number of volunteers managed (<100), volunteer management structure (others manage), time managing volunteers (<25% time), length of time managing volunteers in this position (<1 year and between 1-5 years), and whether a project reports having “enough” volunteers (Table 1.9).

Focusing on managers’ beliefs and beliefs about volunteers illuminated predictors and correlates of shared management orientations. Independent variables about management perspectives included shared beliefs across the broader field of citizen science, beliefs about simultaneous project participation in a singular project, beliefs about sequential participation in projects across the broader filed of citizen science, volunteer involvement in an organization, the level of difficulty recruiting and retaining volunteers, and the broader impacts that a citizen science project reports having (Table 1.10).

RESULTS

Qualitative Interviews

In our analysis of 15 interviews with citizen science project managers, we identified four core themes related to shared management including uncertainty surrounding the quality of volunteer management, a preference for long-term engagement and deeper involvement of volunteers, perceived ownership of volunteers, and concerns about competition between projects.

Uncertainty about Quality Projects and Volunteer Management

Four respondents directly referenced existing evidence from their own project evaluations or published studies. This highlighted a knowledge gap between their personal professional experience and what others perceive in to be true across citizen science more broadly. This gap was repeatedly addressed, and respondents hesitated to speculate about overarching "best practices" regarding different aspects of citizen science including project design, implementation, impacts of their projects on other projects in the field, and potential media attention on their projects. Many project managers emphasized that there is very little we know about how to design and implement citizen science to achieve its full potential. "[Citizen science] is a new instrument that we don't know how to build totally yet…we don't know how to recruit, check data…and it is very variable." Respondents also indicated gaps in knowledge about whether project quality had an impact on recruitment to other projects. One respondent said that they do not have "evidence on whether project quality matters…not a data driven answer." Another respondent said that they do not have "data on horizontal movement [of volunteers]." A desire to base responses on project evaluations and published studies indicates a need for more research about citizen science volunteer best management practices.

Preference for Long-Term Engagement and Deeper Involvement of Volunteers.

Several project managers who offer multiple tiers of participation (short-term and long-term volunteer opportunities) indicated they were extra-appreciative of volunteers who were able to be long-term contributors. These respondents said things like "super volunteers are loyal," and that they are "always looking for the super volunteers and ideally those are doing more." This indicates not only a recognition of super volunteers, but also the desire to provide a good experience to those who contribute more to projects in order to retain them. Claims about how difficult it is to "keep good participants," indicates a preference for vertical movement (participants getting deeper involved in one project) rather than purely horizontal movement (participants switching to a new project with similar tasks or commitment), also indicating a belief that simultaneous participation in projects is not realistic. However, project managers also "worry about bandwidth and how many projects a person can reasonably do," indicating concerns and lack of knowledge about participation patterns among volunteers. Seven managers believed that volunteers stuck to one discipline and not moving around to "other types of projects." This assumption might stem from a perception of what managers think volunteers should be doing, but also from the tendency for single projects to offer deeper engagement. This might indicate to managers that volunteers do not have the time to participate in other projects.

Perceived Ownership of Volunteers

Project managers often expressed an ownership perspective of the volunteers in their project. The ownership perspective is indicative of the idea that volunteers only participate in one project, "recruiting from one project will leave an absence even if it doesn't happen immediately." Respondents used terms like "my volunteers," "vampiring," "wrongful poaching," and referred to "loyalty" of super volunteers. This could indicate a project manager's commitment to maintaining a working relationship with specific volunteers who participate in their project and a desire to maintain that relationship. However, an ownership perspective could also lead to unintended and less desirable consequences such as volunteer burnout. These are concerns related to removing volunteers from an existing volunteer pool. When forming these perspectives, it appears that managers generally do not account for volunteers' participation in multiple projects or potential collaborations with projects of the same type.

Concerns about Competition or Collaboration Between Projects

Most project managers we interviewed indicated that they had enough volunteers in their projects. Six respondents expressed reluctance to adopt systems (like SciStarter.org) that recommend projects to participants. On these third-party platforms, project managers feared certain projects could be favored over others, creating an easier path for volunteers to "view competitors" and therefore leaving a given project. However, sharing data was regarded positively by most interviewees. Many viewed collaboration (or sharing data and volunteers) as an important part of the scientific process. Some volunteers reported that they would be willing to "share" volunteers if there was a prior mutual agreement among project managers or if intentionally planning to share participants was part of the project planning process. Concerns expressed by project managers centered around willingness to collaborate but cautiously, "we can't be too rosy with that." Other perspectives indicated a belief that volunteers spend a "finite amount of time [...] on any one project," so planning for turnover is essential. Managers expressed a combination of unitary beliefs about competition between projects (and the challenge of retaining volunteers) but also a desire to collaborate in favor of science. Overall, uncertainty surrounding volunteer management, a preference for long-term and deeper involvement of volunteers, perceived ownership of volunteers, and concerns about competition between projects indicate an overall presence of unitary beliefs, and project-first volunteer management from the managers interviewed.

Quantitative Surveys

Through quantitative surveys with citizen science project managers, we sought to identify factors associated with shared project management perspectives, including links to volunteer involvement, recruitment and retention, and broader project impacts. Survey responses (n=79) revealed a range of project attributes with respect to volunteer management. In our sample, the majority of respondents in our survey (83%) reported management of less than 1000 volunteers, and the majority of volunteers are managed by paid staff (66%). Most project managers (53%) reported spending less than 25% of their time managing volunteers, and more than half of managers (61%) have been managing volunteers less than 5 years. Approximately a third of managers (32%) reported that they do not feel like they have as many volunteers as they want.

For items about volunteer involvement in an organization (Table 1.5), means for responses ranged from 3.4 to 3.9, indicating volunteers involvement is valued for most managers. However all means are below four on a 5 point scale, also indicating there is room for growth with regard to volunteer involvement.

For items about difficulty with volunteer recruitment (Table 1.6) and retention (Table 1.7), means for responses ranged from 4.03-7 (where the scale ranged from 0-No Difficulty to 10-Extreme Difficulty) indicating that most respondents had some difficulty recruiting and retaining volunteers. For items about broader impacts of a project (Table 1.8), means for responses ranged from 3.8-4.4 indicating that most project managers felt that their projects had some level of broader impacts.

Regression

Results of the first step of our linear regression did not support the existence of a significant relationship between the project attribute variables and project-specific volunteer management orientations (unitary vs. shared), (F (6,66) = 1.34, p=0.252, R^2 = 0.108 (Table 1.9). Within this model, the strongest albeit insignificant predictor of a shared attitude toward managing volunteers is having spent longer than a year managing volunteers (B = -0.437, p = 0.078). In other words, those who have spent less time managing volunteers tend to have more unitary beliefs toward volunteer management.

The second step of the regression (Table 1.10) indicated that both general and specific volunteer management orientations were much better predictors of project-specific volunteer management orientations (unitary vs. shared), F (7,70) = 7.73, p = 0.000, R^2 = 0.436. For example, beliefs favoring shared volunteer management were linked to shared beliefs about citizen science more broadly ($B = 0.324$, $p = 0.006$), (Figure 1.1). Shared perspectives were also strongly related to beliefs that volunteers participate in projects simultaneously ($B = -0.254$, $p = 0.028$, (Figure 1.2) and volunteer involvement ($B = 0.057$, $p = 0.003$, Figure 1.3). Finally, those who reported their citizen science project had stronger broader impacts were also more likely to believe in shared volunteer management ($B = 0.072$, $p = 0.026$, Figure 1.4).

DISCUSSION

Based on our qualitative research results, we found evidence of unitary or proprietary views of volunteers among citizen science project managers. Themes representing these views included uncertainty surrounding quality of volunteer management, a preference for long-term involvement, a preference for deeper engagement in a single project, perceived ownership of volunteers, and concerns about competition between projects. Managers who adopt these views may be embracing management practices from the perspective of individual projects (Cornell Lab of Ornithology Toolkit and Federal Crowdsourcing and Citizen Science Toolkit).

Results from our survey suggest that unitary orientations are likely to yield unitary management practices. For example, those who had unitary beliefs about their own projects also believed that volunteers participate in projects sequentially (Figure 1.1). Sequential participation in projects indicates a belief that volunteers have an expiration date in any given project, and that they do not have the capacity to contribute to more than one project at a time. This also corresponds with the majority of our survey respondents reporting that they do not feel like they have “enough” volunteers in their citizen science projects. This is reflective of citizen science and volunteer management popular practices that suggest projects manage independently of other projects (Gallo & Waitt, 2011; Prysby & Supec, 2007; Cornell Lab of Ornithology Toolkit, Federal Crowdsourcing and Citizen Science Toolkit).

Regardless of their management perspective (shared vs. unitary), managers must recruit and retain volunteers for a successful project. Managers who perceive difficulty recruiting and retaining volunteers in citizen science may view volunteers through a Human Resources Management (HRM) perspective (Howlett, 2010). This approach orients volunteers as employees of an organization and presents a linear volunteer trajectory from recruitment of a new volunteer to strategies to retain the volunteer including reports about performance, ending with volunteer separation (Studer &Von Schnurbein, 2013). Few studies have measured the efficacy of this management method, but criticisms include differences in how organizations view volunteers (laypeople vs. experts) (Merrell 2000, Netting et al. 2005). However, our results suggest that a more regenerative or shared approach to volunteer management, that utilized third-party organizations could be particularly helpful in the context of citizen science.

Benefits associated with shared management include increasing the value of volunteer involvement in an organization and expanding broader project impacts. Those who reported shared volunteer management orientations within their own projects expressed similar views across the broader field of citizen science (Figure 1.1). These patterns suggest that a culture of shared management for volunteers, if normalized, could make practices like sharing data and training volunteers for projects with similar activities more readily acceptable, or even expected, of citizen science projects. Furthermore, shared management beliefs did not appear to impact recruitment and retention (Table 1.6, Table 1.7). This suggests that there are benefits to shared management without major cost.

Project-related attributes were not strongly linked to any particular beliefs about volunteer management (unitary or shared). This indicates that a range of beliefs about volunteer management can exist in any context, and that projects of all kinds can influence (both positively and negatively) volunteer management and broader outcomes. Volunteer management practices impact volunteer experiences, and good (or bad) volunteer experiences have impacts on the overall field of citizen science. This idea is supported by Brudney and Meijis (2009), who suggest that investing in volunteer management is necessary to renew the critical volunteer resource. Citizen science project managers should therefore think more critically about how they view their volunteers and how their perceptions may impact volunteer management practices.

Volunteer participation in citizen science projects requires thoughtful planning on the part of those who manage volunteers. Previous research in the nonprofit sector has studied volunteer management practices and effects on recruitment and retention. However, these practices are not broadly adopted (Hager et al. 2004). Citizen science volunteer management faces a similar predicament, where presumed best management practices for volunteers are easily identified or applied (Tables 1.5, 1.6, 1.7, 1.8, 1.9). While we can learn a lot from volunteer management practices outside of citizen science, there are differences between traditional volunteering and citizen science volunteering. There is an emphasis in citizen science volunteer management best practices on providing data report backs to volunteers (Cornell Lab of Ornithology Citizen Science Toolkit, Federal Crowdsourcing and Citizen Science Toolkit). This is an integral part of maintaining communication with volunteers, which is a standard shared by nonprofit volunteer management literature (Renz & Herman). However, informing volunteers how their contribution to a project advances a research goal is a key difference between the two types of volunteering. By emphasizing a shared or regenerative cohort of citizen science participants, managers may be able to boost volunteer involvement and expand the broader impacts of citizen science. Our findings regarding the value of shared beliefs about citizen science volunteer management and factors associated with those orientations could help to illuminate elusive best management practices and the larger goals of citizen science as a collective field.

IMPLICATIONS AND CONCLUSION

The results of this study suggest that unitary or competitive management of volunteers, though prevalent in citizen science, may be counterproductive, both for volunteers themselves and for larger research goals. We recognize that there may be logistic barriers to volunteer management such as localized project goals, or staffing and funding. While unitary beliefs may grow out of necessity due to some of these barriers, our results suggest this is not always the reason. In many cases, managers make a conscious decision to embrace a proprietary approach. Adopting shared beliefs over unitary beliefs is more conducive for most project management practices, including growing volunteer populations, recognizing and measuring volunteer impacts, and coordinating volunteers. An emergence of third-party organization also supports shared beliefs toward volunteer management. Because we know most volunteers participate in multiple projects, third-party organizations are uniquely positioned to help volunteers find opportunities and collect information about their contributions across projects. The awareness of limitations of unitary or shared beliefs is important for volunteer managers to recognize. The existence of these volunteer beliefs with regard to a project, and importance of each individual citizen science project with regard to how it may fit into an ecosystem of diverse project is good for meeting volunteer needs, for science, and for the future of the field of citizen science.

There is value in adopting shared management approaches on multi-project platforms like SciStarter, which greatly advances the potential of citizen science to produce not just more data for science, but a more engaged community of science whose expertise and interactions span the boundaries of projects. Beliefs about shared volunteers can also support management practices such as measuring the collective impact of a volunteer across multiple projects and providing training for volunteers that can be useful in multiple projects. Such an approach is facilitated by third-party platforms like SciStarter, which already support and provide these functions. In citizen science, things like matching volunteers' skills with appropriate assignments can help to align with the motivations that drive many people to volunteer (Larson et al. 2019, in press). Furthermore, evidence suggests managers who have different ways for volunteers to participate can better accommodate different motivations (Jennet et al., 2016; Cooper et al., 2007). Third-party platforms can also foster volunteer movement between projects that are similar in discipline or activity. Collaboration between projects within the same discipline where one could be used as a "training" or entry point for another project could reduce training resources for citizen science practitioners. Future research could help highlight more ways in which third-party organizations could successfully support individual projects and volunteers navigating the larger citizen science landscape.

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Table 1.1. Description of citizen science project managers interviewed by discipline, location, mode, and how data is submitted to a project.

Project ID	Discipline	Location	Mode	Data Submission
1	Ecology and Environment	United States	Outdoor	Mobile application
2	Ecology and Environment	United States	Outdoor	Online platform
3	Ecology and Environment	Global	Indoor	Online platform
4	Ecology and Environment	United States	Outdoor	Online platform
5	Ecology and Environment	United States	Outdoor	Online platform
6	Ecology and Environment	Within a state	Outdoor	In person
7	Ecology and Environment	Within a state	Outdoor	Email submission
8	Ecology and Environment	Global	Indoor	Online platform
9	Ecology and Environment	United States	Outdoor	Online platform
10	Ecology and Environment	Within a state	Outdoor	In person
11	Ecology and Environment	United States	Outdoor	Online platform
12	Health and Medicine	Global	Indoor	Online platform
13	Pollution	Global	Outdoor	Mobile application
14	Pollution	Within a watershed	Outdoor	In person
15	Transportation and Infrastructure	United States	Outdoor	Online platform

Table 1.2. List of primary interview and probing questions posed to citizen science project manager interviewees.

Primary questions asked
Tell me your impressions about citizen science volunteers and their participation and movement among projects? (asked with respect to their own project)
Tell me your impressions about citizen science volunteers and their participation and movement among projects? (asked with respect to citizen science as a whole)
Probing questions
Do they join one project primarily and others peripherally?
Do they belong equally to several projects at once or move from project to project?
Is there a shortage of volunteers? A shortage of good volunteers?
Do volunteers who do one project submit higher quality than data than those who do many projects?
Are good volunteers hard to recruit?
Do (is it ok for) projects recruit from other projects?
Are good volunteers hard to keep?
Does recruiting and retaining participants require a lot of resources?
Does the abundance of projects (in general and in your domain) make it easier or harder to recruit and retain volunteers?
Does the quality of projects (in general and in your domain) influence your ability to recruit and retain? (positively, negatively, neutral?)
Can/does media attention on one project influence attention to another/your project?
Is there anything else you'd like to add?

Table 1.3 Interview Themes and Related Survey Questions

Interview Theme	**Survey Questions**
Uncertainty surrounding existing best management practices and project design	To effectively manage volunteers, I need to learn more about their broader interests and activities To effectively manage volunteers, I need to learn more about their education and economic status We still have a lot to learn about the effective management of citizen science volunteers My project will never experience a volunteer shortage because there will always be enough volunteers to go around Citizen science volunteers are a renewable resource--they are many and turnover is continual Citizen science volunteers are a limited resource--they are few and turnovers are not replenished
Preference for long-term engagement and deeper involvement of volunteers	I value loyalty in my volunteers Most of my best volunteers only participate in my project. My volunteers are better than volunteers on other projects I think all volunteers are important no matter how much they contribute to my project The best volunteers are dedicated to one project at a time Citizen science volunteers are able to effectively participate in multiple projects at the same time Volunteers prefer to pick one project over another
Perceived ownership of volunteers	I only care about citizen science volunteers when they are engaged in my project I love to see my volunteers joining other citizen science projects
Concerns about competition between projects	My volunteers don’t participate in other citizen science projects I don’t recruit volunteers engaged in other projects If volunteers have bad experiences on other projects, they are less likely to try my project I help my volunteers find other opportunities when they leave my project If volunteers have bad experiences on other projects, they are less likely to try my project Competition for volunteers among similar citizen science projects is less important when volunteer observations go to an open, shared data repository An abundance of exciting citizen science projects is good for volunteer recruitment There is strong competition for volunteer time among similar citizen science projects Competition for volunteers across different types of citizen science projects is not a problem

Table 1.4 Factor Analysis for Scales Describing Citizen Science Project Managers' Beliefs about Volunteer Behavior and Volunteer Management

Factor (with Items)			**Factor Loading**			
	Mean	SD	1	2	3	4
Factor 1: Beliefs about volunteers in their project (simultaneous) (3 items, Cronbach's α = 0.819)						
I help my volunteers find other opportunities when they leave my project (reverse)	3.83	1.086	-0.748			
My volunteers don't participate in other citizen science projects	1.96	0.916	0.889			
Most of my best volunteers only participate in my project	2.18	1.145	0.636			
Factor 2: Beliefs about volunteers across broader field (sequential) (3 items, Cronbach's α = 0.723)						
The best volunteers are dedicated to one project at a time	2.440	1.00953		0.736		
Citizen science volunteers are able to effectively participate in multiple projects at the same time (reverse)	2.0886	0.75430		0.664		
Volunteers prefer to pick one project over another	3.0380	0.82342		0.608		
Factor 3: Collaborative vs. competitive attitudes, project-specific (4 items, Cronbach's α = 0.729)						
I value loyalty in my volunteers	3.29	1.150			0.476	
I think all volunteers are important no matter how much they contribute to my project	4.11	0.928			0.590	
I love to see my volunteers joining other citizen science projects	4.18	0.792			0.775	
I only care about citizen science volunteers when they are engaged in my project (reverse)	4.35	0.748			0.791	
Factor 4: Collaborative vs. competitive attitudes, broader field (3 items, Cronbach's α = 0.608)						
Citizen science volunteers are a renewable resource—they are many and turnover is continual	2.71	1.106				0.552
Competition for volunteers among similar citizen science projects is less important when volunteer observations go to an open, shared data repository	3.10	0.906				0.539

Table 1.4 *(*Continued)

An abundance of citizen science projects is good for volunteer recruitment	3.90	0.815	0.495
Competition for volunteers across different types of citizen science projects is not a problem	3.50	0.785	0.551

Prompt(s): Indicate how much you agree with the following statements about volunteers in your citizen science program.
Indicate how much you agree with the following statements about volunteers in your citizen science program.

Scale: Strongly disagree (1), Disagree (2), Neutral (3), Agree (4), Strongly agree (5)

Table 1.5 Factor Analysis for Volunteer Involvement in an Organization

Factor (with Items)	Mean	SD	**Factor Loading**
Factor 1: Beliefs about volunteer importance to an organization (5 items, Cronbach's α = 0.774)			
Q9_1 The views of volunteers have a big effect on how my program develops	3.953	1.027	0.482
Q9_2 Lots of volunteers feel as though this organization appreciates their efforts	3.870	0.842	0.675
Q9_3 The leadership or senior management in this organization is in touch with the feelings of volunteers	3.406	1.033	0.518
Q9_4 The board/governing body/management committee of this organization receives regular reports about the part that volunteers play in the organization	3.5	1.124	0.702
Q9_5 When this organization makes plans for a new service, activity or project, it makes a big effort to consider the part which volunteers can play in that	3.858	1.135	0.739

Prompt: Please indicate the extent to which you disagree or agree with each of the following statements about volunteer involvement in your organization or project

Scale: Strongly disagree (1), Disagree (2), Neutral (3), Agree (4), Strongly agree (5)

Table 1.6 Factor Analysis for Difficulty Recruiting Volunteers in an Organization

Factor (with Items)	Mean	SD	**Factor Loading**
Factor 1: Recruiting sufficient volunteers (2 items, Cronbach's α = 0.571)			
Recruiting enough volunteers	4.831	2.740	0.527
Recruiting volunteers with the skills needed	4.439	2.780	0.527

Prompt: Please indicate to what extent you experience difficulties with recruiting volunteers

Scale: No difficulty (0), Moderate difficulty (5), Extreme difficulty (10)

Table 1.7 Factor Analysis for Difficulty Retaining Volunteers in an Organization

Factor (with Items)	Mean	SD	**Factor Loading**
Factor 1: Retaining sufficient volunteers (2 items, Cronbach's α = 0.746)			
Retaining enough volunteers	4.634	2.764	0.689
Retaining volunteers with the skills needed	4.036	2.659	0.689

Prompt: Please indicate to what extent you experience difficulties with retaining volunteers

Scale: No difficulty (0), Moderate difficulty (5), Extreme difficulty (10)

Table 1.8 Factor Analysis for Broader Impacts of Citizen Science Projects

Factor (with Items)	Mean	SD	**Factor Loading**
Factor 1: Broader impacts of an organization (3 items, Cronbach's α = 0.774)			
Q18_3 Individual learning (increasing science literacy, increasing science efficacy, improving skills, boosting interest in certain topics)	4.405	0.650	0.587
Q18_4 Building community (connecting fellow citizens, sharing information across networks, cultivating social capital)	4.101	0.856	0.736
Q18_5 Empowering action (stimulating action on science-related issues, giving people a voice in decision-making, increasing public support for science)	3.835	1.09	0.709

Prompt: To what extent do you think your citizen science project is generating the following broader impacts?

Scale: Definitely NOT (1), Probably NOT (2), Not sure (3), Probably yes (4), Definitely yes (5)

Table 1.9. Project attributes that predict unitary vs. shared beliefs with respect to their own project. *(n = 73); $R^2 = 0.108$; p = 0.252*

Variable	*Mean*	*SD*	*B*	*SE*	*P> |t|*
Constant			4.186	0.333	
Number of volunteers managed (<100)	0.441	0.499	-0.242	0.184	0.193
Volunteer management structure (others manage)	0.323	0.469	-0.022	0.181	0.905
Time managing volunteers (<25%)	0.569	0.497	0.017	0.168	0.918
Length of time managing volunteers (<1 year)	0.216	0.414	-0.437	0.244	0.078
Length of time managing volunteers (1-5 years)	0.397	0.492	-0.301	0.179	0.098
Enough volunteers	0.679	0.697	0.047	0.184	0.797

Table 1.10 Project beliefs that predict a unitary vs. shared attitude with respect to their own project. *(n = 73); R^2=0.426, p= 0.000*

Variable	*Mean*	*SD*	*B*	*SE*	*P> |t|*
Constant			1.583	0.720	
Shared beliefs in general[a]	3.314	0.616	0.324	0.113	0.006
Volunteer beliefs (simultaneous)	2.109	0.902	-0.092	0.079	0.249
Volunteer beliefs (sequential)[a]	2.510	0.702	-0.254	0.113	0.028
Volunteer involvement[a]	18.5	3.815	0.057	0.018	0.003
Difficulty recruiting volunteers[b]	9.216	4.625	0.016	0.21	0.441
Difficulty retaining volunteers[b]	9.670	4.845	0.001	0.019	0.925
Broader impacts[c]	12.341	2.153	0.072	0.31	0.026

[a]Scale: 1 = strongly disagree to 5 = strongly agree.
[b]Scale: 1 = no difficulty to 10 = extreme difficulty.
[c]Scale: 1 = definitely not to 5 = definitely yes.

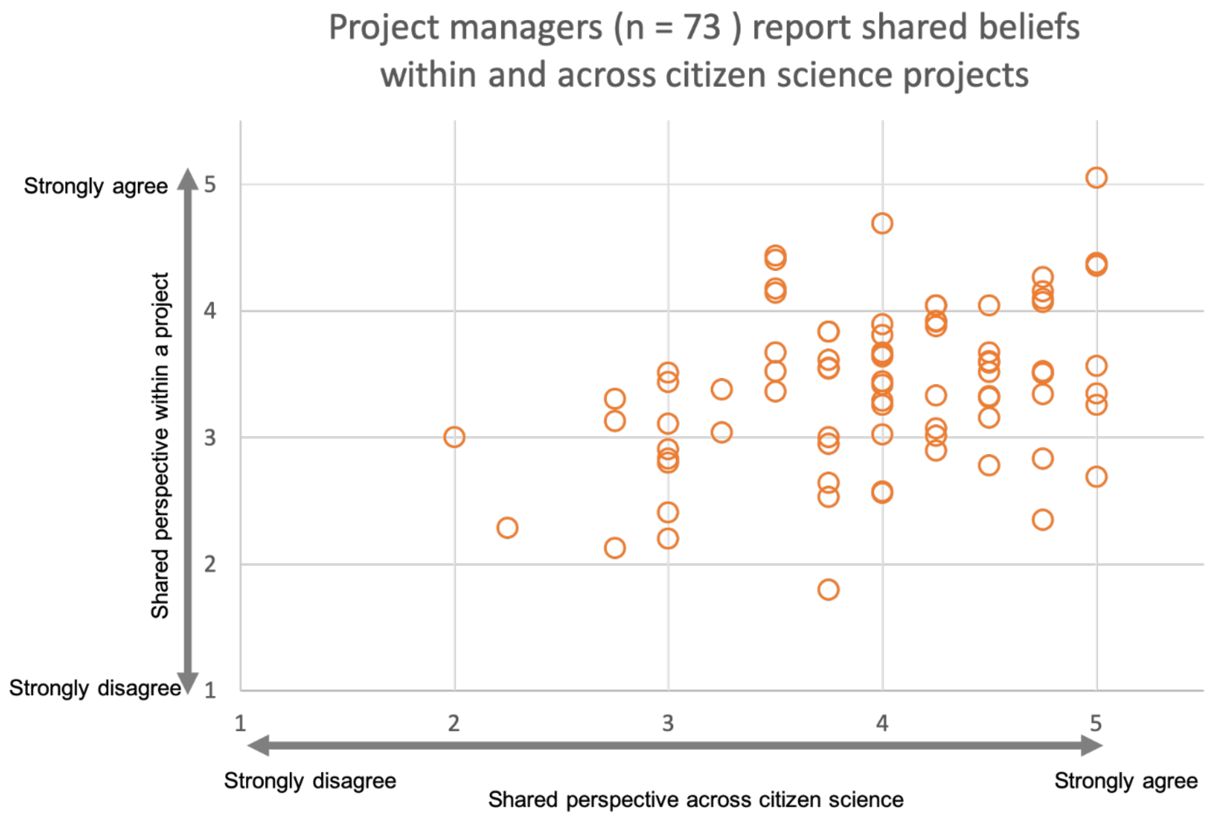

Figure 1.1 Project managers with a shared perspective within their citizen science project also tend to view the field others as having shared management orientations.

Figure 1.2 Project managers with more shared beliefs perceive sequential volunteer participation in projects.

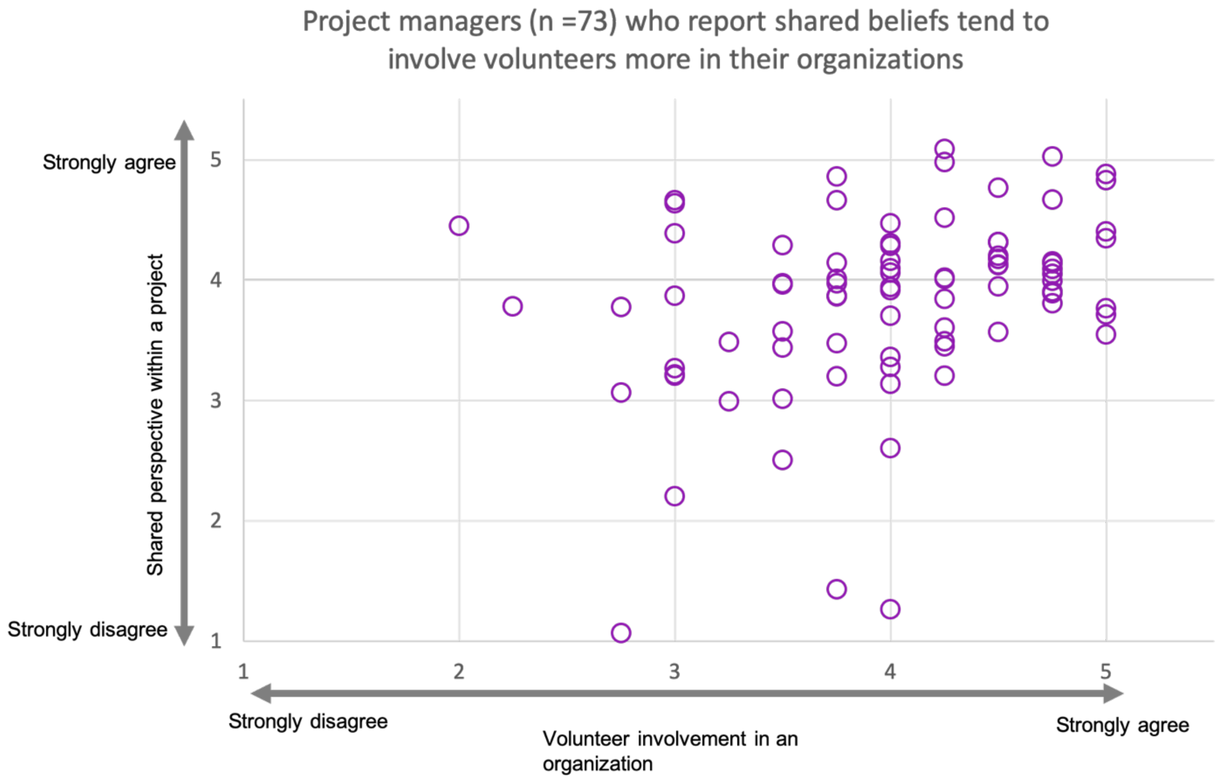

Figure 1.3 Project managers with shared beliefs tend to value volunteer involvement in their organization more.

Figure 1.4 Project managers who have more shared beliefs tend to report stronger broader impacts within their project.

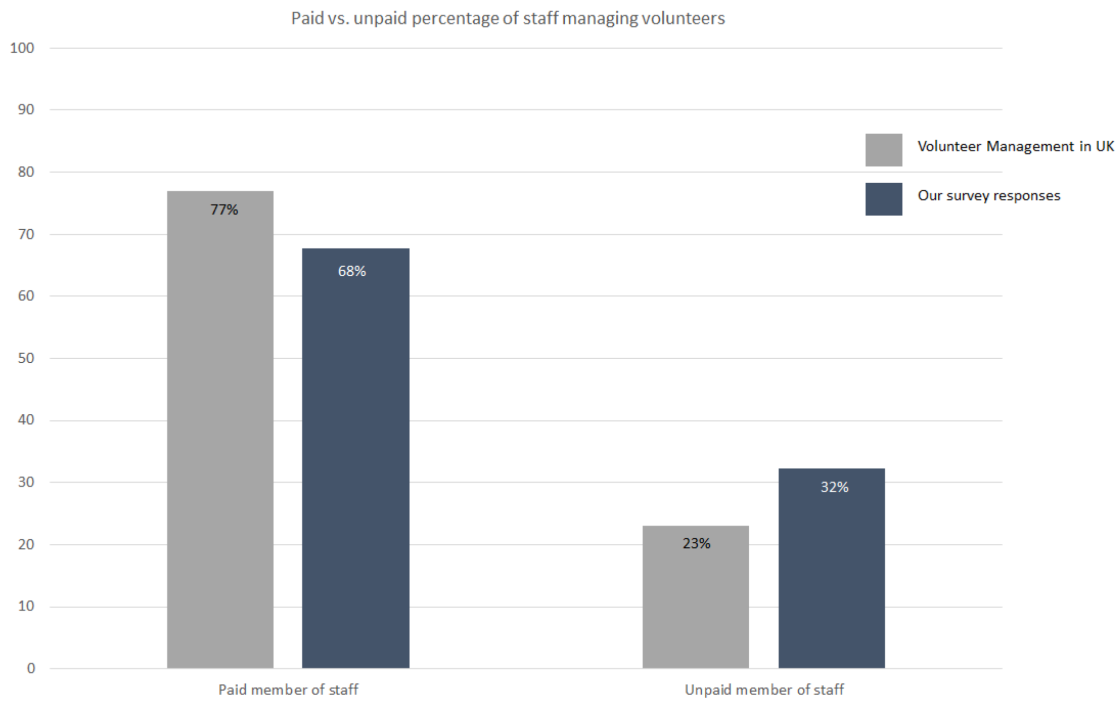

Figure 1.5 Comparison of total percentage of paid staff to unpaid staff who manage volunteers.

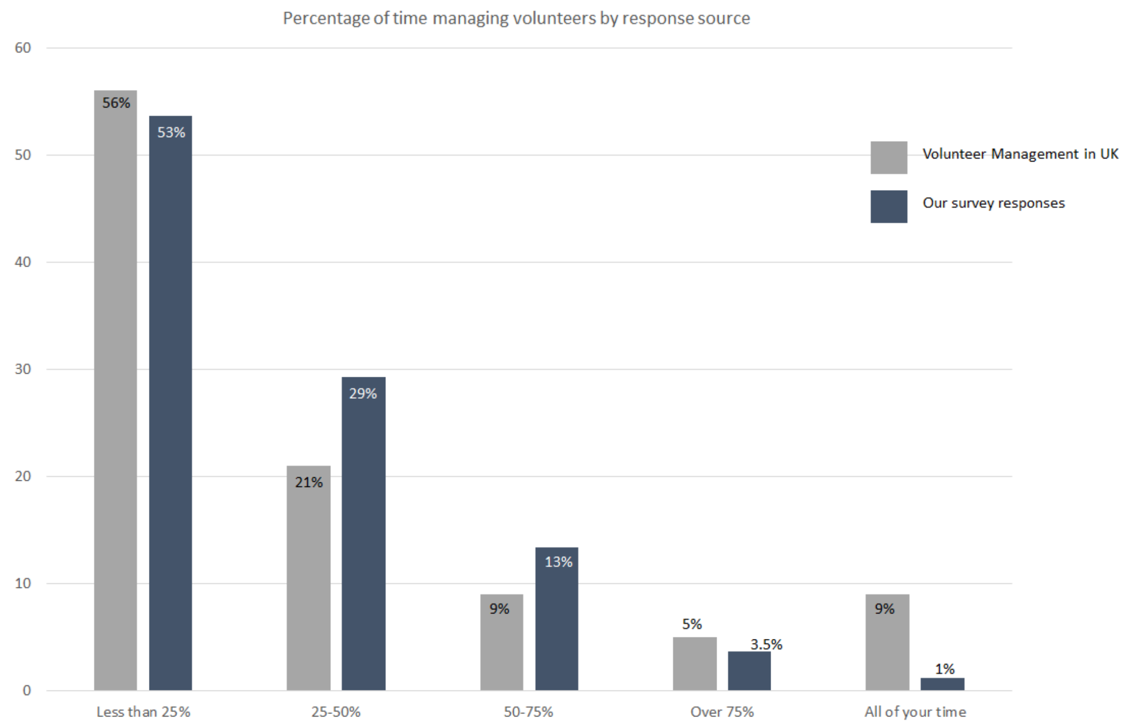

Figure 1.6 Comparison of time spent managing volunteers by survey source.

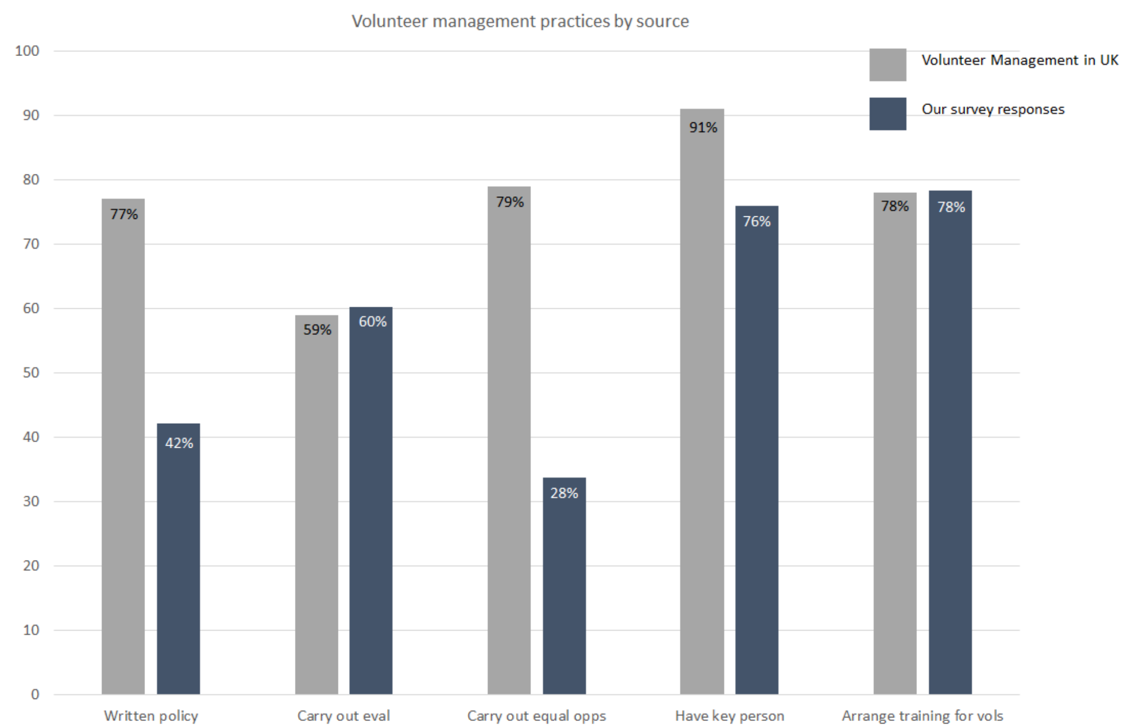

Figure 1.7 Comparison of volunteer management practice by survey source.

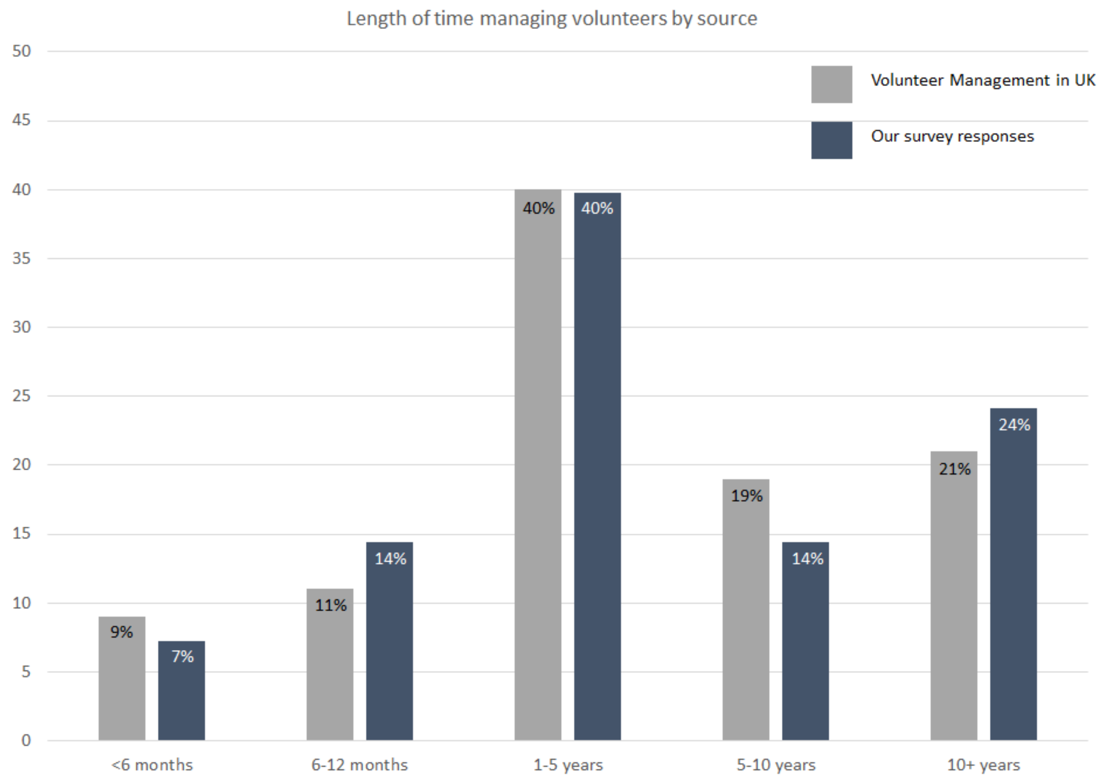

Figure 1.8 Comparison of length of time spent managing volunteers in current position by survey source.

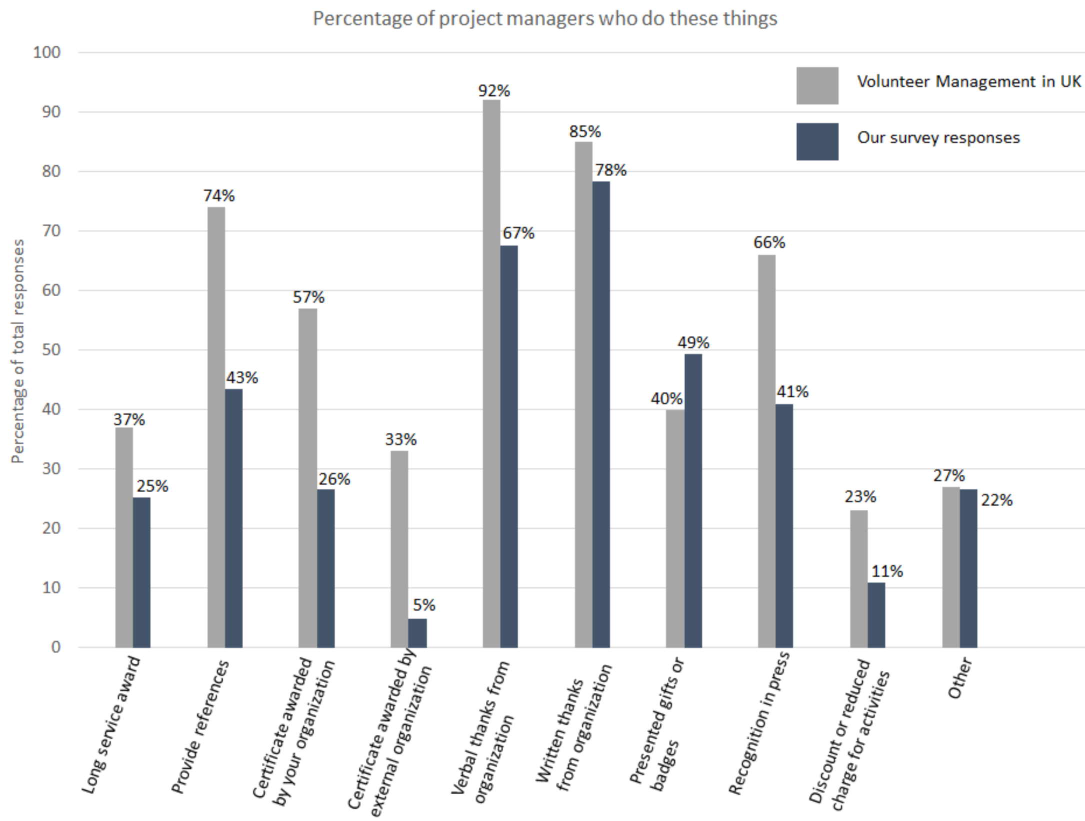

Figure 1.9 Comparison of volunteer recognition practice by survey source.

CHAPTER 2

MEASURING THE SCIENCE AFFINITY, EFFICACY, AND AGENCY OF CITIZEN SCIENTISTS ON A MULTI-PROJECT PLATFORM

ABSTRACT

Evaluating citizen science projects is an important way ensure that a project is meeting its goals. Currently, most evaluation efforts take place within individual projects. However, the emergence of third-party organizations (e.g., SciStarter.org) provides an opportunity to assess volunteer participation and learning across multiple projects, thereby provide a more accurate reflection of volunteers' broader connections to science. We characterized connection to science using three constructs: interest in science (affinity), confidence engaging in science (self-efficacy for science), and intent to integrate science into personal actions (agency). Citizen science, particularly multi-project participation, has the potential to promote these connections. To evaluate this potential, we surveyed citizen science volunteers who are members of SciStarter affiliate projects (n = 185) to examine their science affinity, self-efficacy for science, and science agency. Using digital trace data from the platform, we then examined the participation patterns (e.g., number of projects joined, number of bookmarks, and number of contributions) that were linked to higher levels of connections to science. We found remarkably high scores across all constructs regardless of project participation, suggesting that either (a) citizen sciences fosters high levels of science connection, (b) citizen science attracts individuals who already possess strong connections to science, and/or (c) our survey only reached a self-selected group of exceptionally dedicated volunteers who are not representative of the population. We did not observe connections between connections to science and either breadth (e.g., projects spanning multiple disciplines) or depth (e.g., number and time of data contributions) of participation.

Future research could utilize third-party platforms to continue exploring broader learning outcomes for citizen science volunteers.

INTRODUCTION

Citizen science has grown as a field in the last 20 years, both in number of projects (breadth), and in number of contributions from volunteers (depth) (Silvertown, 2009: Hoffman et al. 2017; Parrish et al., 2019). Measuring the impacts of volunteering on individuals is challenging and has typically been done within individual projects or disciplines (Cooper, 2016; McKinley et al., 2017; Bonney, Phillips, Ballard, & Enck, et al., 2016; Ballard, Dixon, & Harris, et al., 2017). However, we know that most volunteers participate in more than one project (Allf et al., 2019 in prep). Consequently, researchers need to consider volunteer experiences across projects and the ways in which multi-project participation can impact a broader range of learning outcomes. By not assessing volunteer learning across projects, we do not know the full extent of what volunteers gain from their experience or how greater breadth and depth of participation fosters deeper connections to science.

A scientifically literate society is important to understanding and responding to scientific, technological, and environmental issues (Miller, 2004). In the United States, current understanding of scientific inquiry, as measured by the Science and Engineering Indicators (SEI), grew from 32% in 1992 to 43% in 2016 (Chapter 7: Science and Technology, 2018). However, more could be done to improve science literacy. The majority of adults in the United States say that science has positive impacts on society in terms of our health care, food resources, and environment (Pew Research Center, 2015), and those who have higher factual knowledge about science tend to have more positive and trusting views of scientists (Pew Research Center, 2019). Furthermore, understanding the scientific process can help increase trust among scientists and nonscientists (Fischhoff, 2013).

Citizen science is a powerful tool that can address dual goals of generating data to answer scientific research questions while contributing to a larger public understanding of science (Bonney et al., 2009). Participating in a citizen science project can help increase knowledge of scientific facts (Brossard et al., 2005, Trumbull et al. 2005), increase ecological literacy (Jordan et al., 2009), developing new skills, and developing deeper interest in projects (Bonney et al., 2009). Citizen science could be a valuable tool in building public understanding, connection, and trust in science, measured through outcomes such as skills gained and knowledge of the nature of science (Bonney et al., 2016). These expanding connections to science fueled by citizen science participation might manifest in several forms: interest in science (affinity), confidence engaging in science (self-efficacy for science), and intent to integrate science in everyday actions (agency). Other research, like the Cornell Lab of Ornithology's DEVISE instrument scales have been developed to assess learning, skill building, and more across citizen science projects, indicating growing interest in learning across the broader field of citizen science.

Science Affinity

Interest in science is considered a key driver for sustaining this life-long learning in adults (Americans, Life Long Learning, 2016; Dabney et al., 2011; Falk, Storksdieck, & Dierking 2007). Affinity has proven to be an important precursor to action in related sectors. Eco-affinity, or personal interest in nature and intention to engage in pro-environmental behavior, has motivated environmental action (Kals, Schumacher, & Montada, 1999; Larson et al., 2011). A broader definition that spans scientific disciplines should encompass personal interest in the sciences, and capture intention to engage in supporting scientific inquiry. Just as eco-affinity can lead to action in the environmental context, broader science affinity could lead to pro-science behavior.

In K-12 education, there is evidence to suggest that attitudes toward science are predictive of student persistence in science and in science achievement. Stake & Mares (2005) found that after participating in an inquiry-based science enrichment program, students who described themselves as less confident before the program, reported themselves to be more confident and motivated after program completion.

Interest in science, however, has not been as extensively measured in adults (Brossard, 2005; Falk, Storksdieck, & Dierking, 2007), and the ways in which interest in science develops, is promoted, or can dissipate after leaving school requires more attention (Krapp & Prenzel, 2011). In one study, nearly half of adults reported that their understanding of science is derived from leisure and free-choice learning, implying that affinity and interest are key (Falk et al., 2007). Citizen science is uniquely positioned to provide a way for adults, in their free time, to exercise and nurture an interest in science by directly contributing to scientific research. We therefore conceptualized science affinity as one key outcome variables indicating a broader connection to science.

Self-efficacy for Science

Self-efficacy refers to the personal expectations one has about their ability to perform a specific task or behavior (Bandura, 1986). The ability to learn content and perform particular behaviors is associated with choice, effort, and persistence in the pursuit of those behaviors (Bandura 1982; Schunk 1991). Self-efficacy for science is a component of environmental citizenship that involves empowering people to identify their values and goals with respect to the environment and act accordingly (Berkowitz et al. 2005). In the context of science, self-efficacy can be defined in two ways. First, it can be understood as the process of learning about and understanding science. Second, it can also extend to the action of doing science. It is important to measure whether individuals have sufficient skills, knowledge, confidence, and opportunity to identify personal and community values. One study by Andrew (1998) found that within a group of nursing students, those who had higher self-efficacy for science performed better in subsequent years. The study also suggests there is potential for identifying students with lower self-efficacy earlier in their academic careers. In another study, Aschbacher, Li and Roth (2010) found that students who discovered interest and ability in science by participating in scientific activities raised their sense of self-efficacy. In addition to predicting academic achievement, self-efficacy can also be used to predict career decisions across domains and age levels (Britner & Pajares, 2006).

The concepts of choice, effort, and persistence, and self-efficacy may be particularly important when carrying out the principal activities of citizen science projects (Crall et al. 2011). In one study, citizen scientists performed an invasive plant survey following a one-day training. Those who were more comfortable with the activity were also more successful at identifying the correct species (Crall et al. 2011). If an individual has higher self-efficacy (a strong belief in their ability to perform a task), they may be more likely to participate in a citizen science project (Aschbacher, et al., 2010). In addition, exposure to multiple projects may have a positive impact on self-efficacy, however this construct has not been studied across citizen science projects. We therefore conceptualized self-efficacy for science as another key outcome variable indicating a broader connection to science.

Science Agency

The concept of critical science agency was developed with school groups and refers to student reliance on subject-matter knowledge to make change and act on an injustice in their lives (McNeill & Vaughn, 2012). Critical science agency is important to understanding science concepts and the ability individuals have to take action on individual and community levels (McNeill & Vaughn, 2012). Environmental Science Agency (ESA) is defined as 1) understanding environmental science content, 2) identifying areas of their own expertise, 3) using environmental science and community and citizen science to take action (Ballard, et al. 2017). This definition, based on the concept of critical science agency (Basu & Barton, 2010), is especially relevant in environmental justice contexts where individuals or communities are empowered to address issues that affects their health and wellbeing. A similar conceptualization of "agency" – particularly the last two components – could be expanded to discipline-agnostic science in general. We define science agency as science expertise as a foundation for (personal and/or societal) change. Research across multiple sectors suggests agency can indeed foster such change.

In one study of middle school students, Basu and Barton (2010) found that when students were asked about how they would change their science classrooms, they emphasized the importance of free choice to be more challenged and better focused. This enabled students to feel more empowered in their classroom learning. Free-choice learning was also positively associated with science understanding in adults participating in activities like reading books and using the internet (Falk, et al., 2007; Falk & Needham, 2013).

Citizen science may have a unique capacity to foster science agency. Previous studies have found that youth participation in citizen science increases knowledge about environmental sciences and content, ultimately increasing the range and depth of opportunities for students to identify and practice their own roles and areas of expertise within science and conservation (Ballard et al. 2017). However, while there are studies in which citizen science data have effectively changed policies (e.g. the Bucket Brigade) (Conrad & Hilchey, 2011), similar research about science agency has not been conducted with adult populations. Better methods are needed in order to adequately measure if and how citizen science volunteers express and enhance science agency. We therefore conceptualized science agency as a third key outcome variable indicating a broader connection to science.

Managing Volunteers and Measuring Outcomes Across Projects

If citizen science has the capacity to promote constructs like science affinity, self-efficacy for science, and science agency, to what extent are these outcomes realized and how might they be assessed? Because most volunteers participate in multiple citizen science projects, we need better approaches for measuring these science connection constructs to discover how citizen science can impact volunteers.

The emergence of third-party volunteer management organizations and platforms within citizen science can help. For example, SciStarter.org is an online repository for citizen science projects that connects volunteers and project owners. Organizations like SciStarter can facilitate connections to projects, track volunteer participation across projects, and provide that information to project owners. By using SciStarter as our test platform, we can learn about volunteer outcomes that are not specific to any one project or project type but rather cultivated across a broad spectrum of projects. Thus, when measured across project boundaries, constructs like affinity, efficacy, and agency will more accurately reflect connections that multi-project participants have to science.

About Embedded Assessments

Assessing volunteer outcomes across projects presents many challenges, however. In individual projects, learning outcomes are often measured through self-reported survey scales (Phillips et al., 2012). Using surveys to assess learning can be limiting due to response bias, survey fatigue, inaccurate reporting, and a variety of other factors (Phillips et al., 2012). Embedded Assessments (EAs) are an innovative way to understand what people gain from participating in citizen science projects and may provide opportunities for assessing learning outcomes across multiple projects at the same time. EAs can take different forms, but the defining feature of an EA is that it is a natural component of the program (e.g., growing accuracy of species ID during a data submission process), as opposed to an extra activity like a self-reported survey (Becker Klein et al., 2016). Because EAs are integrated into program activities, there is no risk of survey fatigue and learning can be assessed continually. Previous studies using EAs have focused on skill development as learning outcomes linked to participation in individual projects (Becker Klein et al., 2016). Our study explores a platform-wide application of EA in which information about volunteer activity (trace data) is used as a predictor of a volunteer's connection to science across multiple citizen science projects (Table 2.1). Our study attempts to use trace data to examine whether participation metrics could be used as a proxy for connection to science, predicting scores on constructs including science affinity, self-efficacy for science, and science agency. By developing more accurate ways to measure learning outcomes in citizen science, project managers can learn whether the engagement goals for their projects are met.

Using a combination of two approaches (self-reported surveys and trace data), our study investigated citizen science volunteers' connection to science (affinity, efficacy, and agency) and examined how volunteer activity across multiple projects on SciStarter.org corresponds to science connections. We focused on two research specific questions:

1. To what extent do citizen science volunteers express science affinity, efficacy, and agency?
2. What factors and types of citizen science participation are linked to higher levels of science affinity, self-efficacy for science, and science agency?

METHODS

Participants and Context

SciStarter.org is a platform designed to support a community of citizen scientists and project owners. To better understand how participants are moving between projects, project managers can elect to adopt tools to facilitate tracking of volunteer data. An Application Programming Interface (API) is a line of code installed by programmers, and enables tracking of projects that users join, bookmark, or to which they submit data. By studying those who participate in affiliate projects (those that adopt these API tools), we can track interest in a project, joins to a project, and engagement with projects. Interest in a project can be gauged by bookmarks. Project bookmarks refer to projects that are “saved” by a user by clicking a button that says “bookmark.” Users can review all bookmarked projects on their individual user dashboard. We can track the number of projects to which an individual user has contributed (via project joins). Project “joins” refer to individuals who clicked “join” on a project page. Projects joined can be reviewed on an individual user dashboard. Finally, we can track the frequency and intensity of volunteer engagement via project contributions. A contribution refers to a data submission by a user to a project. Contributions to projects can either be submitted through SciStarter, or through an individual project webpage. Individuals who bookmarked and joined projects were indicative of interest in a project, while those who contributed to a project indicated genuine participation in a project.

SciStarter provided estimates of average time per contribution for each project, which is an indicator of effort across projects. SciStarter provided matched survey responses with trace data about the name of each project bookmarked by each individual, 'joined' by each individual and dates of each, and the number of contributions to each project joined by each individual (and dates of each contribution). We refer to this information as trace data, and we used it to assess the breadth (the types of projects individuals participate in) and depth (the number of contributions per project) of volunteer participant across a variety of types of projects. We collected these trace data about volunteer participation from June 2018 to August 2019.

We also used project meta-data such as mode (projects that could be completed entirely indoors vs. projects with an outdoor component) and discipline, which is based on a citizen science project classification system described by Allf et al, (2019) (Appendix 2.2). If a volunteer joined multiple projects across in different disciplines or modes, we determined that they were discipline-spanners or mode-spanners.

Survey content

Our survey instrument was designed to address key outcome variables measuring connection to science, including science affinity, self-efficacy for science, and science agency. We adapted previously validated scales to measure science affinity, self-efficacy for science, and science agency (Appendix 1). Most of our scales were adapted from tools that emerged from the DEVISE (Developing, Validating, and Implementing Situated Environmental Instruments) project. DEVISE was created as an effort to build evaluation capacity for citizen science by creating assessment tools to measure a range of outcomes, and develop online support for the tools (Phillips, Porticella, Constas, & Bonney, 2018). We used a 10 point scale for each item ranked from 0 = "not at all" to 5 = "somewhat agree to 10 = "Strongly agree". This expanded scale allowed for more variation in responses within our group of self-selected citizen scientists, who we presumed would have inherently strong connections to science.

Our science affinity scale was adapted from the DEVISE Interest in Science and Nature scale (Phillips et al., 2015). Affinity refers to the personal interest and intention an individual has to participate in science. Items were changed from an environmental frame to focus on science more broadly. For example, "I want to understand how processes in nature work (e.g. how birds migrate, why leaves change color, how bees make honey etc.)" was broadened thematically and changed to "I want to understand the way the world works through science (e.g. how birds migrate, how viruses spread, how machines work)." The scale was reduced from 12 items to 4 items to reduce redundancy while maintaining core content.

The self-efficacy for science scale was adapted from the DEVISE Self-Efficacy for Science scale (Phillips, Porticella, & Bonney, 2017). Self-efficacy is the expectation, understanding, and ability someone has about doing science. The original phrasing of individual items referencing age comparisons were generalized to make the survey more relatable for adults. For example, items starting with "compared to others my age, I think I'm pretty good at thinking like a scientist" was changed to "compared to others, I think I'm pretty good at thinking like a scientist." Before validation, one item was removed to reduce redundancy in the instrument. One additional item was added in order to capture personal perception of scientific ability "Compared to others, I think I'm pretty good at thinking like a scientist" (Appendix 2.1).

Science agency refers to knowledge of subject-matter and use of knowledge to act on injustice. The science agency scale was adapted from the Changes in Attitude about the

Relevance of Science (CARS) scale (Siegel & Ranney, 2002). Items included things like "science helps me to make decisions about how I interact with the environment" and "science helps me make a difference in my community." More specific action items were adapted from the DEVISE General Environmental Stewardship questions (Phillips, Heimlich, & Ballard, 2017). Respondents were asked to rate the level to which their participation in science-related activities influences "How [they] choose to donate my time to causes," and "The products [they] buy," (Appendix 2.1).

In addition to these outcome variables, we also collected basic demographic information (age, gender) and asked respondents whether they considered themselves to be a STEM professional.

Data Collection

Because our adapted scales for affinity, efficacy, and agency had not been used before, we attempted to validate them with a sample of visitors to the North Carolina Museum of Natural Sciences on June 15, 2019. Our validation sample (n = 82) included more females (54%) and had an average of 36.7 years. Less than half of participants (41%) reported that they considered themselves to be a STEM professional. We used these responses and validation criteria (state below in data analysis) to develop a final scale for use with citizen scientists.

Our final survey instrument was distributed to SciStarter members beginning July 16, 2019, through an invitation that automatically popped up on the screens of citizen science volunteers (i.e., SciStarter members) who had participated in at least one affiliate project. We sent a reminder message through the SciStarter messaging system after one week (on July 23), and after one more week (on July 30). We stopped collecting responses on August 7, 2019. We also distributed the survey link through a SciStarter blog post included in the SciStarter weekly newsletter, a Twitter post, and a Facebook post. We received 185 complete responses. Ten responses were incomplete and therefore not included in the analyses.

The approximate response rate to the survey was 3.6%. While low, this rate aligns with industry standards for online user engagement. Respondents in the sample (n = 185) included more females (63%) and had an age range from 20 to 78 years with an average age of 49.7 years. Almost half of participants (49%) considered themselves to be STEM professionals. Trace data linked to participants' SciStarter membership IDs indicated participants had an average of 15 contributions across an average of 4 projects. This is slightly above the SciStarter average, where the majority of users join 2 projects (Allf et al., In Prep 2019). This indicates our sample has a substantial amount of citizen science experience, more than the average SciStarter user.

Data Analysis

We used Stata for all data analysis. For scales with multiple items, we assessed the reliability of constructs using Cronbach's alpha. Scores were averaged across each scale. We conducted oblique rotation of factor loadings to simplify the data structure (Costello & Osborne, 2008). We verified content validity by ensuring that items within each factor were logical and interpretable. We retained factors that had factor loadings > .400 (Table 2.2). Questions with low factor loading were removed from the final version of the survey. Finally, we verified the validity of adjusted constructs by ensuring that the items within each factor were interpretable and logical.

After confirming the structure of the outcome variables, we ran linear regression models to examine which factors, including demographic attributes and trace data regarding breadth and depth of citizen science participation, could predict each science connection construct. The independent variables for each regression were science affinity, self-efficacy for science (understanding), and science agency (action items). The dependent variables for each regression were discipline spanning (participating in projects across multiple topics), mode spanning (participating in indoor and outdoor projects), total project bookmarks, total project joins, total number of contributions across all projects, total time spent contributing (minutes) across all projects, STEM professional status (self-reported), age, and gender. We examined overall model fit using adjusted R2 and examined the effect of individual variables using parameter estimates.

RESULTS

Factor Analysis for Science Connection Variables

Our exploratory factor analysis (EFA) resulted in five latent factors across the three hypothesized science connection constructs. These five factors that captured the constructs: science affinity, self-efficacy for science (understanding), self-efficacy for science (confidence), science agency (general), and science agency (action items). Self-efficacy for science and science agency, hypothesized as distinct unified constructs, both split into two factors according to factor loadings.

Science affinity resulted in one factor composed of three items including statements like "I like to engage in science related hobbies in my free time" (Cronbach's $\alpha = 0.775$). The science efficacy scale split into two factors. The "self-efficacy for science (understanding)" included three items like "I think I'm pretty good at understanding science topics" (Cronbach's $\alpha = 0.928$). The other efficacy category we interpreted as "self-efficacy for science (confidence)," which included two items like "I feel confident in my ability to explain science topics to others" (Cronbach's $\alpha = 0.88$).

The scale developed for science agency also split in into two distinct factors. We expected this scale to potentially have two distinct focuses, since the questions were distinctly related to how people felt about science in their lives, and about actions they take in their everyday lives. The first factor, which related to how people feel about the impact of science in their lives (general science agency), included two items like "Science helps me to make decisions about how I interact with the environment," (Cronbach's $\alpha = 0.817$). The second factor related to how science influences actions people take (specific science agency) and included three items like "How I choose to donate my money to causes," (Cronbach's $\alpha = 0.727$). Although the five-factor structure deviated from our original expectations, the result factors and items were logical and interpretable.

Average response scores across all science connection constructs were high (Figure 2.1), suggesting that citizen scientists in are response sample had exceptionally high levels of science affinity, self-efficacy for science, and science agency.

Results of Models Predicting Science Connection

Model fit and predictive power were generally poor in each of the five regression models we examined.

The first model predicting science-agency did not indicate a strong relationship between the affinity and volunteer attributes and participation patterns, F (9, 126) = 1.12, $p = 0.352$), with an adjusted R^2 of 0.008. However, there was a tendency for those who both make fewer contributions ($B = -0.003$, $p = 0.047$) and those who spend more time contributing to projects ($B = 0.000$, $p = 0.029$) to have higher levels of science affinity. This suggests that there is a tendency for those who have greater depth in a project (spend more time contributing) have a higher connection to science than those who have more breadth (make many contributions to projects).

In the rest of our models, no relationships were statistically significant. The second model predicting self-efficacy for science understanding indicated poor fit, F (9, 126) = 0.40, p =

0.939), with an adjusted R^2 of -0.0418. The third model predicting self-efficacy for science confidence yielded poor fit, F (9, 126) = 0.97, p = 0.465) with an adjusted R^2 of -0.0018. The fourth model predicting feelings about general science agency also yielded poor fit, F (9, 126) = 0.80, p = 0.613), with an adjusted R^2 of -0.0133 as did the fifth model predicting specific science agency, F (9, 126) = 0.31, p = 0.97) with an adjusted R^2 of –0.0481. Overall, our study does not reveal a discernable relationship between the breadth and depth of citizen science engagement and volunteers' connection to science.

DISCUSSION

Our results suggest that citizen science volunteers, or at least those who are highly engaged on the SciStarter platform, had extremely high scores for science affinity, self-efficacy for science, and science agency regardless of project participation. There are several possibilities that explain this: 1) citizen science participation fosters high levels of science connection; 2) citizen science attracts individuals that already possess high levels of science connection; or 3) our survey reached a self-selected group of exceptionally dedicated volunteers who do not effectively represent their peers or demonstrate enough variability to detect significant relationships.

Previous studies have indicated that participating in citizen science can foster higher levels of affinity, efficacy and agency (Brossard, 2005, Crall et al., 2011, Ballard et al. 2017). Adults who have higher levels of science understanding and interest report that this is derived from leisure activities and free-choice learning (Falk et al., 2007), and citizen science volunteerism fits within this realm. Studies have also found that participating in citizen science project has a positive effect on self-efficacy (Crall et al., 2011, Jordan et al., 2016). Crall et al., (2011) found that those who have more confidence in a task perform the task better. Jordan et al.,

(2016) found that participation in a citizen science project led to greater knowledge and willingness to participate in future citizen science project. Studies with youth participants suggest that citizen science participation can develop long-term science agency, but only if there are clear mechanisms for the outputs of the studies to be used in conservation (Ballard et al., 2017). There are, however, distinct examples of citizen science changing policy, even if connections to science constructs within those participants have not been examined (Conrad & Hilchey, 2011). Our findings support the assertion that citizen science volunteers possess stronger connections to science than the average person, which highlights the potential value of citizen science to both research and society. But is the heightened sense of science connection an artifact of or a precursor to citizen science participation (or both)?

Citizen science would presumably attract individuals who possess higher levels of inherent connections to science. For example, scholars have discussed the challenge of studying learning outcomes in a self-selected population of citizen scientists (Brossard et al., 2005). So, while participation in citizen science could reinforce constructs like science affinity, self-efficacy for science, and science agency, it might not generate these outcomes where they do not initially exist. Our study only measured a snapshot in time using participation data already collected via the SciStarter platform; it was not designed to assess causality. Future research using sequential (e.g., pre-post) or experimental designs could help to illustrate how baseline connection to science and shifting participation rates of volunteers impact science affinity, efficacy, and agency over longer periods of time. In any case, there is value in the reinforcement of these science connection constructs through participation in citizen science.

Finally, based on participation trace data for our sample, we know that our group of survey respondents constitute exceptionally dedicated volunteers who may not effectively represent their peers. This might explain their extremely high average scores across all science connection constructs. If citizen participation breadth and depth did effect science affinity, efficacy, and agency, we might not have been able to detect those effects given our sample. A similar ceiling effect has been noted in other outcome research with self-selected populations (Brossard et al., 2005). Future research efforts should try to reach the "average" citizen science volunteer (via SciStarter or other platforms) to get more accurate representations and therefore greater understanding of the potential significance of trace data as it pertains to learning outcomes.

Despite our null findings, it is still important to consider the implications of using digital trace data to study connections to science. Digital trace data may not be an effective way to approximate the concepts of science affinity, self-efficacy for science, and science agency. Previous studies have illustrated the importance of explicitly stating learning goals to participants and the importance of developing more sensitive measurements to track whether learning goals are being achieved (Brossard et al., 2005). This can be done through skill-based, project-specific embedded assessment, but adopting EA across a platform would require considerations of many different factors including the motivations of a diverse volunteers, the topics they choose to pursue, differential contribution rates across projects, and the broader and intangible outcome metrics derived from multi-project participation (Becker-Klein et al., 2016). Future developments of platform-wide EAs, perhaps in the form of embedded tracking using trace data, might explicitly consider the connections to science that many citizen science projects aspire to nurture and reinforce. For example, individual citizen science projects could explicitly indicate the learning outcomes they have for volunteers (e.g., stronger connection to science) on individual project pages. Stating learning objectives for volunteers might make volunteers more cognizant of project goals more likely to report changes in those learning goals. Setting clear objectives and goals when building a program enables better, more accurate program evaluation throughout the life of the program (Crall et al., 2011, Cornell Lab of Ornithology Toolkit). A platform-wide approach to EA could also require more direct interventions designed to assess change among scientifically-aware citizens. For example, future platform-based EA designs could incorporate an entertaining activity such as quiz for volunteers integrated into the platform interface and experience. These quizzes or activities could have prompts that ask volunteers to think explicitly about what they have learned from participating in multiple citizen science projects. Platforms could benefit from a more intentional strategy for assessing broader learning outcomes in order to see if citizen science is collectively achieving connecting the public to science.

Limitations

There are several limitations to this study including a small sample size, a low response rate, and the likely present of a response bias in our sample (skewing towards more dedicated and engaged citizen science volunteers). Furthermore, our assessment of science connection outcomes was based on self-reported data from adapted versions of survey instruments like DEVISE and CARs. Though validated, responses to these scales might still be impacted by desirability bias. Furthermore, we had limited access to trace data. At the time of our research, SciStarter had only been collecting trace data for one year (a mere snapshot in the life of a citizen science volunteer). With more data capturing more aspects of participation (beyond bookmarks, joins, and contributions), it is possible that we could observe significant relationships. Nevertheless, the results of our study suggest that trace data alone may be insufficient to assess science affinity, self-efficacy for science, and science agency constructs across projects. Future research could utilize data tracking via platforms like SciStarter to capture more nuanced participation data across diverse volunteers and projects. Future studies could also consider more creative and objective (i.e., non-survey-based) EA strategies for measuring the science affinity, self-efficacy for science, and science agency of citizen science volunteers (both with EAs and in traditional survey form). Sequential experimental designs that include specific interventions through the platform and that target certain subsets of volunteers (including those who are not self-selected but extrinsically motivated could also provide a better gauge of change and true learning outcomes.

CONCLUSION

Understanding levels of science affinity, self-efficacy for science, and science agency in a volunteer population can help citizen science practitioners foster a scientifically literate and action-oriented public. Science and Engineering Indicators (SEI) reports that Americans who have more exposure to science and technology also tend to understand more about science, see science in a positive light, and engage with science more often (Chapter 7: Science and Technology, 2018). Citizen science is one way for people to exercise and increase those connections to science, thereby boosting science affinity, self-efficacy for science, and science agency Understanding user participation patterns and outcomes on a multi-project platform like SciStarter is valuable considering the multitude of citizen scientists who participate in different ways (offline vs. online) and across different topics and disciplines. Such an approach can illuminate the multifaceted benefits volunteers derive from citizen science participation beyond contributions to scientific research, highlighting the broader contributions that citizen scientists make to science and society.

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Table 2.1. Factor Analysis Exploring Distinct Constructs of Science Affinity, Self-Efficacy for Science, and Science Agency

Factor (with Items)			**Factor Loadings**				
	Mean	SD	1	2	3	4	5
Factor 1: Science Affinity (3 items, Cronbach's α = 0.775)							
I enjoy learning more about science.	9.586	0.882	0.778				
I like to engage in science related hobbies in my free time.	8.505	2.075	0.735				
I want to understand the way the world works through science (e.g. how birds migrate, how viruses spread, how machines work).	9.271	1.24	0.821				
Factor 2: Self-Efficacy for Science (Understanding) (3 items, Cronbach's α = 0.928)							
I think I'm pretty good at understanding science topics	8.255	1.516		0.882			
Compared to others, I think I can quickly understand new science topics	8.217	1.655		0.952			
Compared to others, I think I'm pretty good at thinking like a scientist	8.130	1.696		0.867			
Factor 3: Self-Efficacy for Science (Confidence) (2 items, Cronbach's α = 0.88)							
I feel confident in my ability to explain science topics to others	7.690	1.889			0.840		
I feel confident about my ability to explain how to do scientific activities to others	8.152	1.736			0.840		
Factor 4: Science Agency (3 items, Cronbach's α = 0.817)							
Much of what I learn from science is useful in my everyday life	8.347	1.652				0.732	
Science helps me to make decisions about how I interact with the environment	9.038	1.290				0.816	
Science helps me make a difference in my community	8.298	1.835				0.734	
Factor 5: Science Agency (Actions) (3 items, Cronbach's α = 0.727)							
How I vote in elections (local, state, national)	7.760	2.523					0.800
How I choose to donate money to causes	7.815	2.337					0.735
Interactions with my friends/family	7.070	2.239					0.455

Prompt(s): Please indicate how you feel about the following statements related to science. Please indicate how much you agree or disagree with the following statements by selecting the choice in the appropriate column.

Table 2.1 (Continued)
Please indicate how you feel about the following statements related to the role of science in your life.
Please indicate how much you agree or disagree with the following statements by selecting the choice in the appropriate column.

Scale: Not at all (0), Somewhat agree (5), Strongly agree (10)

Table 2.2. Citizen science volunteer attributes and participation patterns that predict science affinity. *(n = 136); Adjusted* $R^2 = 0.008$; $p = 0.352$; $F(9, 126) = 1.12$

Variable	*Mean*	*SD*	*B*	*SE*	*P> |t|*
Constant			25.557	13.756	
Discipline spanner (1-yes)	0.540	0.499	-0.265	0.243	0.277
Mode spanner	0.356	0.480	0.082	0.253	0.746
Sum of bookmarks	2.38	6.611	0.005	0.018	0.772
Sum of joins	3.679	5.994	-0.003	0.023	0.885
Sum of # of contributions	14.869	67.535	-0.003	0.001	0.047
Total time on contributions (minutes)	951.72	2422.987	0.000	0.000	0.029
Non-STEM professional	0.505	0.501	-0.143	0.190	0.452
Year born	1969	14.91	-0.008	0.006	0.239
Male	0.393	0.529	0.076	0.179	0.669

Table 2.3 Citizen science volunteer attributes and participation patterns that predict self-efficacy for science understanding. *(n = 136); Adjusted $R^2 = -0.0418$; $p = 0.9339$; $F(9, 126) = 0.40$*

Variable	*Mean*	*SD*	*B*	*SE*	*P> |t|*
Constant			28.602	19.549	
Discipline spanner (1-yes)	0.540	0.499	0.213	0.345	0.538
Mode spanner	0.356	0.480	0.036	0.359	0.919
Sum of bookmarks	2.38	6.611	-0.24	0.026	0.355
Sum of joins	3.679	5.994	0.012	0.033	0.698
Sum of # of contributions	14.869	67.535	-0.0003	0.002	0.861
Total time on contributions (minutes)	951.72	2422.987	8.78e-06	0.000	0.903
Non-STEM professional	0.505	0.501	0.113	0.270	0.675
Year born	1969	14.91	-0.010	0.009	0.297
Male	0.393	0.529	0.073	0.255	0.774

Table 2.4. Citizen science volunteer attributes and participation patterns that predict self-efficacy for science confidence. *(n = 136); Adjusted* $R^2 = -0.0018$; $p = 0.465$; $F\ (9, 126) = 0.97$

Variable	*Mean*	*SD*	*B*	*SE*	*P> |t|*
Constant			44.478	20.565	
Discipline spanner (1-yes)	0.540	0.499	-0.238	0.363	0.514
Mode spanner	0.356	0.480	0.001	0.290	0.997
Sum of bookmarks	2.38	6.611	-0.016	0.021	0.440
Sum of joins	3.679	5.994	0.159	0.268	0.555
Sum of # of contributions	14.869	67.535	0.000	0.001	0.825
Total time on contributions (minutes)	951.72	2422.987	0.000	0.000	0.785
Non-STEM professional	0.505	0.501	0.262	0.314	0.406
Year born	1969	14.91	0.000	0.115	0.958
Male	0.393	0.529	0.108	0.296	0.714

Table 2.5. Citizen science volunteer attributes and participation patterns that predict general science agency. *(n = 136); Adjusted* $R^2 = -0.0133$; $p = 0.613$; $F(9, 126) = 0.80$

Variable	*Mean*	*SD*	*B*	*SE*	*P> |t|*
Constant			23.925	15.794	
Discipline spanner (1-yes)	0.540	0.499	-0.212	0.279	0.447
Mode spanner	0.356	0.480	0.001	0.290	0.997
Sum of bookmarks	2.38	6.611	-0.164	0.021	0.440
Sum of joins	3.679	5.994	0.015	0.026	0.555
Sum of # of contributions	14.869	67.535	0.000	0.001	0.825
Total time on contributions (minutes)	951.72	2422.987	0.000	0.000	0.374
Non-STEM professional	0.505	0.501	-0.067	0.218	0.757
Year born	1969	14.91	-0.007	0.008	0.334
Male	0.393	0.529	0.294	0.206	0.155

Table 2.6. Citizen science volunteer attributes and participation patterns that predict science specific science agency. *(n = 136); Adjusted* $R^2 = -0.0481$*;* $p = 0.970$*;* $F\ (9, 126) = 0.31$

Variable	*Mean*	*SD*	*B*	*SE*	*P> |t|*
Constant			6.179	22.747	
Discipline spanner (1-yes)	0.540	0.499	-0.263	0.402	0.514
Mode spanner	0.356	0.480	0.462	0.418	0.271
Sum of bookmarks	2.38	6.611	0.001	0.030	0.957
Sum of joins	3.679	5.994	-0.008	0.038	0.822
Sum of # of contributions	14.869	67.535	0.002	0.002	0.292
Total time on contributions (minutes)	951.72	2422.987	0.000	0.000	0.785
Non-STEM professional	0.505	0.501	0.262	0.314	0.406
Year born	1969	14.91	0.000	0.115	0.958
Male	0.393	0.529	0.108	0.296	0.714

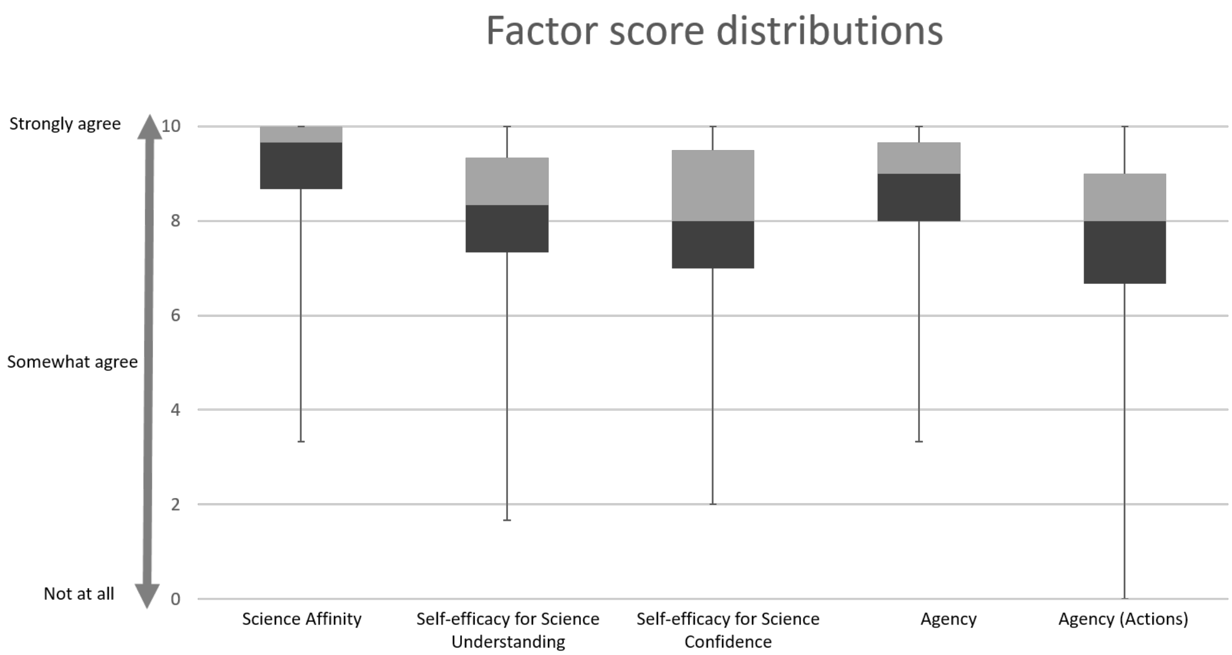

Figure 2.1 Distribution of Science Connection Variable Scores for Citizen Science Volunteers on the SciStarter Platform (n=136).

RECOMMENDATIONS AND IMPLICATIONS

As part of sharing research about the field of citizen science, our team of researchers at NC State wrote this blog post to share our findings.

Citizen science is growing and expanding quickly. Over the last 20 years, the number of projects and volunteers in citizen science has grown a lot! The emergence of so called "third-party organizations" like SciStarter.org, CitSci.org, and Anecdata present unique opportunities to share many different kinds of projects with volunteers all over the world. Third-party organizations help connect volunteers to projects, thereby increasing capacity for scientific data collection. In turn project managers can learn more about volunteers, ultimately helping to sustain their projects. But what do project managers, who are accustomed to thinking about their own project volunteers first and foremost, need to know (and potentially do) to maximize the potential of this shared citizen science landscape?

Our team of researchers at North Carolina State University recently found that project manager's beliefs about volunteers can promote or inhibit the success of third-party organizations. Adopting practices that support volunteers who participate in multiple projects (which we call a "shared" perspective) is conducive for most citizen science project management practices like recruiting participants, recognizing volunteer contributions, and coordinating volunteers. In addition to creating a more engaged and productive citizen science community, our work also suggests that shared volunteer management practices can promote broader engagement outcomes for volunteers.

We found that managers who embraced shared perspectives were more likely to report shared orientations across citizen science more broadly, perception of simultaneous participation in multiple projects, stronger volunteer involvement in an organization and broader project impacts. Our research also suggests that science affinity, self-efficacy for science and science agency can be promoted and reinforced through citizen science. Third-party organizations like SciStarter are valuable because they can both facilitate volunteer participation in multiple projects (across various modes and disciplines) and track volunteer activity patterns across all of those projects, providing unique insights to managers with respect to the growth and development of volunteers. Our research supports the idea that citizen science is a way people can increase their interest in science, gain new skills, or increase their science literacy. Shared volunteer management and third-party organizations can more accurately help assess what people get out of participating in citizen science projects.

So what can citizen science project managers do to facilitate this shift and support the growth of their projects, volunteers, and citizen science as a whole?

- **Provide training for volunteers** that can be useful for multiple projects, helping volunteers move between projects to find the best opportunities for them. Such heightened efficiency can also streamline the training efforts of project managers and build science literacy and capacity among volunteers – making them more effective contributors!
- **Get to know volunteers.** What motivated them to join your project? What do they hope to get out of participating? What are they struggling with? Strengthening personal relationships in this way can foster trust and stronger project engagement. It also provides key information and builds a stronger foundation to inform shared management practices.
- **Encourage movement between projects** that are similar in activity or location. By communicating and working with other projects, managers can more easily

provide different ways to participate (and accommodate different motivations) by providing a variety of opportunities to their volunteers. This can be especially helpful for smaller or seasonal projects that often struggle with recruitment and retention.

- **Share data** with similar projects. What better way to advance your own research goals than to learn about what other projects are finding? Sharing data volunteers collect could help collectively advance scientific knowledge. Sharing data about volunteers (their motivations, preferences, activity patterns, etc.) could lead to more efficient and effective recruitment and retention. It can also help to foster volunteer learning trajectories across multiple projects.
- **Join a third-party organization** like SciStarter.org. In the case of SciStarter, for example, a whole website is dedicated to helping you find other project managers and volunteers near your location or within your project discipline. The platforms are designed to facilitate connections – the very connections that make shared management of citizen science volunteers such a powerful tool.

Project managers who do these things are better equipped to build stronger relationships with diverse volunteers and facilitate their movement across the larger citizen science landscape. Citizen science is still a new and growing rapidly field, and researchers are always learning new information about their own projects and how to make those projects more efficient and meaningful - both for their volunteers and the generation of scientific knowledge. If we can extend that search for new knowledge across project boundaries via shared management practices, we can better harness the power of citizen science and help it achieve its full potential.

APPENDIX

Appendix 1.1 Project Manager Survey

1. How many volunteers does your citizen science program manage?
    a. Tens of people (less than 100)
    b. Hundreds of people (between 100 and 1000)
    c. Thousands of people (more than 1000)
2. Are the volunteers of your citizen science program managed by (Choose ONE)?
    a. Paid member(s) of staff
    b. Unpaid member(s) of board
    c. Volunteer unpaid member(s) of staff
    d. Other (specify)
3. Who manages your volunteers?
    a. I am the only one who manages volunteers
    b. I co-manage volunteers with a team of people
    c. Other people manage volunteers and report up to me
    d. Other people manage volunteers, who I report up to
    e. Other structures exist
4. What percentage of your job is dedicated to managing volunteers?
    a. Less than 25% of time
    b. 25-50% of time
    c. 50-75% of time
    d. Over 75% but not all of the time
    e. All of your time
5. How long have you been managing volunteers in your citizen science program?
    a. Less than six months
    b. Six to twelve months
    c. Between one and five years
    d. Between five and ten years
    e. More than ten years
6. Please indicate whether or not your organization participates in the following volunteer management practices. Check all that apply
    a. Have a written policy on volunteer involvement
    b. Evaluate the impact of volunteers for the organization's services or activities
    c. Monitor diversity and opportunity of volunteers
    d. Have a key person(s) who volunteers can go to for advice and support
    e. Arrange training for volunteers
    f. Use "report backs" or data feedback to show volunteers how their contributions are useful
    g. Require signed liability waivers for volunteers
7. Please indicate whether or not your organization recognizes volunteer contributions in any of the following ways. Check all that apply
    a. Long service award
    b. Provde references
    c. Certificate awarded by your organization
    d. Certificate awarded by external organization
    e. Verbal thanks from the organization

   f. Written thanks from the organization
   g. Presented gifts or badges
   h. Recognition in press
   i. Discount card/reduced charges for activities
   j. Other (specify)
8. Please indicate the extent to which you disagree or agree with each of the following statements about volunteer involvement in your organization or project (Strongly Disagree-1 to Strongly Agree- 5)
   a. The views of volunteers have a big effect on how my program develops
   b. Lots of the volunteers feel as though this organization appreciates their efforts
   c. The leadership or senior management in this organization is in touch with the feelings of volunteers
   d. The board/governing body/management committee of this organization receives regular reports about the part that volunteers play in the organization
   e. When this organization makes plans for a new service, activity or project, it makes a big effort to consider the part which volunteers can play in that
9. In general, do you feel like you have as many volunteers as you want?
   a. Yes
   b. No
10. Please indicate to what extent you experience difficulties with recruiting volunteers from no difficulty (0) to extreme difficulty (10)
   a. Recruiting enough volunteers
   b. Recruiting volunteers with the skills needed
   c. Recruiting volunteers from a wide range of social and demographic backgrounds
11. Please indicate to what extent you experience difficulties with retaining volunteers from no difficulty (0) to extreme difficulty (10)
   a. Retaining enough volunteers
   b. Retaining volunteers with the skills needed
   c. Retaining volunteers from a wide range of social and demographic backgrounds
12. Indicate how much you agree with the following statements about volunteers in your citizen science program. (Strongly Disagree-1 to Strongly Agree- 5)
   a. I value loyalty in my volunteers
   b. I help my volunteers find other opportunities when they leave my project
   c. I don't recruit volunteers engaged in other projects
   d. My volunteers don't participate in other citizen science projects
   e. Most of my best volunteers only participate in my project
   f. To effectively manage volunteers, I need to learn more about their broader interests and activities
   g. If volunteers have bad experiences on other projects, they are less likely to try my project
   h. My volunteers are better than volunteers on other projects

i. I think all volunteers are important no matter how much they contribute to my project
j. To effectively manage volunteers, I need to learn more about their education and economic status
k. I love to see my volunteers joining other citizen science projects
l. I only care about citizen science volunteers when they are engaged in my project
m. My project will never experience a volunteer shortage because there will always be enough volunteers to go around

13. Indicate how much you agree or disagree with the following statements about volunteers in citizen science in general (Strongly Disagree-1 to Strongly Agree-5)
    a. Citizen science volunteers are a renewable resource--they are many and turnover is continual
    b. Citizen science volunteers are a limited resource--they are few and turnovers are not replenished
    c. The best volunteers are dedicated to one project at a time
    d. Competition for volunteers among similar citizen science projects is less important when volunteer observations go to an open, shared data repository
    e. An abundance of exciting citizen science projects is good for volunteer recruitment
    f. There is strong competition for volunteer time among similar citizen science projects
    g. Citizen science volunteers are able to effectively participate in multiple projects at the same time
    h. Volunteers prefer to pick one project over another
    i. Competition for volunteers across different types of citizen science projects is not a problem
    j. We still have a lot to learn about the effective management of citizen science volunteers
14. Do you think volunteer management could be altered or improved to advance the broader field of citizen science? If so, how?
15. To what extent do you think your citizen science project is generating the following broader impacts? (Mark ONE response for each item.) (Definitely NOT (1)- Definitely YES (5))
    a. Advancing research (improving capacity to generate/analyze data, building scientific knowledge)
    b. Advancing policy (informing science policy and decision making, enhancing management and regulatory capacity)
    c. Individual learning (increasing science literacy, increasing science efficacy, improving skills, boosting interest is certain topics)
    d. Building community (connecting fellow citizen scientists, sharing information across networks, cultivating social capital
    e. Empowering action (stimulating action on science-related issues, giving people a voice in decision-making, increasing public support for science)

f. Other (please specify):

Appendix 2.1 Volunteer Survey

Science Affinity

Please indicate how you feel about the following statements related to science on a scale of "Not at all" (0), "Somewhat agree" (5), "Strongly agree" (10).

1. I enjoy learning more about science.
2. I like to engage in science-related hobbies in my free time.
3. I want to understand the way the world works through science (e.g. how birds migrate, how viruses spread, how machines work).

Science efficacy

Please indicate how much you agree or disagree with the following statements by selecting the choice in the appropriate column "Not at all" (0), "Somewhat agree (5), "Strongly Agree" (10).

1. I think I'm pretty good at understanding science topics.
2. Compared to others, I think I can quickly understand new science topics.
3. I feel confident in my ability to explain science topics to others.
4. I think I'm pretty good at following instructions for scientific activities.
5. I feel confident about my ability to explain how to do scientific activities to others.
6. Compared to others, I think I'm pretty good at thinking like a scientist.

Science agency

Please indicate how you feel about the following statements related to the role of science in your life from "Not at all" (0), "Somewhat agree (5), "Strongly Agree" (10).

1. Much of what I learn from science is useful in my everyday life.
2. Science helps me to make decisions about how I interact with the environment.
3. Science helps me make a difference in my community.

Science agency actions

Please indicate how much you agree or disagree with the following statements by selecting the choice in the appropriate column on a scale from "Not at all" (0), "Somewhat agree (5), "Strongly Agree" (10).

My participation in science-related activities (doing citizen science, visiting science museums and zoos, etc.) influences...

1. How I vote in elections (local, state, national).
2. How I choose to donate money to causes.
3. How I choose to donate my time to causes.
4. The products I buy.
5. Interactions with my friends and family.
6. The media I choose to consume (books, news, podcasts, videos).

Demographics

1. Do you consider yourself to be a professional in a STEM field (science, technology, engineering, or math)?
2. In what year were you born? (yyyy)
3. What is your gender?

Appendix 2.2 Typology of Citizen Science Projects
A typology of citizen science projects based on a project's disciplinary topic. Projects from all data sources were coded within this typology. Allf, B., Cooper, C., Larson, L., Dunn, R., Futch, S., Sharova, M., (2019). The New Citizen Scientist: Multi-Project Participation. (In progress).

Typology of Citizen Science Projects

Project Topic	**Description**	**Sub-Topics**	**Exemplar Project(s)**
Ecology & Environment	Projects that focus on wildlife and/or the connection between wildlife and the environment.	Animals, Plants & Fungi, Broad Ecology, Freshwater Ecology, Marine Ecology, Phenology	iNaturalist, Candid Critters, Christmas Bird Count
Pollution	Projects that are related to specific human effects on air, water, sound, soil, etc.	General People & the Environment, Pollution, Invasives	Globe at Night, Sound Around Town, iSeeChange
Geology & Earth Science	Projects focused on earth-based physical sciences.	Weather, Earth & Geology, Hydrology	CoCoRaHS, Globe Observer: Clouds, Landslide Reporter
Astronomy & Space	Projects focused on telescopes, outer space, galaxies, the solar system, etc.	None	Mars Mapper, Clickworkers, Galaxy Zoo
Math & Physics	Projects focused on mathematics, numbers, graphing, non-astronomy-focused physics and quantitative methods of science.	None	Quantum Moves
Anthropology	Projects focused on people and the systems or objects that people make, including archaeology, political and cultural projects. Does not include health-focused, infrastructure-focused or computer/tech-focused projects.	Archaeology, Cultural, Human World Transcription, Other Human World	Lingscape, GlobalXplorer, Anti-Slavery Manuscripts
Health & Medicine	Projects focused on human health, disease, well-being and medicine. Includes projects about human genetics.	Stall Catchers, Other Health & Medicine	Stall Catchers, Eterna, Flu Near You

Computers & Technology	Project related to technology, hardware, software and computer programming. radios. Also includes distributed computing projects and games used to help improve computer algorithms.	None	BOINC
Cell & Molecular	Project related to the "micro" side of biology, including: genetics, microbiology, biochemistry, development, virology, studies of microbes (in a non-medical context) and cell and molecular biology.	EyeWire, Other Cell and Molecular	EyeWire, Foldit, Microscopy Masters
Food and Agriculture	project related to the science or practice of farming, including cultivation of the soil for the growing of crops and the rearing of animals to provide human services like food and clothing.	None	Falling Fruit, Sourdough Project
Psychology	project related to the scientific discipline that deals with the mind and behavior, including language, sleep and cognitive development.	None	Project Implicit, The Online Wisdom Lab, Project Soothe
Transportation & Infrastructure	project related to the human physical and organizational structures and facilities (e.g. buildings, roads, power supplies) needed for the operation of a society or enterprise.	None	Open Street Mapping, The National Map Corps
Geography	Project related to the intersection of human activity and the physical features of the earth and its atmosphere, including studies on population, resources, land use, and industries.	Disasters, Other Geography	Slavery from Space, TOMNOD

Pets	Projects focused on dogs, cats and other domestic animals. Includes projects on pet psychology, pet tracking, breed identification, etc.	None	Cat Tracker, MuttMix Project, FeBARQ
Multi-Topic Platform	This is the bin for projects that cross multiple disciplinary boundaries and for hubs for projects that contain lots of different kinds of projects when the survey-taker does not specify which kind of project on the hub they participated in.	None	Zooniverse, SciStarter, CitSci