ABSTRACT

SMITH, HALEY ELIZABETH. Exploring the Role of Facilitator Organizations in Citizen Science. (Under the direction of Dr. Caren Cooper).

Citizen science, or public engagement in scientific research, is a global phenomenon that provides benefits to both research practice and members of the public who participate. Historically, citizen science has been envisioned as occurring in the context of discrete projects - individual research efforts or data collection platforms focused on a specific type of observations. However, there is a growing recognition that the citizen science landscape is more complex than just projects, project staff, and participants, with online platforms, communities of practice, and resource hubs focused on citizen science growing exponentially over the past decade. Additionally, with the growing popularity and recognition of citizen science, many third party groups are choosing to implement citizen science to achieve their own programmatic goals or learning outcomes; we call these groups *facilitator organizations*. Facilitator organizations may include special interest groups hoping to promote research on a certain topic, such as the International Dark Sky Association or the National Pollinator Garden Network, or formal and informal educational groups like museums or scouting groups seeking an engaging way of promoting STEM or environmental learning. In this dissertation, I investigate the roles of facilitator organizations in the citizen science landscape. In my first research chapter, I looked at overall trends in participation on the SciStarter platform using metrics of breadth and depth and compared these trends between self-selecting and facilitated users. In the next chapter, I qualitatively examined a case study of the Girl Scouts' Think Like a Citizen Scientist Journey, assessing learning outcomes and community action that resulted from participation in the journey. In my last research chapter, I conducted a qualitative, multiple case study of US public libraries implementing citizen science programming, investigating how these experiences with

citizen science support the process of science socialization, both for librarians and library patrons. My findings across all three chapters demonstrate the potential facilitator organizations have to expand learning and extend impact from citizen science participation, if facilitation is designed intentionally. In my final chapter, I conclude with recommendations for future research as well as practical suggestions for librarians and resource hubs like SciStarter.

Exploring the Role of Facilitator Organizations in Citizen Science

by
Haley Smith

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North Carolina State University
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Doctor of Philosophy

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APPROVED BY:

Caren Cooper Committee Chair	K.C. Busch
Lincoln Larson	Kathryn Stevenson

DEDICATION

Dedicated in loving memory of my grandmother, Ruth H. Stamey (1934-2024) and to my sweet girls, Gemma and Lacey, for their steadfast companionship.

BIOGRAPHY

Haley was born and raised in Asheville, North Carolina, where she grew up surrounded by the beauty and biodiversity of the Blue Ridge Mountains. Her early love for the natural world was fostered by summer camp experiences hiking and backpacking throughout the mountains of Western North Carolina and opportunities to conduct benthic macroinvertebrate samples, test water quality, and perform research on acid mine drainage in middle and high school. Those interests led her to pursue a double major in Biology and Environmental Studies as an undergraduate at Washington and Lee University, located just up the Blue Ridge in southwest Virginia. While in college, she had the opportunity to study abroad for a semester in Kenya and Tanzania at the School for Field Studies' Center for Wildlife Management Studies, where she conducted collaborative research on water resources and public health. This experience opened her eyes to the complex relationships between humans and the environment and set her on a path to becoming an environmental social scientist.

After graduating, Haley spent two years serving as an Education and Outreach Associate with the Southern Appalachian Highlands Conservancy through the AmeriCorps Project Conserve Program, before relocating to Fort Collins, Colorado to pursue a Masters in Conservation Leadership from Colorado State University. In 2020, Haley returned to North Carolina, this time to Raleigh, to begin a PhD in Forestry and Environmental Resources at NC State, with a focus on studying the educational and behavioral outcomes of participatory science experiences. Throughout her time at NC State, Haley was very involved in her graduate community, serving as a member and two-term president of the Forestry and Environmental Resources Graduate Student Association and as a co-chair to the College of Natural Resources' Graduate Student DEI committee. She became a member of several professional organizations, serving on committees and working groups for the Association for Advancing Participatory Sciences (AAPS) and International Association for Society and Natural Resources (IASNR). Haley also joined the NC State Environmental First Year Program (ENVFY) in the Fall of 2022, first as a TA, then as an instructor. Starting in August 2024, Haley became the interim Program Director of EcoVillage at NC State and now serves as a permanent staff member in this role where she continues to partner with ENVFY and implement a residential learning curriculum centered on sustainability.

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CHAPTER 1: Executive Summary

A note about terminology

First emerging in the 1990s, citizen science is a term that has for decades been used to describe the phenomenon of public participation in scientific research, both in the US and globally (Bonney, 1996; Irwin, 1995). In recent years, particularly in a US context, this terminology has been brought into question as issues of citizenship status remain a contentious area of public discourse. Many practitioners have chosen to adopt alternate terminology out of a desire to be more inclusive in their language, often choosing "community science" as a preferred alternative. Academics have pointed out that community science already has a specific meaning, referring to community-led projects and often used in environmental justice contexts. Therefore the appropriation of this term to "citizen science" contexts is misleading and inaccurate (Cooper et al., 2023). In 2023, the US-based professional association formerly known as the Citizen Science Association (CSA) announced a name change to the Association for Advancing Participatory Sciences (AAPS) in recognition of this discourse, choosing participatory sciences as an umbrella term that encompasses a variety of participatory methods, and that aligns with their South American counterpart organization, the Ibero-American Network of Participatory Science (RICAP) (Putnam, 2023). That being said, citizen science is still a widely recognized and used term, both in the US and globally, with other regional professional networks still embracing the term, including: the European Citizen Science Association (ECSA), the Australian Citizen Science Association (ACSA), CitSci Africa, and CitizenScience.Asia. Similarly, while CSA changed its name to AAPS, their affiliated journal (Citizen Science: Theory and Practice) has retained its name. Throughout this dissertation, I use the terminology of citizen science, not to ignore or sidestep this ongoing debate, and certainly not with the intent to exclude, but because citizen science remains both the most consistently used term globally, and because this terminology in particular reflects the more "contributory" nature of most of the projects included in this research, as opposed to more collaborative or community-led projects (Shirk et al., 2012).

Dissertation context

As recognition of citizen science and the various forms of participatory sciences have been growing in recent decades, more research has begun to emerge around the organization, practice, and outcomes of these various forms of public participation in science. Much of this research to date has taken a project-centric approach (Allf et al., 2022), with a project being a defined effort of a researcher or platform to collect or curate data of a specific type or to address a specific research question (for example: iNaturalist, eBird, StallCatchers). However, given the fact that many participants engage in more than one project (Allf et al., 2022) and bring their own interests, motivations, and experiences with science when they participate in citizen science, there has recently been an increased interest in taking a more participant-focused approach in research, particularly in exploring learning and behavioral outcomes associated with participation in citizen science.

Alongside this push for more participant-focused research has come a recognition that there are more actors in the citizen science "landscape" than just projects and participants (Allf et al., 2022). Rather than only the two traditionally envisioned pathways to engagement - projects recruiting participants or participants seeking out projects in pursuit of an existing interest or hobby - many participants' first encounter with citizen science instead comes in facilitated contexts. Such contexts include situations where an individual (such as a teacher) or an organization (such as the Girl Scouts) introduces an audience to citizen science in pursuit of specific learning or action goals. Facilitators' prior knowledge of their audiences and the learning supports provided by facilitated experiences create the potential for enhanced learning and inclusion in citizen science. However, additional research is needed to understand the specific contextual factors that may lead to more inclusive pathways and improved learning outcomes in facilitated citizen science and how these factors influence the participant experience. Throughout the three chapters of my dissertation, I have further explored three different aspects of facilitated citizen science, representing four unique facilitated contexts.

Research Summary

In Chapter 2, I explored overall trends in participation across the citizen science landscape using digital trace data from SciStarter.org. I then compared these trends between "typical" (self-selecting) participants and facilitated participants from the Girl Scouts' Think Like a Citizen Scientist program, Verizon's corporate volunteer program, and college students from various universities across the US. My findings demonstrate that while there is wide variation in both breadth and depth of participation within and across projects, the majority of contributions come from a very small fraction of participants, with most participants contributing only sporadically and eventually lapsing in their participation. There were distinct differences between "typical" and facilitated participants, but these differences varied by facilitator. Girl Scout participants were more likely to have higher breadth and depth than all other participants, and their experience was the most intentionally curated and highly facilitated. University students and Verizon volunteers, on the other hand, had generally lower breadth and depth than "typical" participants. These differing outcomes in various facilitated contexts suggest not only that the nature of the facilitated experience may impact participation, but also that possible interactions between facilitation and motivations for participating in citizen science (for example, perhaps more intrinsic motivations for Girl Scouts vs. more extrinsic motivations for students and corporate volunteers) can influence participation. While my research did not allow for a full understanding of these interactions, these findings suggest that while facilitation can lead to enhanced participation in citizen science, the specific facilitation context matters, opening up the need for additional research on the impacts of specific elements of facilitated citizen science experiences, as well as on the interactions between facilitation and participant motivations.

In Chapter 3, I more closely examined the facilitated context of the Girl Scouts' Think Like a Citizen Scientist Journey. In particular, this chapter sought to understand the potential for facilitator organizations like the Girl Scouts to enhance learning outcomes associated with participation in citizen science. I also explored how the program supported civic science education and civic action. Using thematic analysis of open-ended responses from Girl Scout troop leaders, I found that the structured activities included in the Journey - from participation in STEM learning activities to contributing to a citizen science project, and finally completing a Take Action Project in their community - supported a wide variety of informal science learning outcomes. They also paved the way for environmental action and civic engagement among the girls who participated, demonstrating the synergies that are possible for facilitator organizations who employ citizen science activities in alignment with their own goals.

Finally, in Chapter 4, I took a holistic, life-course view of learning to investigate the role that facilitated citizen science experiences in public libraries play in the lifelong process of science socialization. Using a multiple case study approach involving interviews with nine public librarians in rural, suburban, and urban locations across the US, I adapted the five domains of socialization identified in Bixler et al.'s (2011) environmental socialization theory work to explore how library-based facilitated citizen science programming supports *access, accumulation of experiences, competency development, social support, and identity formation.* Libraries provide a unique community-based context for lifelong STEM learning, and librarians offer unique insights thanks to their familiarity and deep understanding of their patrons' experiences with their programs. My findings validate the use of this framework in citizen science contexts and demonstrate that libraries are supporting all five domains of socialization - most notably access, accumulation of experiences, and social support. This supports prior work indicating that facilitated citizen science has the potential to engage more diverse audiences, and my findings suggest specific opportunities for libraries (and other facilitators) to better support the socialization process, for example by offering more directly facilitated citizen science programs rather than just opportunities for independent engagement, and by designing recurrent or series-based programs to encourage repeated participation.

Chapter 5 - Conclusions and Recommendations provides a summary of key takeaways and recommendations for researchers, practitioners, and resource hubs (like SciStarter.org) affiliated with citizen science practices. Key recommendations include: a need for continued research on the interactions between motivations, facilitation, and participation as well as additional research on how citizen science fits into participants' lifelong experiences with science; facilitators designing citizen science programs that intentionally address the five domains of science socialization; citizen science platforms helping participants connect to new opportunities for engagement; and resource hubs helping to cultivate facilitator resources in a repository, including a catalog of financial, content expert, and partnership resources that can help them in offering robust citizen science programs.

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CHAPTER 2: Exploring Multi-dimensional Citizen Science Participation on the SciStarter Platform: Overall Trends and Impacts of Facilitation

Abstract

The majority of research on citizen science to date has taken place in single-project contexts, with a project being a defined effort of a researcher or platform to collect or curate data of a specific type or to address a specific research question (for example: iNaturalist, eBird, StallCatchers). However, recent research has demonstrated that participants may engage in multiple projects simultaneously or in succession (Allf et al., 2022; Ponciano and Pereira, 2019). These findings, along with an acknowledgement that participants bring unique motivations to the table and may also join projects through non-traditional pathways, such as via facilitator organizations (libraries, museums, educational programs, etc.), has led to a call for more participant-focused research (Allf et al., 2022). In this chapter, I explore overall trends in participation across the citizen science landscape using digital trace data from SciStarter.org. I then compared these trends between “typical” (self-selecting) participants and facilitated participants from the Girl Scouts’ Think Like a Citizen Scientist program, Verizon’s corporate volunteer program, and college students from various universities across the US. My findings demonstrate that while there is wide variation in both breadth and depth of participation within and across projects, the majority of contributions come from a very small fraction of participants, with most participants contributing only sporadically and eventually lapsing in their participation. There were distinct differences between “typical” and facilitated participants, but these differences varied by facilitator. Girl Scout participants were more likely to have higher breadth and depth than all other participants, and their experience was the most intentionally

curated and highly facilitated. University students and Verizon volunteers, on the other hand, had generally lower breadth and depth than "typical" participants. These differing outcomes in various facilitated contexts suggest not only that the nature of the facilitated experience may impact participation, but also that possible interactions might exist between facilitation and motivations for participating in citizen science. My findings suggest that while facilitation can lead to enhanced participation in citizen science, the specific facilitation context matters, opening up the need for additional research on the impacts of specific elements of facilitated citizen science experiences, as well as on the interactions between facilitation and participant motivations.

Introduction

Citizen science overview

Citizen science is a globally recognized term encompassing a variety of forms of public participation in scientific research. The term was originally conceived in the mid-1990s in two different contexts – first as a way to promote the democratization of science and the use of science to address societal challenges (Irwin, 1995), and secondly as a way to increase public participation in the practice of science (Bonney, 1996). Today the term encompasses a spectrum of scientific endeavors involving the public in formats that are reminiscent of both of these original definitions, from community-led partnerships with scientists seeking to address issues of local concern such as pollution and threats to public health, to scientist-led projects involving the public in data collection and/or analysis (Haklay et al., 2021; Shirk et al., 2012).

Research on citizen science has framed this variety of practices in a number of ways. Most commonly, practices are considered within the context of "projects," which are discrete efforts to answer a specific scientific question (such as the "Belly Button Biodiversity project" that focused on participants collecting and contributing swabs from their belly buttons to develop a better understanding of the microbial communities therein (The Public Science Lab, 2020)) or collect a specific type of data (such as eBird, which involves participants all over the globe making and submitting observations of avian species in support of a variety of scientific efforts (eBird, 2022)). The most common framework for considering different types of citizen science projects is derived from Arnstein's ladder of citizen participation (Arnstein, 1969) and classifies citizen science projects based on the level of participant engagement, including categories such as *contributory* - in which participants are primarily involved in the collection of data or submission of samples, *collaborative* - in which participants are involved in more of the scientific process of the project, including helping to formulate questions, analyze data, and/or disseminate results, and *co-created* – in which participants are involved throughout every stage of the process, including project conception and design, execution, and application/dissemination of findings (Bonney et al., 2009; Shirk et al., 2012). Other frameworks focus more on the "type" of project, classifying projects based on their goals and interactions with the physical environment, including: *action* projects - which take more of the form of Irwin's idea of citizen-led efforts to address local concerns; *conservation* projects – which as the name suggests fall primarily in the realms of ecology and natural resource management and tend to also be place-based; *investigation* projects - which involve some type of physical data collection; *virtual* projects -which occur entirely online with no physical interactions required; and *education* projects – which could align with other types in the typology except that they put educational goals at the forefront (Wiggins and Crowston, 2011).

Increasingly, research on citizen science has begun to look beyond outcomes for projects and their scientific goals to consider the experiences of participants themselves (Peter et al., 2019; Peter et al., 2021). Consideration of participant experiences can help to inform the design and execution of projects in ways that can improve outcomes for both projects and participants. For example, by examining participant motivations and interests and incorporating knowledge from adjacent fields such as volunteerism and marketing, research can inform efforts to improve participant retention while making experiences more engaging and fulfilling (Hart et al., 2022; West and Pateman, 2016). Investigations of participant motivations in citizen science have generally revealed a variety of extrinsic and intrinsic factors, or a combination of both (Larson et al., 2020; West et al., 2021). They have also found that motivations are not static over time but may require different supports and types of opportunities or engagement to sustain participation (Larson et al., 2020; West and Pateman, 2016). Therefore, project owners are advised to cater to a variety of possible motivations to increase participation in and inclusivity of projects and create avenues for supporting changing motivations over time (Larson et al., 2020; West and Pateman, 2016; West et al., 2021).

Citizen science participant typologies

In efforts to better understand participation trends in citizen science projects and thereby inform recruitment and retention efforts, researchers have classified and developed typologies of participation patterns based on a variety of factors. One of the earliest efforts to do so was undertaken by Eveleigh et al. (2014), who examined the relationship between participant contribution levels (defined by percentiles of total contributions) and motivations measured with a survey. The study of 299 participants in a single project on the Zooniverse platform revealed a skewed contribution pattern highly characterized by self-described “dabblers” as well as participants who ultimately dropped out. Critically, the authors suggested that while project managers tend to agonize over the need for high engagement and retention of participants, amidst an ever-growing landscape of citizen science projects it may be unrealistic to expect participants to not test out many projects and perhaps drop in and out of several over the course of participation. This aligns with more recent findings by Allf et al. (2021) that just 23% of citizen science participants across 3894 survey respondents participated in only a single project. Yet, as discovered by Eveleigh et al. (2014), even participants who “dabble” can still contribute significantly to a project. Therefore, they suggest leaning into participants’ tendencies to dabble and designing efforts to retain such participants, as well as those who are highly committed to a single project.

Many other participant typologies have considered more complex measures of participant engagement involving multiple metrics, such as Ponciano and Brasiliero (2014), who used hierarchical and k-means clustering techniques incorporating the level and frequency of activity, time contributed, and overall length of time associated with two online citizen science projects to construct a categorization of 5 engagement profiles of participants: *hardworking, spasmodic, persistent, lasting,* and *moderate.* Aristeidou et al. (2017) later adapted Ponciano and Brasiliero’s (2014) measurement framework for use in assessing participation in a “citizen inquiry” project and compared their findings to the previous categories. Their cluster analysis revealed four categories of *loyal, persistent, hardworking,* and *lurking* participants, as well as *visitors* who participated 2 or fewer times and whose contributions therefore could not be computed as part of the cluster analysis. Importantly, Aristeidou et al. (2017) noted the differences between their results for a more engaged form of citizen science project as opposed to the categories found across two online, contributory-style projects by Ponciano and Brasiliero (2014), and emphasize that different contexts may require different approaches based on varying forms and profiles of engagement.

Yet another study employed a different methodology – latent profile analysis (LPA) – to examine participation in Snapshot Wisconsin and compared the outcomes of this approach to the use of k-means clustering (Anhalt-Depies et al., 2022). Their methodology revealed 4 categories: *short-term dabblers, long-term dabblers, long-term persistent volunteers,* and *intense temporary volunteers.* For better comparison to previous studies, they also performed a k-means cluster analysis limited to 4 groupings and found similar results, noting that they believed the LPA approach to be more discriminating for certain metrics than k-means. However, the authors also concede that LPA is currently only fully achievable through the use of proprietary software, whereas k-means and similar clustering approaches can be successfully performed in open-source software. Furthermore, the authors had to exclude nearly two thirds of their potential participants due to low participation (1-2 days total) which made some of the quantitative metrics inapplicable; this was similar to Aristeidou et al. (2017) who preemptively classified these participants as "visitors."

A final framework developed recently sought to classify not only current participants but also those whose participation has lapsed (Fisher et al., 2021). Labeled the "Nibble-and-Drop" Framework, the authors seek to capture the "natural arc of volunteer engagement" (Fisher et al., 2021, pg. 4) and highlight a variety of potential dropping-off points by looking at two metrics of engagement: length of participation (temporal aspect) and level of contribution. The authors developed the framework *a priori* to consist of 5 categories*: initial-droppers* (who never make a contribution), *nibble-droppers* and *hooked-droppers* (both of whom have lapsed in participation but made varying levels of contributions), and *nibblers* and *hooked* participants (who are still active at low and high levels respectively). The authors then demonstrate how the framework could be applied to 3 selected GLOBE Observer projects (or "protocols") – Clouds, Mosquito Habitat Mapper, and Land Cover – using specified cutoffs for each metric, and conducting Chi-Squared tests to compare the frequencies of different demographic, recruitment, and motivational groups across each of the 5 categories. The authors emphasize that because the project was developed in a project-agnostic manner, it is meant to be adaptable and consider a variety of metrics and levels as relevant to any given project. A critical finding made by the authors through the exploration of their framework paired with participant survey responses is that many participants who "drop" were never committed to the project in the first place and were either only "window shopping" or testing the waters before realizing a project is not the right fit for them (Fischer et al., 2021). Similar to Eveleigh et al.'s (2014) acknowledgment, while these trends can often be seen as failures in the eyes of project managers, it is a reality of voluntary participation that is best accepted and used to improve management efforts in the future.

Multi-project participation

While each of these studies has made valuable contributions to the understanding of volunteers' patterns of engagement with citizen science, they have all examined only 1 project or project family at a time, with samples ranging from 77 to 782 participants, and incorporating data from periods between 14 weeks to approximately 2 years in duration. Only two known studies to date have examined such trends in the context of multiple, unrelated projects. The first by Ponciano and Pereira (2019) looked at participation on 3 online crowdsourced micro-tasking-style citizen science platforms over the course of 2 years and hosting varying numbers of projects: Crowdcrafting (2012-2014, 22 projects), Socientize (2013-2015, 10 projects), and GeoTag-X (2014-2016, 16 projects). The researchers looked at a number of metrics from both participant, project scientist, and platform perspectives, and found that less than 1/3 of volunteers participated for longer than a day and fewer than 6% contributed to more than one project on a platform. As others before them had found, they discussed the applicability of the 1% rule to the platforms they explored, in which a very small number of users make the vast majority of contributions. However, the authors found some promise in the fact that when participants *did* engage in multiple projects, they seemed to stay engaged with the platform for a longer period of time.

The low levels of multi-project engagement observed by Ponciano and Periera (2019) are contrary to the other known study examining participation across projects. Through the results of surveys from 3,894 participants in two offline citizen science projects and one citizen science web platform (SciStarter), combined with digital trace data for 3,649 participants on the SciStarter platform, Allf et al. (2021) discovered that 77% of participants in their sample joined two or more projects. The study also explored the tendencies of participants to engage in projects in multiple disciplines (e.g. ecology and astronomy) and various "modes" (offline vs. online) and found that multi-project participants were evenly split between discipline specialists (39%) and discipline spanners (38%). However, most participants seemed to stay within a single mode of participation (52% were mode specialists) as opposed to spanning both online and offline modes (25% were mode spanners). While this study made important steps towards beginning to elucidate the dynamics of multi-project participation, it lacked many of the participation metrics examined in other studies cited here, such as participation frequency, level, and duration. This information, combined with the concepts of mode and discipline spanning presented by Allf et al. (2021), could facilitate a truly holistic understanding of participant engagement with citizen science across multiple projects over time.

Facilitated citizen science participation

A final key aspect of citizen science relates to the pathways individuals take to participation. Traditionally, this pathway has been envisioned as participants seeking out projects they have an affinity for (e.g. birders participating in eBird or Christmas Bird Count), or projects actively recruiting participants. Either way, the focus typically revolves around a single-project context. Yet, as discussed above, participants seldom participate in only a single project over the course of time, or even at one time. Online citizen science platforms like SciStarter, AnecData, Zooniverse, and others, have increased participant access to multiple projects on a variety of topics, and enable a central location for connecting with projects, logging and tracking contributions, and more.

Similarly, as the phenomenon of citizen science has grown, numerous third parties have adopted the practice and encouraged participation for the purposes of supporting scientific research on a particular topic or boosting science literacy and agency. Such third parties, which we here refer to as "facilitator organizations," can include academic institutions, libraries, community organizations like churches or scout troops, corporate volunteer programs, and more (Lin Hunter, 2023; Smith et al., 2023). Each of these organization types have a variety of reasons for bringing new audiences to citizen science, including audiences who historically may have been excluded from citizen science due to a number of barriers (Lin Hunter et al., 2023).

Whether and how individuals who participate in citizen science through a facilitator organization might differ in their trajectories from the more traditionally-studied, self-selecting participants provides another aspect of participation patterns to explore and better understand. Doing so can enhance management decisions made by projects, platforms, and facilitator organizations to better support the diverse needs of participants.

Research Questions

Given the still limited understanding of citizen science participation patterns across multiple projects – and particularly projects of multiple modes (offline and online) – the current study seeks to fill this gap by applying metrics of both depth and breadth of engagement to participants on the SciStarter platform. This study also seeks to investigate how these patterns might differ between individuals whose participation is facilitated vs. individuals who self-select into citizen science. In exploring these participation trends, we seek to answer the following questions:

1. What are the trends of citizen science participation across the SciStarter platform, in terms of both breadth and depth?
2. Do these trends differ between self-selected users vs. users who participate through facilitator organizations?

Methods

SciStarter

SciStarter.org and its users serve as the study context and subjects of this investigation. As an online platform with nearly 200,000 registered users, millions of visitors to the site, and featuring over 3,000 citizen science projects across a variety of disciplines and varying modes of engagement (online, offline, combined, etc.) (Bautista-Puig et al., 2024; SciStarter, 2022), SciStarter offers a microcosm of the citizen science landscape for study. Applying previous typological metrics to the SciStarter context therefore allows for one of the most comprehensive explorations of citizen science participation to date. Through the use of SciStarter's API (Hoffman et al., 2017), the site is also able to track contributions for projects that have "affiliate" agreements with SciStarter. These agreements allow users to connect their accounts on multiple sites and track their contributions all in one central location via their SciStarter dashboard. Affiliate projects include some of the more popular project platforms and apps in the citizen science landscape, such as iNaturalist and the NASA GLOBE Observer suite of projects.

SciStarter's existing partnerships with numerous facilitator organizations also enabled the research team to explore differences between facilitated participation vs. self-selected participation. SciStarter has created uniquely tailored "microsites" for many of their facilitator organization partners (for example: NASA, libraries, and museums). These microsites serve as dedicated landing pages for individuals participating through a specific facilitator organization, often feature a selection of curated projects based on the facilitator's goals and/or participant interests, and allow facilitator organizations to access analytics for their users.

Data collection and cleaning

As research partners of SciStarter.org, the research team from NC State University received anonymous digital trace data (DTD) from the SciStarter website in March 2024. This DTD contained records of project participation for 157,654 SciStarter users, as well as the date each user created their SciStarter account and any tags associated with the user (for example, a user's administrator status, completed trainings, and their affiliation with any microsites). The data were exported in JSON and csv formats and the research team imported the data into R for extraction, cleaning, and analysis.

The first phase of data cleaning and preparation involved determining which users to retain for analysis. In addition to providing a platform for prospective participants to connect with a variety of citizen science projects, SciStarter also serves as a resource and training hub for both practitioners and members of the public interested in learning more about the participatory sciences, as well as a host for numerous online and in-person events related to citizen science and adjacent topics. Because of this, not all users who create an account on the platform ultimately join a citizen science project. Those who do indicate interest in participating in a project are tagged as “joining” a project. This tag is applied to any users who navigate to a project's website off of SciStarter, those who manually indicate on SciStarter that they have joined a project, and/or those who log contributions to an affiliate project. Within the data I received, 54.9% (86,573) of the users with SciStarter accounts have a record of joining at least one project. Additionally, not all users listed as “joining” a project had records of actually contributing to a project, either because they contributed to a non-affiliate project, or because they behaved as “initial-droppers,” described by Fischer et al. (2021) as those who join a project but never participate. Because I was interested in exploring actual participation patterns within and across projects on the platform, I limited the majority of my analysis to users with at least one verifiable record of contributing to a project. Such contribution data are available for all affiliate projects, of which SciStarter had at least 295 over the timespan of the data provided. After performing some exploratory summary statistics for users who did not have any recorded participation (see Results: Characterizing non-participation), the data used in the remainder of the analysis was limited to only that of users with at least one recorded contribution to one or more affiliate projects. This left me with records for 36,065 users with participation data, or 22.9% of individuals with SciStarter user accounts.

The next phase of data preparation involved employing user tags to categorize users by type. I first used a list of tags developed in collaboration with SciStarter to exclude administrators (including SciStarter staff; research, media, and other partners; collaborators managing other citizen science platforms; etc.) and project staff (including project scientists, volunteer managers, etc.) from our data. Next, using a variety of tags associated with trainings and resources designed for formal and informal educators –including many librarians– I was able to identify and exclude known facilitators, who were likely to be primarily engaging with SciStarter for continuing education purposes or to prepare themselves to support others in engaging with citizen science. Another handful of users were excluded who were unable to be definitively classified into any particular user group based on their user tags. These exclusions left 33,637 users to categorize.

The remaining users were categorized as either "typical" (self-selected) or "facilitated" users. Typical users were identified as those without any site or project administrator tags and who had never been affiliated with a microsite. These users are more likely to have found their own way to SciStarter and engaged with the platform and any citizen science projects in a generally self-guided manner. Facilitated users were those who had a user tag associated with accessing a microsite, and therefore those whose participation was facilitated by a third party group or individual. Because microsites can be accessed by anyone on the internet, only users who had a tag for the microsite in question (and no other microsites), and whose accounts were created after the launch date for the microsite, were included in the user data for each microsite.

Among facilitated users, I initially identified individuals associated with 19 microsite partners (some partners such as Girl Scouts had multiple microsites for different audiences). However, based on low usage on some sites and input from SciStarter about the level of facilitation provided by these partners, I ultimately ended with three primary categories of facilitated users: Verizon corporate volunteers; University Students from a number of institutions of higher education; and Girl Scout participants (see Table 1 for additional information about each of these user groups). After removing the handful of users from fully facilitated microsites with too small a sample size (as few as two users with project participation for one site), I was left with 33,339 users falling into one of these facilitated user categories or the "typical" user category.

Measuring participation

To assess participation patterns across the SciStarter platform, the research team selected representative metrics of both depth (within-project) and breadth (across projects) of participation from among the many previously conducted participant typologies.

Breadth metrics are categorical and borrow terminology from Allf et al. (2021):

- **Single vs. Multiple Projects**: this metric categorizes participants as *singletons* (who contribute to 1 project only) vs. *multi-project* participants (contribute to 2+ projects).
- **Mode preference**: this metric classifies participants as *online-only* (participating only in projects which occur 100% online), *offline-only* (participate only in projects which have an offline component), and *mode-spanners* (participate in at least one project of each

mode). Although designed directly following Allf et al.'s (2021) work, this online-offline categorization of projects also aligns well with Wiggins and Crowston's (2011) *virtual* and *investigation* categories.

- **Discipline preference:** this metric is based on hand-coded discipline classifications of the topics of projects an individual participates in (e.g. ecology and environment, health and medicine, astronomy and space, etc.), with *discipline specialists* participating in projects only within a single discipline and *discipline spanners* participating in projects of 2+ disciplines.

Depth metrics represent numeric variables adapted from other previous typologies. As described by Fischer et al. (2021), these two metrics account for the temporal aspect (length) and level of engagement in considering overall depth of participation.

- **Average Contribution Percentile:** Following Eveleigh et al. (2014) and Fischer et al. (2021), I considered the level of contributions based on percentiles. Participants' contribution percentiles were calculated for each project they contributed to (that is, the percentile where they fell as compared to *all* users contributing to that project). Then, I calculated each users' average percentile score across all of the projects they participated in to characterize their overall level of contribution. Scores fell between 0 and 1.
- **Average Activity Ratio:** Following the *relative activity duration* used by Ponciano and Pereira (2019), I next calculated a relative activity ratio for each participant and each project they have participated in, defined as "the number of days between the first and the last contribution of the volunteer in relation to duration of the user relationship with the

platform (measured as the number of days since the volunteer joined the platform until the day when the data of the platform was collected)" (Ponciano and Pereira, 2019, pgs. 3-4). Some SciStarter users were active contributors to certain affiliate projects prior to joining SciStarter. These participants therefore have contributions dated before their platform join date, leading to some users' *relative activity ratios* falling outside the expected range of 0-1. Because of this, I had to calculate an *adjusted activity ratio*, only taking into account contributions occurring on or after the date a user created their SciStarter account. I then averaged participants' *adjusted activity ratios* across all projects they participated in to get a final *average activity ratio*.

Before moving on to more formal analyses, I first conducted general summary statistics to get an overall sense of patterns of participant breadth and depth. Following the typology analysis, a further 17 users were excluded as they only participated in a single project for which they were the only contributor. Therefore, no contribution percentile could be calculated for them. Yet another 183 users were excluded who had records of participation through the connected API with affiliate projects, but had no participation recorded since joining SciStarter (ie, all participation predated them making their SciStarter account). This left me with 33,139 final users. See Table 1 for a final count of users by user type.

Hierarchical clustering to characterize participation trends

In order to address our first research question and better understand trends of citizen science participation across the SciStarter platform, I conducted a hierarchical cluster analysis using the breadth and depth metrics I developed. Because singletons and multi-project users by default have different metrics (singletons can never be mode spanners or discipline spanners), I performed separate clustering of these two groups. This decision was supported by early rounds of clustering including all users in which singletons and multi-project users overwhelmingly fell into separate clusters.

Prior to performing our cluster analysis, I converted our depth metrics (Average Contribution Percentile and Average Activity Ratio) into categorical variables using tertiles to create three approximately equal groups of low, medium, and high contributions or activity for the two variables, respectively. For Average Contribution Percentile, the tertiles broke down as follows: Low (n = 11,055), average percentile <= 0.026; Medium (n = 11,022), average percentile >0.26 and <= 0.566; High (n = 11,062), average percentile > 0.566. For Average Activity Ratio, the distribution was heavily right skewed. To adjust for this prior to dividing users into tertiles, I first used a reciprocal transformation (1/*(Adjusted)* Average Activity Ratio) to make the data more normal. Due to the use of the reciprocal activity ratio, these were named appropriately so that the lower tertile of reciprocal activity (ie 1/higher number) was labeled as high activity, as it equates to a higher actual activity ratio. The tertile breaks and total users in each were as follows: Low Activity (n = 11036), ; Medium Activity (n=11056), reciprocal activity ratio >263.6667 and <= 1063; High Activity (n=11047 users), reciprocal activity ratio <= 263.6667.

Converting and using all categorical variables allowed for more even weighting of all variables in the analysis versus having to manually weight numeric vs. categorical variables (Liu et al., 2024). These tertiles were considered as ordinal variables in our analysis with Low < Medium < High, while Mode and Discipline were considered as nominal variables.

Using these nominal and ordinal inputs, I first calculated the dissimilarity matrix for our singletons and our multi-project datasets using the Gower distance metric, which is indicated for mixed and non-numeric data in clustering (Gower, 1971). For singletons, the dissimilarity matrix was calculated based on Mode, Average Contribution Tertile, and Average Activity Tertile variables, as all singletons are discipline specialists, and therefore this variable had no variation for singletons. For multi-project participants, I also included the Discipline variable in the analysis. Using the resulting dissimilarity matrices, I then performed agglomerative hierarchical clustering of singletons and multi-project participants using the hclust() function of the fastcluster package in R (Müllner, 2013). Performing hierarchical clustering with a dataset of this size was computationally challenging, and the fastcluster option improved performance. I employed the complete linkage method in our analysis, which combines clusters based on the complete linkage distance, or the maximum of all pairwise distances between the two clusters (Nielsen, 2016). The appropriate number of clusters was determined by examining the resulting dendrograms and selecting a cutoff through the tallest "branches" of the dendrogram (Manning et al., 2008). Each user's cluster assignment was then merged back in with the original data so that I could create summaries of the users in each cluster and perform further analysis.

Multinomial logistic regression exploring differences in facilitated vs self-selecting users

The final piece of our analysis sought to answer RQ2 in assessing whether the trends in participation determined through our cluster analysis differ between "typical" (self-selecting) users and those whose experience was more facilitated. To explore this relationship, I performed a multinomial logistic regression with the clusters obtained above as our dependent variable. As our independent variables, I used the categorical variables below to explore the relationship of different elements and types of facilitation on participation:

- **User type:** This categorical variable represents the user groups identified during data cleaning: "typical" users (the reference group for this variable), Verizon corporate volunteers; University Students; and Girl Scout participants.
- **Training completed:** SciStarter offers the Foundations of Citizen Science Training to all visitors to the site. The training serves as a virtually-facilitated introduction to citizen science, providing an overview of the SciStarter platform, the concept of citizen science, and how to get started participating in projects. Using a separate .csv dataset provided by SciStarter, I was able to label each participant as having completed this training or not. The reference group for this variable was "Did Not Complete Training," while all others fell into the "Completed Training" category.
- **Digital Facilitation:** Because SciStarter offers frequent communications and supplemental content to all of their users, both "typical" and facilitated users may from time to time engage in other "digitally facilitated" activities or events through the platform. Working with SciStarter, I was able to identify tags that represented users engaging with these types of activities - from participating in a Citizen Science Month campaign or projects related to the April 2024 Solar Eclipse, to users who engaged with special documentary or webinar content (Table 2). The level of direct facilitation from these types of opportunities is generally quite low compared to the highly structured facilitation represented by the training and programs such as those run by Verizon, university instructors, and the Girl Scouts. However, I felt this "digital facilitation" was still worth exploring in relation to participation trends. Users

were categorized based on whether they were tagged as having engaged with one or more of these digitally facilitated experiences (Digitally Facilitated Tags - yes/no) with no digital facilitation being the reference group for this variable.

I performed the multinomial logistic regression in R using the multinom() function of the nnet package (Venables and Ripley, 2002). The largest cluster (Cluster 1 - higher depth, online-only singletons (n=10,593)) was used as the reference group for the dependent variable. Reference groups for the independent variables are specified above alongside the variable descriptions. Estimated coefficients for cluster 10 for girl scouts were very high because there were no girl scouts in that particular cluster. Therefore, these numbers were replaced with a zero so the estimated values were not artificially inflated.

Results

Characterizing non-participation

As indicated in Methods, only 23% of users with accounts on SciStarter had verifiable records of participating in at least one project. However, it is worth reiterating here that not all projects with records of "joins" are able to track participation data. Only affiliate projects provide this possibility. However, the majority of project joins recorded (59%) were also for affiliate projects. This is likely because these are the projects most widely promoted across the SciStarter platform and therefore the most likely to be discovered by users of the platform. Even though non-affiliate projects still received 41% of recorded joins, these were spread across 2,820 unique projects vs. the 295 affiliate projects, leading to a much higher join rate for affiliate projects. Affiliate projects had a median of 42.5 joins per project vs. 4 joins per non-affiliate project.

To get a sense of the rate of "initial dropper" behavior (Fischer et al., 2021) among SciStarter users, I explored instances of non-participation for users who joined affiliate projects - in other words, situations where participation data would have been available if it existed, but it still did not. Out of the 71,222 users with a record of "joining" affiliate projects, 63.3% (45,080 users) "initial dropped" from at least one project, while 49.6% (35,305 users) never participated in any affiliate projects. 271 of the 295 affiliate projects represented in the data had at least one user who joined but never participated. Of users with initial drop behavior, the median number of drops per person was 1, mean 1.5, and max of 84.

Summaries of breadth and depth

Approximately 1 in every 6 of the final 33,139 SciStarter users retained for analysis (16.4%) participated in 2 or more affiliate projects and were therefore classified as "multi-project users." The remaining 83.6% were classified as "singletons." Among the singletons, offline projects were slightly more popular than online projects, with 56.6% of users participating in an offline project, and the remaining 43.4% participating in online projects. Multi-project users were most likely to be mode spanners, with nearly half (48.3%) participating in at least one offline and one online project. Of the remaining multi-project users, it was an even split between all online vs. all offline projects (25.8% and 25.9% respectively). All singletons were by default discipline specialists since they only participated in a single project. Multi-project participants, however, were nearly twice as likely to be discipline spanners (participate in projects of multiple disciplines, 65.8% of multi-project users) than to be discipline specialists (34.2%).

In terms of depth, users' average contribution percentiles spanned the full range of possible values from 0 to 1, and were somewhat right-skewed, with a large proportion having very low contribution scores. However, the rest of the users were fairly evenly distributed across the 0 to 1 range, and overall these scores have an acceptable skewness value of 0.29. The median average contribution percentile was 0.35 and the mean was 0.37.

The adjusted activity ratio calculations for users ranged from participating approximately 1 out of every 500 days since joining SciStarter (adjusted activity ratio of 0.0002), to being active every day since joining (adjusted activity ratio of 1). Overall this metric was highly right-skewed (skewness of 3.88), with an upper quartile of 0.0071. There was a slight spike in highly active users with a ratio at or around 1, but the vast majority of users had very low ratios. It is worth noting here that users with low adjusted activity scores may have been highly active at one point in their history on SciStarter but have become lapsed users. In general, the longer a user has been associated with SciStarter, the more likely they are to have lower activity, unless they participate every day; whereas a newer user, for example, could have only been active one day ever but only joined 10 days ago, and have a relatively much higher activity ratio.

Participation trends - hierarchical clustering results

Hierarchical clustering of singleton participants (n = 27,703) resulted in identification of four clusters, distinguished first by mode of participation (online vs. offline), then depth of participation (lower vs. higher) (Figure 1). Cluster analysis of multi-project participants (n = 5,436) resulted in identification of seven clusters, distinguished by a combination of characteristics (Figure 2). The first branching of the dendrogram separated all offline-only participants into one clade, mixed-mode discipline specialists into another, and mixed-mode discipline spanners into a third. For offline-only participants, the final clades (clusters) were distinguished by a combination of discipline and depth metrics. For the other two initial mixed-mode clades, the final clusters were distinguished by mode (online only vs. mode spanning) and represented varied breadth metrics. A more detailed breakdown of the characteristics of participants in each cluster can be found in Table 3.

Impacts of Facilitation - Multinomial Logistic Regression Results

As discussed in methods, the resulting 11 clusters from above were used as the outcome variable for the multinomial logistic regression, with the largest cluster (Cluster 1, Higher-Depth Online Singletons) as the reference group. In examining the relationship between User Type and cluster assignment, Girl Scouts were significantly more likely than "typical" users to be in clusters 3, 5, 7, 8, or 11 than the reference cluster (Figure 4, Tables 3 & 4). These clusters are generally characterized by being offline or mode-spanning (a combination of offline and online) as opposed to online-only, and of mixed to high breadth. In contrast, university students were significantly more likely than "typical" users to fall into clusters 1, 5, 9 and 10 as opposed to the reference cluster (clusters characterized by being generally lower-depth and online, with the exception of cluster 5), and significantly *less* likely than typical users to fall into clusters 3, 4, 6, 7, and 11 as opposed to the reference cluster (clusters characterized by being offline or mixed-mode and discipline spanning for multi-project clusters). Finally, Verizon users were significantly more likely than typical users to be in clusters 2 or 9 as opposed to the reference cluster (both characterized by being online-only and lower-depth). Verizon users were also significantly *less* likely than typical users to fall into clusters 3-8 and 11 as opposed to the reference cluster. These clusters are all defined by being offline or mixed-mode (offline and online) as opposed to online-only.

When examining the relationship between additional training and facilitation opportunities and cluster assignment (Figure 4), those who have engaged with digital facilitation opportunities are significantly more likely than those who have not to fall into clusters 2 and 7-11 as opposed to the reference cluster. There do not appear to be any clear patterns in the characteristics of these clusters associated with digital facilitation tags. These users are also significantly less likely than those without digital facilitation tags to fall into clusters 3 and 4 as opposed to the reference cluster. In other words, they are less likely to be offline-only singletons (regardless of depth), than high-depth online-only singletons. Those who had completed the Foundations Training were significantly more likely than those who had not completed the training to fall into Cluster 11 as opposed to the reference cluster (Cluster 11 is arguably the cluster with the highest combined depth and breadth of all clusters), and were significantly less likely than those who haven't completed the training to fall into clusters 2-7 and 9-10 than the reference cluster. This generally seems to indicate that those who have completed the training are most likely to be higher-depth online only users if they are singletons and higher-depth and -breadth users if they are multi-project participants.

Discussion

Engagement with the SciStarter platform

We found that users on SciStarter behave heterogeneously in terms of their engagement with citizen science projects presented on the site, ranging from creating an account but never joining or participating in a citizen science project, to joining and participating in multiple projects across disciplines and modes. Almost half of users who make accounts on the platform never join a project, likely because of the other diverse offerings available on SciStarter. The site offers training and resources for project managers, educators, librarians, and other individuals who may primarily access the site for those reasons. SciStarter also features science-related events and programs happening across the country and the globe, and hosts a blog and newsletter, which may draw in additional users.

In terms of facilitating structures provided by SciStarter, we found that affiliate project status seems to boost engagement from SciStarter users. While some affiliate projects still had very low participation (as low as a single contributor), they overall saw more than ten times more joins per project than non-affiliate projects. Despite this higher rate of project joins, "initial dropper" (window shopping) behavior (as coined by Fischer et al., 2021) is still common among users who joined affiliate projects. In fact, we found the rate of initial-dropper behavior on SciStarter (49.6%) to be more than double the 21.9% rate reported by Fischer et al. (2021). This higher number may be influenced by the fact that SciStarter is fairly liberal with what it counts as "joining," and it does not always require an intentional effort to join by the user, thereby inflating the number of reported project joins.

Trends in participation breadth and depth among SciStarter users

In addressing RQ1, as with general user behavior on the site, breadth and depth trends across the platform were highly varied. Our cluster analysis based on breadth and depth metrics led us to identify 11 distinct clusters of users. As described in Methods, due to inherently different metrics between multi-project users and singletons, multi-project behavior was the most distinctly differentiating factor among users, leading us to run separate cluster analyses for these two groups. We observed a rate of multi-project participation (16.4%) somewhere between the 77% reported in Allf et al. (2021) and the <6% rate described by Ponciano and Pereira (2019). In reality, the actual rate of multi-project participation among SciStarter users is almost certainly higher than 16.4%, as we were unable to account for participation in non-affiliate projects or projects not featured on the SciStarter platform in our count. However, it seems unlikely that the current rate is as high as the 77% that Allf et al. (2021) found with their use of survey data and SciStarter digital trace data (DTD) from 2017-2018. It is worth noting that the data they used only contained DTD from 3,649 SciStarter users, who were likely highly engaged early adopters of the site, and self-reported survey data from 423 SciStarter volunteers, who were engaged enough to respond to the survey. Their project participation metrics were also based only on joins, rather than verified contributions to projects, which means their 77% metric is also likely somewhat inflated by "initial droppers."

Mode of participation (online vs. offline) was the next most distinguishing metric, with offline vs. other users defining the first branching of our singletons cluster analysis, and offline-only vs. mode spanning/online-only users defining the first branching of the multi-project cluster analysis. Among singletons, offline projects were only slightly more popular than online-only projects (57% vs. 43% of users). Similarly, among our multi-project participants, we found a balanced number of mode-spanners vs mode specialists (48% vs. 52%), as well as an even split among online-only vs. offline-only mode specialists (both 26% of multi-project users). It is worth noting here that only 71 of the 295 affiliate projects (24%) included in the data provided by SciStarter were online-only projects, so these online projects seem to have received proportionally higher participation among both singletons and multi-project users compared to projects with at least some component that is offline. This is a distinct shift towards more online-only project participation from the analysis by Allf et al. (2021), who reported that only 35% of singleton users in their DTD and 21% of singleton survey respondents participated in online projects, and a very low 11% of multi-project users participated only in online projects. Mode-spanning tendencies also decreased from the 64% reported among Allf et al. (2021)'s digital trace data to ours.

While singletons by default only participated in a single project of one discipline, discipline preferences were the next most defining metric in our cluster analysis of multi-project participants. In fact, discipline preferences seemed more distinctive than mode preferences for online only and mode-spanning users, characterizing the second and third clades of our multi-project dendrogram (Figure 2). For offline-only users, mode seemed more distinctive, with sub-clades defined by a combination of discipline preference and depth metrics (Figure 2). Interestingly, while mode-spanning behavior seems to have decreased since 2018 with a shift towards more online-only specialization, discipline-spanning behavior seems to have slightly increased compared to the analysis by Allf et al. (2021), who reported 62% discipline spanners as opposed to our 68%. Both of these shifts are more interesting given that the general variety of projects on offer has not changed substantially since 2018 in terms of either mode or discipline (Appendix A). Perhaps one explanation is that SciStarter has helped to bring greater awareness, and therefore participation, to some of the other types of projects on offer beyond the more conventional, field-based ecological citizen science projects (iNaturalist, eBird, Christmas Bird Count, etc.). Again, it is worth noting here that Allf et al. based all of their calculations on project *joins* rather than verified participation. Since SciStarter interprets joins liberally, it is possible that these apparent differences are due to the fact that participants are more likely to initial drop (ie join/explore but not participate in) offline – and by extension, Ecology and

Environment projects, which are more often offline than not – as opposed to the online and other discipline projects they ultimately ended up participating in. Despite this distinction, however, our numbers aligned much more closely with Allf et al.'s (2021) 2018 DTD than the self-reported numbers of their survey respondents. This likely indicates (a) how skewed their self-report data was towards highly-engaged offline and discipline-specialists and (b) that while join data may be a better proxy for participation data than self-reported survey data, it is not completely reflective of actual participation trends.

Through the use of verifiable participation data, we were able to add the dimension of *depth* of participation to our analysis in addition to breadth. In our depth calculations, we considered both contributions (modelled after Eveleigh et al. (2014) and Fischer et al. (2021)) and activity (modelled after Ponciano and Pereira (2019)). Overall we found that both contributions and activity were heavily right-skewed. These skewed participation metrics align with previous research documenting the phenomenon of uneven contributions in citizen science, in which a small percentage of participants make the majority of contributions to a project. This phenomenon has been equated to the Pareto principle, which suggests that 80% of outcomes are due to 20% of causes (Allf et al., 2022; Parrish et al., 2019) and to the 1% rule in computing in which 1% of users generate 90% of content (Cooper et al., 2017; Ponciano and Brasiliero, 2014). Our data corroborated this pattern, with the top 1% of participants making 86% of total contributions across the 295 affiliate projects represented in our data. Perhaps even more shockingly, a single participant made over 35% of the total contributions recorded (6.9 million contributions, nearly all to StallCatchers).

Despite this "super-user" behavior for one project, this multi-project participant merely "dabbled" in a second project (Eveleigh et al., 2014). Because we averaged contribution percentiles across projects, this user ended up with an average contribution percentile of only 0.5, landing them in the "medium" contribution tertile. However, their dedication and commitment to making regular contributions to the StallCatchers project impacted their activity ratio, (0.5, or participating on average 1 of every 2 days they have been affiliated with the platform), which landed them solidly in the "high" activity tertile. This demonstrates the value of considering multiple contribution metrics aside from just the number of contributions.

In assessing users' activity ratios, we found that this metric was even more heavily skewed than the contribution percentiles, indicating that the vast majority of participants contribute either extremely sporadically or only a little before dropping out. This pattern supports Fisher et al.'s (2021) finding that "window shopping" and "nibble-dropping" behaviors are relatively common. The authors suggested that this behavior should be considered a normal part of the participant arc as users explore different options before finding the right fit. Both Fisher et al. (2021) and Eveleigh et al. (2014) discuss the importance of project managers acknowledging and designing for these ebbs and flows in user behavior, while continuing to identify and remove barriers that may lead to early lapses in participation. SciStarter, as a platform that bridges gaps between projects, encourages users to "sample" many different projects through their project finder tool, newsletter, website banners, and more. This both allows users to try multiple projects until they find a good fit, and potentially helps to link users to their next project when their engagement with another comes to the end of its natural arc.

Impacts of facilitation on participation trends

In addressing RQ2, our multinomial logistic regression revealed that trends in participation do indeed differ between self-selecting or "typical" users and facilitated users.

However, the types of differences depend on the type of facilitator. In particular, Girl Scouts seemed the most likely to fall into clusters that participate in offline projects and had relatively higher depth (contributions and/or activity). Conversely, university students and Verizon employees were generally *more* likely to fall into clusters that participate in online projects and have lower depth, and were *less* likely to fall into clusters with offline or mixed-mode participation.

These trends seem to reflect that facilitation adds another level of complexity to previously researched interactions between users' motivations and their patterns of participation in citizen science (Allf, 2023; Eveleigh et al, 2014; Larson et al., 2020). Much of this previous research has investigated how different intrinsic vs. extrinsic motivations for participating in citizen science may impact participation (Allf, 2023; Tiago et al, 2017). Students participating in the classroom, for example, are far more likely to be extrinsically motivated and to feel like they have no choice in their participation (Bedell and Gates, 2021; Dabrowski and Marshall, 2018; Smith et al., 2021; Tiago et al., 2017). Our analysis aligns with these previous findings, in that the university students in our sample, who participated in citizen science through a college class, overall demonstrated low breadth and depth of participation, even as compared to "typical" users. This acts as a cautionary tale of sorts, following Bedell and Gates' (2021) conclusions that participation in citizen science in the classroom does not necessarily set students up for future participation in citizen science. On the contrary, as our findings suggest, most students only ever participated briefly and at low levels, potentially indicating that poorly facilitated experiences with citizen science in the classroom might serve as a barrier to continued engagement with citizen science.

Perhaps even more distinctly than university students, Verizon users who participated through Verizon's corporate volunteer program generally had lower breadth and depth of participation than "typical" users. This is somewhat unexpected given that surveys of Verizon volunteers on SciStarter performed by Allf (2023) indicated that these users were overall more intrinsically than extrinsically motivated; the authors suggested that corporate social responsibility programs such as Verizon's are a promising source of citizen science volunteers. However, given their 0.3% response rate, it is likely that their survey respondents represented a highly motivated (and potentially biased) sample pool. Overall, Verizon users were the largest population of facilitated users in our data, and therefore our results might reflect the fact that while some of their users were highly motivated and had high levels of breadth and depth, the vast majority were very light "dabblers," as reported by Allf (2023).

Finally, while users associated with facilitator organizations may have differing motivations and goals for participating as compared to more traditional citizen science "volunteers," our results provide some initial evidence that facilitators have the potential to encourage greater breadth and depth. For example, Girl Scouts users in our sample had the overall highest breadth and depth of participation. These users participated in citizen science through one of three larger, structured programs that also connected them to other action steps and behaviors they could take to have an impact on their community or the environment. Girl Scouts is a voluntary program, and - while many Girl Scout troops decide to all work on a journey or badge together - the nature of their microsite provided girls with a large variety of projects to choose from that could meet diverse interests. The projects and curricula were also intentionally designed to be age-appropriate for girl scouts of different levels (Smith et al., 2023). All of these facilitated elements make these experiences much more likely to fulfill Girl

Scout participants' social, contribution-, and curiosity-based motivations for participation in a way that individual participation directly in a citizen science project would not.

Our analysis suggests that different facilitated contexts result in different participation profiles. However, given our approach, we can only make general conclusions about relationships between facilitation and participation, and not necessarily the motivations and other multitude of factors which may interact with these elements. That being said, further investigations on the interactions between these three factors – facilitation, motivations, and participation – in a variety of different facilitated contexts would be a valuable area for future research, aligning with previous suggestions emphasizing the importance of designing based on context (Aristeidou et al., 2017; Smith et al., 2023). Such research could help to gain a better understanding of how facilitators can create experiences that fulfill users' motivational needs such as their senses of autonomy, relatedness, and competence, as defined by self-determination theory (Allf, 2023; Bedell and Gates, 2021; Ryan and Deci, 2000).

Limitations and future research

Limitations of our findings include the incomplete picture of participant engagement provided by digital trace data. As noted previously, we were only able to examine actual contributions and participation across affiliate projects, rather than the complete landscape of projects on and beyond SciStarter. In addition, the incorporation of both categorical and numeric metrics presented a challenge in applying the quantitative methodologies used by previous participant typology research. Both k-means cluster analysis and latent profile analysis are designed for use on numerical variables only. We therefore landed on the use of hierarchical cluster analysis, which was computationally very intensive and slow with a dataset as large as ours. That being said, it was a good fit for our exploratory clustering to determine general trends in breadth and depth across SciStarter and allowed us to include all users with participation data in our analysis. Future studies may be able to use a combination of methods such as a *k*-prototype algorithm to perform a cluster based on categorical and numerical measures (Huang, 1998). Finally, without any survey responses or other information to supplement our analyses, we are currently unable to make any definite claims about causal links between facilitation and participation.

Challenges with quantitative analysis of user participation in citizen science are not uncommon, either. While our analysis was limited only to verifiable participation data from affiliate projects, our methods allowed us to include all of these users in our cluster analysis, whereas previous researchers have had to exclude users with low participation from analysis due to resulting calculation errors (Anhalt-Depies et al., 2022; Aristeidou et al., 2017). Despite these limitations, we have still been able to provide one of the most comprehensive analyses of participation across the citizen science landscape achievable to date and begin to dig into the value and challenges associated with facilitated participation in citizen science.

The field would benefit from further research that seeks to further elucidate the relationships between motivations, facilitation, and participation and to more explicitly understand the factors that lead to the trends we have observed. For example, are participation patterns always driven by individual interest, the presence or absence of barriers, social norms and support, etc.? Research that qualitatively explores the multi-faceted and individual nature of citizen science participant experiences to better get at factors influencing decisions to stay or leave and to contribute at different levels, would be valuable to inform project managers and facilitators of where best to spend their time creating support structures for participants. One promising area of overlapping research is human-computer interaction and design research related to user experiences with citizen science platforms (Dowthwaite and Sprinks, 2019; Huang et al., 2025; Preece et al., 2016; Skarlatidou et al., 2019). Project owners, platforms, and facilitators alike should be taking into account details of the user experience at all levels and designing intentionally to provide the best outcomes for scientists and the greatest benefits to volunteers, whether their participation is facilitated or not.

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Table 1 Summary of User Categories within Final Participation Data.

User Type and Microsite Sources	**Number of Users in final Analysis**	**Description**
Girl Scouts	246	Users who participated in one or more of the following Girl Scout partner programs with SciStarter: (1) Think Like a Citizen Scientist Journey, (2) Girl Scout Climate Challenge, (3) Girl Scout Tree Promise. Each of these programs includes citizen science as one element in a larger series of activities, often including observation and exploration and some form of action or community engagement. Due to the young age of many target participants, user accounts sometimes represent a supervising adult or a troop leader inputting data for an individual girl scout or an entire troop. Older girl scouts may have their own accounts.
University Students	2,902	Users are university students who participated in one or more projects as part of a class they were enrolled in, or through another campus program, like a bioblitz. This group includes users from: Arizona State University, Brandeis University, NC A&T University, and NC State University. If incorporated in a course, participation may have been accompanied by additional required activities, including the Foundations of Citizen Science Training on SciStarter.
Verizon Volunteers	6,071	Users in this category participated in citizen science as part of a corporate volunteer partner program between Verizon and SciStarter.
"Typical" Users	23,920	Users with no tags who therefore are not likely to be practitioners, researchers, site managers, or affiliated with a known facilitator organization. Generally representative of more "traditional" or "self-selecting" citizen science users.

Table 2 Digitally Facilitated Tags and Program Descriptions.

Tag/Microsite Name	Description
2024 Total Solar Eclipse Page	A landing page for projects, events, and resources related to citizen science for the solar Total Solar Eclipse that occurred in North America on April 8th, 2024. Post-eclipse, this page provides statistics, findings, and a debrief webinar related to all of the citizen science efforts that occurred on that day. Open to all users of SciStarter, and heavily promoted through newsletters and other communications.
CitSciDay and CitSciMonth Pages	From 2016-present, various pages and tags have existed on the SciStarter platform promoting participation in citizen science month (previously citizen science day) to various audiences. Some of these pages have been available to specific groups of users (for example the ASU citizen science month page, which was intended for users of the ASU community), while others have been widely promoted to all current SciStarter users and beyond. Current features of the page include individual participation pledges, site-wide goals ("One Million Acts of Science"), resources for projects, participants, and facilitators, and more.
COVID-19 Landing Page	A microsite launched during the peak of the COVID-19 pandemic that connected users to projects that allowed them to help track and combat the pandemic. It was promoted to all current site users via banners on all pages of the site, as well as to prospective users through external media sites.
NASA and NASA Live	Pages launched in partnership with NASA and featuring links to NASA's Globe Observer suite of projects, eclipse projects and information ahead of the 2023 and 2024 North American eclipses, and other space-themed projects. These pages also link to various resources for participants and facilitators, and NASA Live at one point hosted regular "Do NASA Science Live" Webinars.
Pollinator Gardens Page	A page initiated in partnership with the National Pollinator Garden network that features projects and educational resources related to pollinators. The page was promoted to all users, particularly via newsletters.
National Geographic	A page with projects curated in partnership with National Geographic. The page received a lot of traffic briefly when SciStarter's founder, Darlene Cavalier, became a NatGeo Explorer in 2019, but has otherwise reportedly seen little use according to the SciStarter team.

Table 3 Cluster Attributes.

Cluster Number	Attributes
1 - Higher Depth Online Singletons	• Singletons • Online project • Mixed average activity ratios • Medium-high participation
2 - Lower Depth Online Singletons	• Singletons • Online project • Generally medium-low activity • Low participation
3 - Higher Depth Offline Singletons	• Singletons • Offline project • Medium-high activity • Mixed participation (low, medium, and high)
4 - Lower Depth Offline Singletons	• Singletons • Offline project • Low activity • Generally low participation
5 - Multi-project, Offline-Only Discipline Specialists - Higher Depth (HD)	• Multi-project participation • Only offline projects • Single discipline (discipline specialists) • Generally higher activity • Generally higher participation
6 - Multi-project, Offline-Only, Discipline Spanners - Lower Depth (LD)	• Multi-project participation • Only offline projects • Multiple disciplines (discipline spanners) • Low activity • Medium-low participation
7 - Multi-project, Offline-Only Discipline Spanners - HD	• Multi-project participation • Only offline projects • Multiple disciplines (discipline spanners) • Generally higher activity • Mixed, but generally medium-high participation
8 - Multi-project, Mode-spanning, Discipline Specialists, Mixed Depth	• Multi-project participation • Offline and only projects (mode spanners) • Mixed activity (low, medium, and high) • Generally medium participation
9 - Mult-project, Online-only, Discipline Specialists, Mixed Depth	• Multi-project participation • Only online projects • Single discipline (discipline specialists)

Table 3 (continued).

	• Mixed activity (low, medium, and high) • Medium-high participation
10 - Multi-project, Online-only, Discipline Spanners (Mixed Activity, High Participation)	• Multi-project participation • Only online projects • Multiple disciplines (discipline spanners) • Mixed activity (low, medium, high) • Generally medium-high participation
11 - Multi-project, Mode-spanning, Discipline-spanners (Moderate Depth)	• Multi-project participation • Online and offline projects (mode spanners) • Multiple disciplines (discipline spanners) • Generally medium-high activity • Generally medium participation

Table 4 Multinomial Logistic Regression Summary. [a] Model Nagelkerke pseudo $R^2 = 0.307$ (Cox Snell = 0.297, McFadden = 0.103). *, **, *** denote statistically significant odds ratios at $\alpha = 0.1$, 0.05, and 0.01, respectively.

	Variables in Model[a]					
		Facilitation Scaffolding		User Types		
	Constant	Digitally Facilitated Tags (Yes)	Foundations Training (Completed)	Girl Scouts	University Students	Verizon
Percent of Sample	--	3.7%	17.5%	0.7%	8.8%	18.3%
Cluster 2						
Beta	-2.294	.405	-1.321	0.500	0.541	0.890
SE	0.049	.145	0.108	0.622	0.097	0.063
OR	--	1.499***	.267***	1.649	1.718***	2.434***
Cluster 3						
Beta	0.612	-1.065	-0.897	1.624	-1.490	-2.090
SE	0.019	0.086	0.041	0.241	0.060	0.045
OR	--	0.345***	0.408***	5.071***	0.225***	0.124***
Cluster 4						
Beta	0.130	-1.188	-3.096	-0.309	-0.838	-2.738
SE	0.021	0.144	0.116	0.368	0.062	0.074
OR	--	0.305***	0.045***	0.734	0.432***	0.065***
Cluster 5						
Beta	-2.269	-0.051	-0.992	2.316	0.469	-3.291
SE	0.050	0.183	0.123	0.329	0.097	0.293
OR	--	0.951	0.371***	10.140***	1.598***	0.037***
Cluster 6						
Beta	-3.021	-0.222	-1.908	0.950	-0.446	-3.028
SE	0.071	0.301	0.297	0.746	0.204	0.384
OR	--	0.801	0.148***	2.585	0.640**	0.048***
Cluster 7						
Beta	-2.649	0.507	-0.572	1.741	-2.000	-1.778
SE	0.059	0.169	0.135	0.423	0.322	0.170
OR	--	1.660***	0.564***	5.704***	0.135***	0.169***
Cluster 8						
Beta	-4.911	1.124	-0.430	2.424	-0.690	-1.266
SE	0.174	0.374	0.350	0.761	0.527	0.411
OR	--	3.077***	0.351	11.291***	0.502	0.282***
Cluster 9						
Beta	-2.541	0.570	-0.222	-0.516	0.728	0.135
SE	0.054	0.146	0.085	1.026	0.094	0.078

Table 4 (continued).

OR	--	1.769***	0.801***	0.597	2.072***	1.144*
Cluster 10						
Beta	-3.413	0.723	-0.218	-6.812	1.227	0.0093
SE	0.081	0.204	0.121	35.326	0.121	0.119
OR	--	2.060***	0.804*	0.001	3.410***	1.097
Cluster 11						
Beta	-1.868	0.299	1.718	1.597	-0.765	-0.969
SE	0.038	0.094	0.048	0.297	0.084	0.063
OR	--	1.349***	5.572 ***	4.936***	0.465***	0.379***

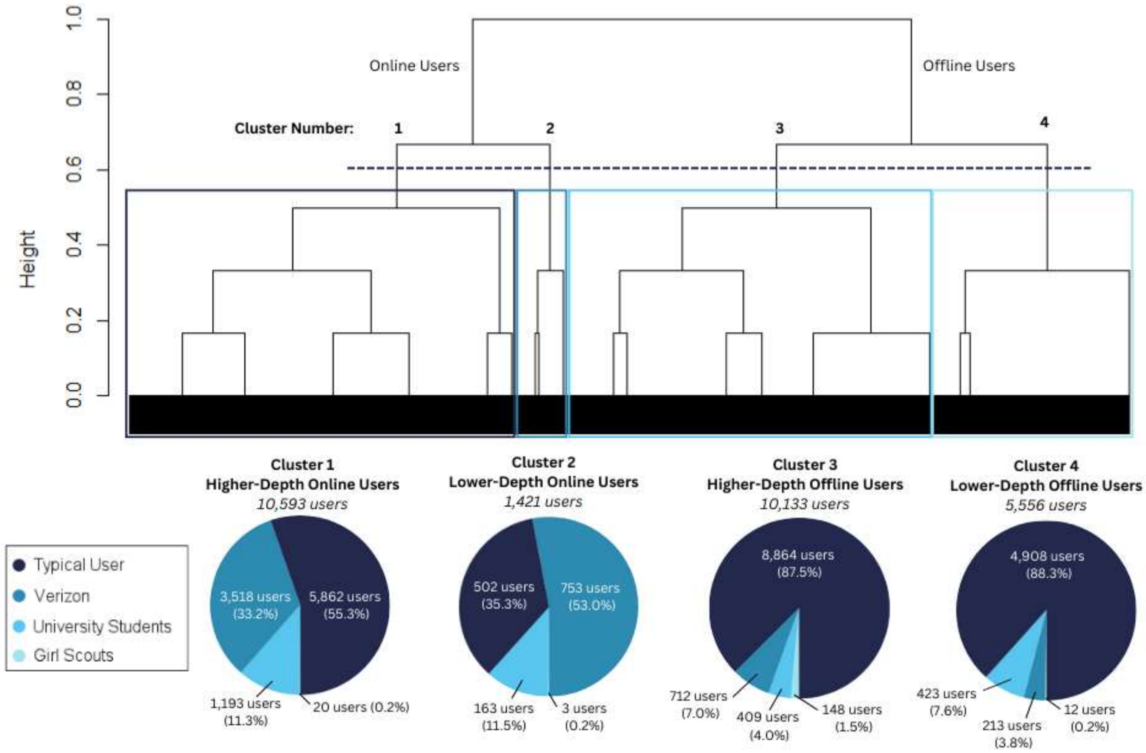

Figure 1 Agglomerative hierarchical clustering output, complete linkage method. Singleton participants only (n = 27,703)

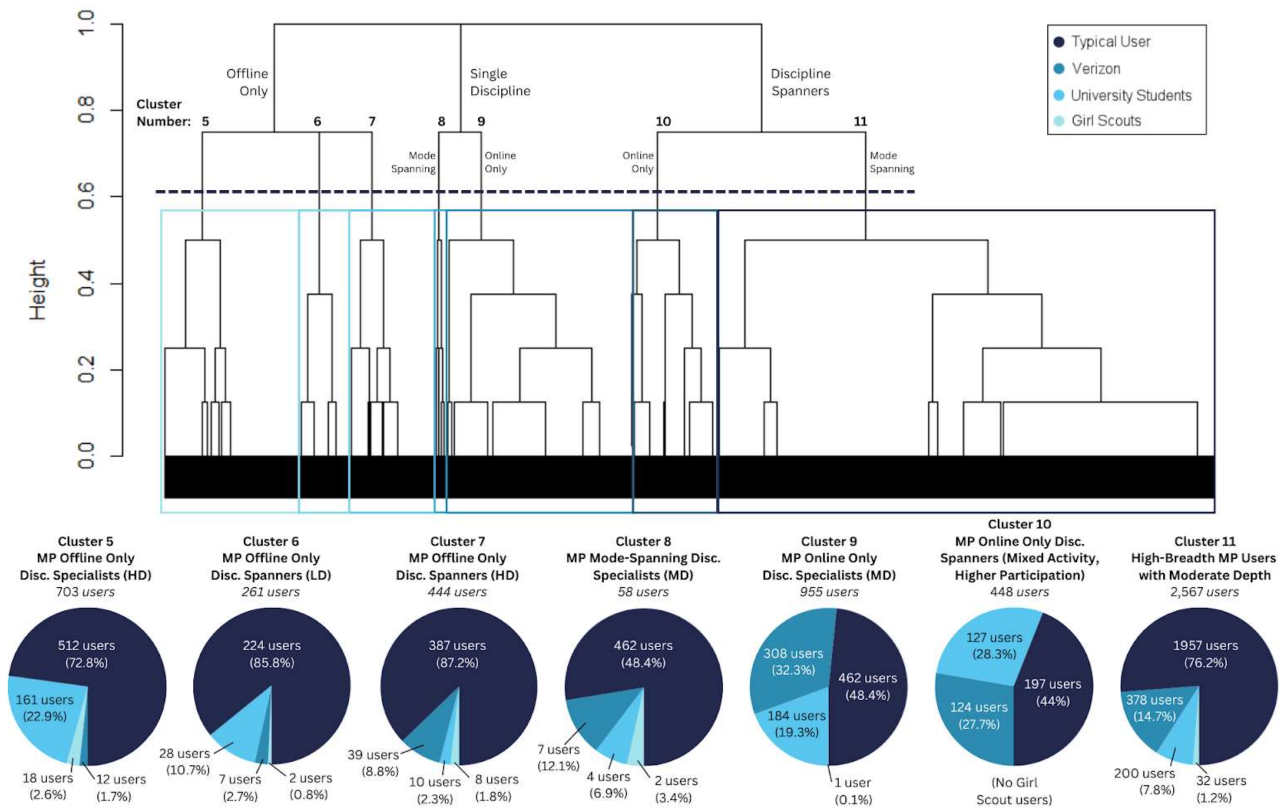

Figure 2 Agglomerative hierarchical clustering output, complete linkage method. Multi-project participants only (n = 5,436)

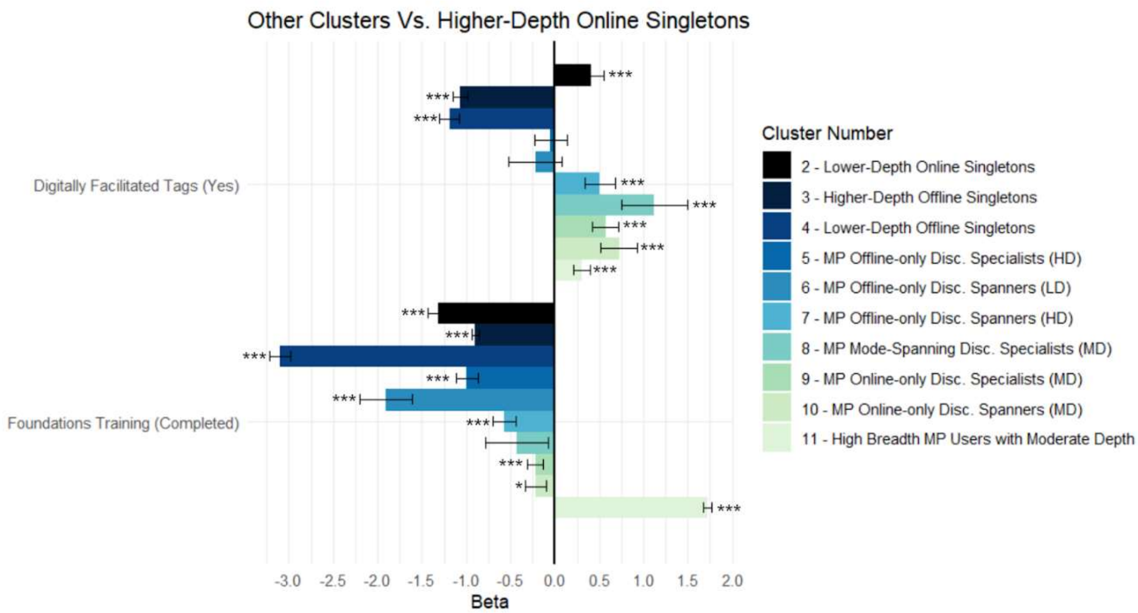

Figure 3 Multinomial logistic regression outputs showing relationships between facilitated user types and assigned clusters. The x-axis depicts Beta coefficients for clusters 2-11 in reference to Cluster 1 (Higher-Depth online singletons). *, **, *** denote statistically significant odds ratios at $\alpha = 0.1$, 0.05, and 0.01, respectively. MP = multi-project. LD = lower-depth, HD = higher depth, MD = mixed depth (not to be confused with moderate depth in cluster 11).

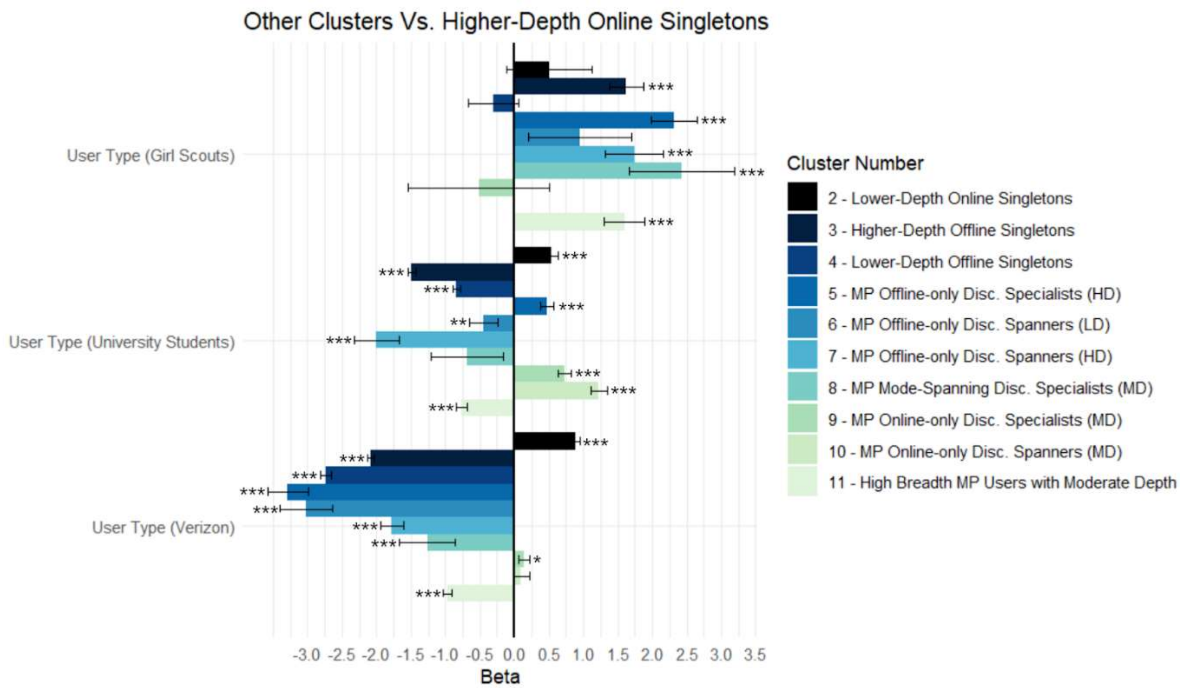

Figure 4 Multinomial logistic regression outputs showing relationships between additional forms of facilitation on the SciStarter platform and assigned clusters. The x-axis depicts Beta coefficients for clusters 2-11 in reference to Cluster 1 (Higher-Depth online singletons). *, **, *** denote statistically significant odds ratios at α = 0.1, 0.05, and 0.01, respectively. MP = multi-project. LD = lower-depth, HD = higher depth, MD = mixed depth (not to be confused with moderate depth in cluster 11).

CHAPTER 3: Facilitator Organizations Enhance Learning and Action Through Citizen Science: A Case Study of Girl Scouts' Think Like a Citizen Scientist Journey on SciStarter

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Abstract

Engagement in citizen science can result in participant outcomes including increased science and environmental literacy and civic action. One factor which may increase the likelihood of these outcomes is facilitation by groups such as employers, schools, or other organizations. We examined how a partnership between SciStarter and Girl Scouts of the USA facilitated participation in citizen science to shape participants' learning and civic engagement. Between July 2017 and February 2020, participants from over 200 Girl Scout troops completed the Think Like a Citizen Scientist Journey, consisting of science learning activities, participation in an environmental citizen science project on SciStarter, and a Take Action Project (TAP). Troop leaders provided open-ended descriptions of TAPs which we analyzed qualitatively. Responses provided evidence of learning outcomes spanning informal science learning goals, Girl Scout Leadership Experience outcomes, and Girl Scout STEM outcomes. Participants' TAPs overwhelmingly related to science and environmental topics (81%) and the majority sought to educate and inspire others (66%), reaching audiences of peers, adults, the general public, and civic leaders. This program demonstrates the potential for facilitator organizations to

leverage existing citizen science projects to promote learning outcomes, civic science education, and community action with participants as young as 4-5 years old.

Introduction

Benefits of citizen science for scientific research

The phenomenon of public participation in scientific research, or citizen science (CS), involves members of the public in various stages of the scientific process, including formulating research questions, making observations, and analyzing and interpreting data (Crowdsourcing and Citizen Science Act, 2017; Haklay et al., 2021; Shirk et al., 2012). CS has made notable contributions to scientific research, especially in environmental fields such as ecology, natural resource management, and conservation biology – particularly through the public's ability to collect and analyze data on much greater spatial and temporal scales than professional researchers alone (Bonney et al., 2014; Chandler et al., 2017; Cooper et al., 2014; Fraisl et al., 2022; Miller-Rushing et al., 2012).

Both adults and youth can make valuable contributions to scientific research through participation in CS. For example, a 2017 study of students, teachers, and corporate volunteers collecting marine debris data for a CS project in Australia demonstrated that the quality and efficiency of data collection by youth rivaled that of data collected by adults, including professional researchers (van der Velde et al., 2017). Regardless of the age of participants, the scientific outcomes of a CS project are often dependent upon the suitability of the research question being addressed by a CS approach (typically related to the level of expertise and/or the types of equipment required for data collection and analysis), the quality of protocols and training available to participants, quality control performed on the data collected, and the availability of feedback and communications between participants and project scientists (Bonney et al., 2009; McKinley et al., 2017).

Benefits of CS for participants

In addition to its contributions to science, other key outcomes of CS include participant learning and civic action (Ballard et al., 2017; Turrini et al., 2018). Particularly for the environmental field, in the face of global challenges such as climate change, air and water quality impairment, and habitat and biodiversity loss, it has never been more important to empower the public with the knowledge to recognize environmental challenges and the ability to help address those challenges (Ballard et al., 2017; Schultz, 2011; Wals et al., 2014). Especially for youth, instilling knowledge and environmental science agency through CS participation can be critical to paving the way to future actions which can benefit the complex socio-ecological systems of which they are a part (Ballard et al., 2017; Tidball & Krasny, 2010).

CS is in many ways uniquely situated to promote science learning, given its inherently scientific context, the unique nature of participation, and existing infrastructures that support learning (National Academies of Sciences, Engineering, and Medicine [NASEM], 2018). Commonly cited CS learning outcomes include the potential to enhance scientific literacy and content knowledge (Bonney et al., 2016; Jordan et al., 2011). However, science learning can also be understood in a broader sense to include precursors to knowledge gain, such as interest, affective connections to science (e.g., science identity and self-efficacy), and the application of knowledge and skills through the practice of science (NASEM, 2018; National Research Council [NRC], 2009). These interrelated facets of learning are captured by the six strands of Learning Science in Informal Environments (LSIE) proposed by the National Research Council: (1)

sparking excitement and interest, (2) understanding scientific content and knowledge, (3) engaging in scientific reasoning, (4) reflecting on science, (5) engaging in scientific practices, and (6) identifying as a science learner (NRC, 2009) (Appendix B). CS has the potential to achieve each of these outcomes, and the intended learning outcomes of many CS programs align well with the LSIE strands, as demonstrated by Phillips et al. (2018).

Another key outcome of CS is the potential to influence civic action (Ballard et al., 2017; Turrini et al., 2018). While CS participation can itself be seen as a form of civic action – working collaboratively to address questions with important implications for society – CS can also pave the way to further civic participation as a form of civic science education. Levy et al. (2021) defined civic science education as “educational experiences that support individuals’ ability to understand, explore, and take informed action on public issues related to science” (p. 1054). In the context of environmental CS projects, the epitome of participant outcomes is often seen as participants going beyond engaging in CS to adopt other pro-environmental behaviors, such as teaching others about environmental topics, improving or managing habitat, and voting or lobbying to influence environmental policies (Haywood et al., 2016; Lewandowski & Oberhauser, 2017; McKinley et al., 2017; Phillips et al., 2018). While voting may not be an option for youth, many examples exist of impactful youth civic environmental action associated with participatory learning experiences, including: students adopting long-term pro-environmental attitudes and behaviors and promoting inter-generational learning after participating in an environmental service-learning program in Mexico (Schneller, 2008); youth participants in a disaster risk-reduction program in the Philippines influencing community action through the use of participatory video (Haynes & Tanner, 2015); and students in North Carolina, USA influencing concern and policy support related to marine debris among community leaders and adults following a year-long marine debris-related curriculum (Hartley et al., 2021). This final example also demonstrates the value of CS as a potential pathway to cultivating community science literacy, or the collective and distributed capacity of a community to apply scientific knowledge and tools to address issues of priority to the community (including environmental challenges) (Gibson et al., 2022; NASEM, 2016; NASEM, 2018).

Designing CS to promote participant outcomes

While such isolated examples of learning and action following CS participation exist across the literature, there remains a limited understanding among both CS practitioners and theoreticians about how participant experiences can be designed to better foster desired learning and action outcomes (Peter et al., 2021). As demonstrated by a recent study of Chilean school children sampling plastic marine debris, participation in a CS project alone may not be sufficient to achieve such outcomes, and complementary learning experiences may be necessary (Wichmann et al., 2022). Furthermore, research on pro-environmental behaviors has repeatedly demonstrated that learning and knowledge gains do not necessarily translate directly into actions or behavioral change (Kollmuss & Agyeman, 2002; Nelson et al., 2022; Wals et al., 2014), though they can certainly contribute (Varela-Candamio et al., 2018). Therefore, considering specific contexts and conditions that may facilitate both learning and action is critical to developing a better understanding of how to effectively design and execute CS programming to achieve desired participant outcomes.

One unique context that warrants closer examination is CS participation that is facilitated by groups external to the project leadership or administration, such as an employer, school, community organization, library, or other entity. Such *facilitator organizations* have no influence on project design but enable participation by individuals who may not otherwise engage in CS. These organizations also have the potential to enhance learning and other outcomes of CS by contextualizing participation within their program designs to support learning experiences.

The concept of facilitator organizations in citizen science (and the participatory sciences more broadly) has been referred to as “third-party organizations” who recruit, train, and otherwise manage CS volunteers (Sharova, 2020), “enablers” who facilitate interactions between scientists and participants (Salmon et al., 2021), and “intermediary units” who support citizen-driven research projects (Gresle et al., 2021). The facilitator organization role also bears some similarities to the idea of “learning brokers" in environmental education, where an individual (often a parent), supports another individual’s (often a child’s) learning by connecting them to a learning opportunity or experience (Barron et al., 2009). However, it is worth noting that we here emphasize the role of a larger program, organization, or entity when describing facilitator organizations, rather than the impact of a single individual on another’s learning. We choose to use the term “facilitator organization” in identifying these parties as unique players in the CS “ecosystem” (Allf et al., 2022), as we feel it best captures their role in fostering participation, supporting learning, and facilitating the achievement of desired outcomes. Consideration of these facilitators’ roles is an important step for building a more holistic and volunteer-centric understanding of CS participation outside the context of individual projects (Allf et al., 2022).

Many facilitator organizations bring their own organizational goals to the table, often along with pre-existing program structures to achieve these outcomes. When these goals align with those of a CS project or the practice of CS as a whole, the facilitator organization may choose to employ CS in their programming. Yet adoption of CS by facilitator organizations to achieve these common goals has the potential not only to fulfill existing organizational and CS project goals, but also to achieve synergistic outcomes promoting participant learning and action through structured programming and learning supports (Ballard et al., 2017; Wichmann et al., 2022).

While a variety of learning outcomes have been associated with CS participation and experiences, most research to date has focused on only a small subset of these outcomes at a time, primarily among adults, and often in the context of discrete CS projects. For example, many studies have explored changes (or lack thereof) in project-relevant content knowledge (Branchini et al., 2015; Forrester et al., 2016; Greving et al., 2022; Jordan et al., 2011; Price & Lee, 2013; among others). Others have addressed the development of scientific literacy and understanding of the processes or nature of science through participation in a CS project, with evidence again mixed (Bonney et al., 2016; Jones et al., 2017; Jordan et al., 2011; Price & Lee, 2013).

Another segment of research has explored more affective learning outcomes, including evidence for the development of interest and engagement in science and environmental topics through participation in CS, particularly in formal educational contexts where participation is less likely to be inherently interest-driven (Schneiderhan-Opel & Bogner, 2020; Smith et al., 2021; Toomey & Domroese, 2013; Vitone et al., 2016). Some studies have also shown that participation in CS helps cultivate a sense of self-efficacy or agency related to science and the environment in youth (Ballard et al., 2017; Hiller, 2012), college students (Smith et al., 2021), and adults (Haywood et al., 2016). Another small but growing set of literature has begun to explore the development of science identity through participation in CS (Ballard et al., 2018; He et al., 2019; Williams et al., 2021), again with differing outcomes noted.

A final area of the literature has focused on attitudinal and behavioral outcomes from CS participation, with some studies demonstrating modest changes in attitudes towards science, the environment, or a project-specific subject (Bruckermann et al., 2021; Chase & Levine, 2017; Greving et al., 2022; Santori et al., 2020; Toomey & Domroese, 2013), while others reported little to no changes in attitudes (e.g. Forrester et al., 2016). One difficulty often encountered in these studies is that CS participants typically have pre-existing positive attitudes towards science and the environment. Similarly, studies of behavior changes and action following CS participation have demonstrated mixed results, perhaps related to high pre-existing engagement in such behaviors among participants (Forrester et al., 2016; Haywood et al., 2016; Jordan et al. 2011; Santori et al., 2020; Toomey & Domroese, 2013).

Regardless of the types of outcomes being considered, there is a growing understanding among the CS literature that these outcomes don't simply happen as a result of participation in CS and require intentional design and structured learning supports to be achieved (Bela et al., 2016; Bonney et al., 2016; NASEM, 2018; Peter et al., 2021; Roche et al., 2020; Wichmann et al., 2022; among others). There is, therefore, a great need for research examining the contexts and factors which facilitate these varied participant outcomes.

Research aims

To this end, the current study explores the unique context of facilitated CS and seeks to answer the following questions:

1. How and to what extent do facilitator organizations expand possible CS learning outcomes?

2. In what ways do facilitator organizations extend and support civic science education and civic action through CS experiences?

We address these questions through a case study that demonstrates the potential for structured participation in CS via a facilitator organization to fulfill expected project and programmatic goals and promote a broad spectrum of participant outcomes. Specifically, we investigate the potential for a facilitator organization to extend community science literacy and civic science education through community action as encouraged by the Girl Scouts' Take Action Project. We conclude with a research agenda to pursue a better understanding of the roles of facilitator organizations within the CS ecosystem.

Methods

Study context

The paper reports on a case study (Yin, 2009) of CS participation supported by a facilitator organization. The context for this case study is the Think Like a Citizen Scientist Journey (hereafter referred to as "the Journey"), a partnership between Girl Scouts of the USA (the facilitator organization) and SciStarter.org (an online platform which provided planning support, resources, and other infrastructure critical to the implementation of the Journey). Girl Scouts of the USA (GSUSA) is an organization dedicated to leadership development for K-12 girls that focuses on making positive change in the world while building skills in the following areas: STEM, Outdoors, Life Skills, and Entrepreneurship (GSUSA, 2022a). GSUSA supports girls in acquiring STEM and other skills by completing individual activities to earn "badges" and more in-depth experiences called "journeys," where girls can earn awards for digging deeper into content and making a difference in their communities. Girl Scout Journeys are scaffolded learning experiences guided by a curriculum which encourages girls to build on what they learned from earning a badge by completing a Take Action Project (TAP) in their community. SciStarter is an online CS hub connecting participants to thousands of CS projects worldwide. SciStarter partners with many facilitator organizations such as Girl Scouts and provides critical infrastructure to enable CS programming, including the design of learning pathways, project curation, launching pages (or "microsites"), and progress tracking. SciStarter's digital infrastructure enables research and evaluation such as this case study through data tracking, resource repositories for uploaded content, and the integration of questionnaires and embedded assessment tools across the site.

The Journey was co-created by GSUSA and SciStarter and piloted in 2017 with the goal of encouraging Girl Scouts to engage in citizen science to support STEM learning. The Journey's pilot phase targeted girls in grades K-5 (Girl Scout levels "Daisy" (grades K-1, ages 4-7), "Brownie" (grades 2-3, ages 6-9), and "Junior" (grades 4-5, ages 8-11)) and initially featured 11 curated CS projects (Appendix C). These projects were recommended by SciStarter in alignment with Girl Scout's requested criteria (outdoors, simple or no specialized instruments, suitable for a variety of age-groups, project scientists willing to provide welcome and thank you videos, and engagement of SciStarter affiliates that could enable digital tracking of participation). Girls could choose projects by going to a SciStarter landing page specifically designed for the Journey. This page, hereafter referred to as "the microsite," expanded over time to feature up to 20 projects. During the Journey, girls earned an initial award for completing program content consisting of (1) a series of age-appropriate STEM learning activities; and (2) making a SciStarter account and participating in a citizen science project through the microsite. Girls earned a second award for completing (3) a TAP in their community (Figure 1).

The stated outcomes for the Journey were for girls to: (1) “Explore how scientists do research and create solutions to some of the most important problems faced by people, animals, and the environment;” (2) “practice making scientific observations and collecting data;” (3) “participate in a citizen science project;” and (4) “do a Take Action project to address an issue in [their] community” (GSUSA, n.d.a, p. 1).

During the pilot phase, Journeys were generally completed by Girl Scout troops working together as a group. During the first step of the Journey (Figure 1), girls completed age-appropriate, preparatory STEM activities, which varied by age level and included practicing skills such as observation, prediction, data collection and analysis, etc. After completing these activities, girls then participated in a CS project on SciStarter. Projects were selected from the curated list of age-appropriate projects featured on the SciStarter microsite (Appendix C).

The final step to fulfill the Journey curriculum was for girls to complete a TAP. The goal of a TAP is to “address an issue by tackling the factors that cause or contribute to it” (GSUSA, 2022b, Activity Details section). As opposed to a Community Service Project which might make a one-time impact, TAPs are intended to enact a long-term change that “addresses a root cause of an issue” (GSUSA, 2022b, Table 1) and is “sustainable.” Suggested ways of making a sustainable change include: “1. Make your solution permanent, 2. Educate and inspire others to be part of the change, and 3. Change a rule, regulation, or law” (GSUSA, 2022b, Activity Details section). While these TAPs can be standalone, inclusion in the Journey provides a pathway for girls to build on what they have learned and done throughout the rest of the Journey curriculum when developing a project. However, the nature of the project was ultimately up to the girls and their project leaders.

Data collection and preparation

After completing all Journey components (preparatory activities, CS project, TAP), GS troop leaders were asked to mark the Journey as complete on SciStarter and fill out a brief survey comprised of three open-ended questions to describe their troop's TAP: (1) What problem did you want to solve with your Take Action project?, (2) What was your solution?, and (3) How did you make your solution sustainable? (For example: Did you educate and inspire others to follow your lead? Did you create something permanent? Did you get a rule or a law changed?). SciStarter then provided the research team with records of each Journey, including participation dates, participant age ranges, CS project chosen, and responses to the open-ended survey, exported in SQLITE format. This data was acquired in accordance with approval under NC State University Institutional Review Board protocol #12200 and was deemed exempt.

We performed initial data merging and cleaning in RStudio using R version 4.1.3 (R Core Team, 2022). We merged Journey dates, participant ages, CS project, TAP responses, and other related data by Journey number to create a single entry for each Journey, beginning with 456 entries. After removing all duplicate Journeys and uncompleted Journeys (never marked as "complete" on SciStarter), we were left with 286 entries.

While the Journey later expanded to include all GS levels (K-12 or GS levels "Daisy" through "Ambassador"), older girls outside of the initial K-5 pilot age range often completed their Journeys independently or in smaller groups. Additionally, the onset of the COVID-19 pandemic around March of 2020 led to Girl Scout troops not being able to meet in person and younger girls also completing Journeys alone or in smaller groups. To ensure greater consistency across the Journeys, we retained for analysis only Journeys completed by Girl Scout troops with pilot grade levels K-5 *and* those completed before March 1st, 2020, resulting in 253 entries.

Following initial data cleaning and export, the coders (HS and LT) read through open-ended responses and manually removed entries where respondents only wrote brief responses such as “NA” or “yes” or mistakenly described their participation in a CS project as part of Step 2 of the Journey instead of their TAP. This resulted in a total of 245 completed Journeys with responses for analysis.

Analysis

We performed manual qualitative analysis of the open-ended survey responses guided by the following analytic questions:

1. Are troops who complete the Journey achieving expected learning outcomes (informal science learning, Girl Scout Leadership Experience (GSLE) outcomes, and Girl Scout STEM outcomes?
2. Are troops’ TAPs related to the science and environmental themes addressed throughout the Journey?
3. In what ways are troops “taking action” through their TAPs?

We used a combination of deductive and inductive coding with a constant comparative method (Merriam & Tisdell, 2015). To address our first analytic question, we deductively coded responses to the three open-ended questions, using 15 *a priori* codes developed from: (1) the six strands of Learning Science in Informal Environments (LSIE); (2) the five GSLE outcomes and (3) the four Girl Scout STEM outcomes (Table 1). As is common in STEM programming, the explicitly stated goals of the Think Like a Citizen Scientist Journey put a primary emphasis on traditional science content, skill, and process learning rather than affective, behavioral, and cognitive correlates to learning (NASEM, 2018). These stated outcomes aligned well with many of the LSIE strands, and in turn with many of the overarching goals for CS programming more broadly (Appendix B). The codes we chose therefore capture both the typical learning outcomes expected to occur through CS experiences (as encompassed in the LSIE strands) and specific organizational goals of the Girl Scouts as a facilitator organization (Leadership and STEM Leadership goals). For a complete codebook, sample quotes, and detailed explanation of alignment between codes and intended outcomes, see Appendix B.

To answer question 2, we used inductive coding of open-ended responses cross-referenced with the name of the CS project type to develop in vivo codes representing the ways in which girls' TAPs were related to science and environmental themes (or whether they were unrelated) (Table 2). For question 3, we further examined the types of actions performed in projects which were related to science and environmental themes. We used inductive coding of open-ended responses to develop in vivo codes characterizing the nature of the actions taken (Table 3). We classified projects which were not related to science and environmental topics as 'unrelated' and did not code them further.

In investigating answers to these initial questions, it became clear that "educating and inspiring others" was an overwhelmingly common action taken by girls on their Journey. Therefore, we also sought to answer the following question:

4. What audiences are girls engaging about scientific and environmental topics?

We used inductive coding of responses to the three open-ended questions to develop codes characterizing the girls' audiences for projects related to science and environmental topics (Table 4). Again, we classified projects which were unrelated to science and environmental topics as 'unrelated' and did not code them further.

For questions 2-4, the initial list of codes was developed by a single university-affiliated member of the research team, but with an option of "other" included. To establish inter-rater reliability, a second member of the research team affiliated with the Girl Scouts of the USA worked with the first member to agree upon code definitions. These two individuals then independently coded 59 responses (24% coverage of all responses) for analytic questions 1-4. The 59 responses were selected to represent a broad array of codes. Percent agreement was calculated across these 59 responses and was 84% overall (Miles et al., 2018). Based on this high percent agreement which indicated code stability, the first member of the research team completed coding for the remaining 186 responses.

After coding was completed, the coded data was then imported back into R to create summary statistics to address each of these questions 1-4.

Results

Across the 245 completed journeys that we analyzed, there were participants from 231 GS troops representing 90 different councils across the US. This included participants from 43 states and Washington DC, as well as one GS troop from the USA Girl Scouts Overseas Program. Of the 231 GS troops, 130 were single-level troops, meaning all girls were roughly of the same age or grade and fell into a single GS level - Daisy (n = 53 GS troops), Brownie (n =

41), and Junior (n = 49). The remaining 101 GS troops were multi-level troops with 2 or more GS levels represented.

Troops participated in 11 different CS projects in the journeys we analyzed, although 90% of troops chose among just 5 popular projects: Ant Picnic (70 journeys), Stream Selfie (59), Project Squirrel (49), GLOBE Observer: Clouds (22), and Globe at Night (20) (Appendix C).

Expected learning outcomes

Analysis of learning outcomes in accordance with analytic question 1 revealed that all 15 possible learning outcomes were represented at least once (Figure 2). Notably, the three most common outcomes spanned the three code categories of GSLE Outcomes, LSIE Strands, and GS STEM Outcomes, and reflected girls' ability to address problems in their communities, understand scientific content and knowledge, and develop STEM confidence.

GSLE Outcome 5: Identify and Solve Problems in the Community was the most common outcome, occurring 355 times (48% out of a possible 735 responses: 245 journeys x 3 responses per Journey). This outcome was often apparent in descriptions of the problem and solution addressed through a TAP. For example, one Girl Scout troop leader presented the following problem and solution:

> The girls would like to limit the amount of school supply waste by recycling used and worn out items that are being thrown in the trash. We will partner with Crayola and other companies to place recycling bins through out [sic] the school for markers, crayons, and paper and send them to be repurposed.

The next most common outcome was LSIE Strand 2: Understanding Scientific Content and Knowledge (161 occurrences, 22% of responses). In demonstrating an understanding of scientific content and knowledge, girls sometimes shared project-relevant content they learned during participation in their chosen citizen science project, for example: “The girls wanted to inform the public about light pollution after completing the Stars at Night.”

They also often shared information about the process of participating in citizen science and what they learned through that process. For example, the leader of a Girl Scout troop that participated in the Ant Picnic project stated: “The girls talked with their classmates about science and being Citizen Scientist [sic]. They showed them their posters on the different foods ants like to eat and what they were not crazy about.”

However, many troops also explored new science and environmental topics through their TAPs, as evident in the report by the leader of a troop who completed the Stream Selfie citizen science project:

> Bat populations are facing difficulty. Bats need clean water and a place to roost and raise young. The troop researched bat boxes and built 12 boxes to be donated to state parks as well as the area where our citizen science project took place.

The last of the most common three codes was Girl Scout STEM Outcome 2: STEM Confidence (147 occurrences, 20% of responses). This was typically characterized by girls demonstrating their understanding of the scientific processes they engaged in to others. For example, one troop leader stated: "The Daisies told many people what they did and shared how important it is to collect data and interpret results."

Relevance to science and the environment

In addressing analytic question 2, six codes were inductively developed to characterize the relevance of a TAP to science and environmental themes (Figure 3). While girls had the option to solve any problem in the community for their TAPs, most (81%) chose to take an action related to science or the environment. Projects involved activities both related and unrelated to the original CS project completed in Step 1, participating in another CS project or encouraging others to do so, and addressing access to resources for cultivating science literacy in the community.

Some projects encompassed more than one code, and therefore percentages represented in Figure 3 are non-exclusive, except for the 19% of projects which were not related to science or the environment. For example, some troops completed a TAP directly related to the citizen science project they participated in (31%), which also was related to an environmental theme. Many troops who contributed to Stream Selfie chose to follow up with a stream clean-up and/or additional water testing:

> We went to the stream observed and recorded the clarity of the water. We cleaned up what little litter we found. We then reported the issues of skin irritation and signs of pesticide and fertilizer runoff we found…to city officials and others in our neighborhood.

Other troops completed a project related to an environmental theme or issue, but unrelated to the citizen science project they completed. For example, one troop who participated in the Globe at Night project – a project focused on recording light pollution (Appendix C) – completed a TAP related to water conservation:

> Our Girl Scout Troop wanted to help educate family, friends and the community on how easy it is to recycle rainwater for use in gardens and landscaping. Our Troop made a small-scale model of a home with a downspout and a rainwater collection barrel out of cardstock, a straw and a small solo cup. Each Girl Scout will then show their family, friends and community what they made and, hopefully, start a conversation on how easy it is to recycle rainwater for use in the garden.

Several others took action by either participating in another CS project themselves, or encouraging others to do so. While less frequent, a notable handful of troops chose to complete TAPs related to science literacy. For example, after their experience completing the journey, one troop leader stated:

> We wanted other kids to know how much [fun] science could be and easy ways they could enjoy science. [They] made a flyer with different tv shows, web sites and books that are STEM related and are fun to to [sic] watch, play and read.

Types of action

After addressing analytic question 2, we did not seek to further characterize TAPs which were unrelated to science and environmental topics. We therefore excluded those 47 projects from the remaining analyses. To address analytic question 3, five codes were inductively developed to characterize the types of actions taken during the remaining 198 projects (Figure 4). Again, these codes were non-exclusive, meaning a single project may involve more than one type of action. For example, many troop leaders reported their troop's choice to improve habitat or participate in another citizen science project, but also incorporated "educating and inspiring others" into their project by getting others to participate with them or telling others about what they did and how they could participate in the future. One troop who participated in Project Squirrel chose to participate in a second project (Stream Selfie), host a stream cleanup, and educate others about clean water:

> Trash near streams impacts our drinking water. We cleaned up all the trash we saw and also contributed data to Stream Selfie. We contributed data to help the scientists with their efforts and will continue to educate others on how everyone can help scientists with data and aldo [sic] how important it is to keep our waters clean.

A small but notable subset of troops took civic action to achieve long-term solutions to the problems they identified. For example, one individual Girl Scout addressed the following challenge:

> We do not have a recycling bin on our Scout House. I met with two members of the city's recycling commission to ask their help in asking the city to put in a recycling bin. They helped me write a presentation to present to the city staff. I will teach our troop what to put into the bin and what not to put into the bin.

Audiences engaged

As seen in Figure 4, "Educating and Inspiring Others" was the most common type of action girls performed during their TAPs, occurring in 74% of projects related to science and environmental topics. Among projects that *were* related to science and the environment (81%, Figure 3), we further examined the types of audiences girls engaged on these topics in pursuit of analytic question 4. We identified 4 main audience categories: peers, adults, the general public, and civic leaders, with additional codes for "unspecified" audiences and "unrelated" projects. With the exception of "unrelated," these categories are again non-exclusive, as girls often spoke to more than one type of audience.

Of the 151 TAPs which sought to "educate and inspire others," *peers* (including other Girl Scouts, siblings, classmates, and friends) were the most frequently engaged audience (n = 85), with the *general public* (n=39) and *adults* (teachers, parents, etc.; n = 37) being fairly common as well (Figure 5). A smaller number of troops (n = 9) approached civic leaders about enacting change in their communities. Many respondents also simply wrote that they "educated others," thus the audience was categorized as "unspecified" (n = 66).

Examples of projects with audiences spanning multiple categories include ones who engaged their families (parents and siblings, or adults and peers):

> Every scout made a clean water pledge and decided on one action she and her family can do to reduce water pollution (ie do not litter). Each scout intends to make a permanent change and include her household members in the pledge;

other Girl Scouts, teachers, and classmates (peers and adults):

> We passed out flyers [about fun STEM activities] to our fellow girls [sic] scouts. We also brought flyers to our schools and gave them to our teachers so that they could give them out to the other kids in our classes;

and members of the school community and local community more broadly (peers, adults, and general public):

> [Our Troop] wanted to educate their school and local community about how they could use SciStarter to engage in citizen scientist projects. The Brownies in [Troop Number] designed a flyer that was distributed to everyone in their k-8 school about how to join citizen scientist projects using SciStarter...They are also trying to get the information printed in the local newspaper.

Discussion

Expanding CS learning outcomes through facilitation

The structure provided by the facilitated curriculum of the Think Like a Citizen Scientist Journey and SciStarter platform demonstrated great potential to support varied forms of learning. Our analysis identified a wide array of cognitive, affective, and behavioral outcomes among participants. By completing the three scaffolded Journey steps, girls implicitly made progress towards at least three of the expected learning outcomes (Table 1). The science learning activities in step 1 of the Journey included practicing observation and data collection and therefore facilitated achieving LSIE Strand 3: Engaging in Scientific Reasoning, while step 2 – participating in a CS Project – fulfilled LSIE Strand 5: Engaging in Scientific Practices (NASEM, 2018). Completing a TAP in step 3 fulfilled GLSE Outcome 5: Identify and solve problems in the community (GSUSA, 2017).

While a more targeted quantitative assessment of learning outcomes during the first two steps of the Journey may have allowed measuring changes in knowledge and certain affective and behavioral components to learning, our analysis of learning here helps to address the dearth of literature qualitatively exploring outcomes of participation in CS learning experiences (Phillips et al., 2019). The open-ended nature of responses allowed troops to reflect and identify the salient aspects of learning from their Journey.

Our analysis revealed that not only these three implicit outcomes but all 15 possible learning outcomes were present, including the development of content knowledge and science literacy as well as affective and behavioral outcomes such as science identity, STEM confidence, and taking actions to address scientific and environmental challenges (Figure 2; Appendix B). While our analysis centered on the TAP phase of the Journey, it was evident from troop leaders' responses that the scaffolded and facilitated nature of this learning experience was self-reinforcing, with troops building on the science learning which occurred in steps 1 and 2 of the Journey during the TAP phase. Such intentional learning supports are one key element of facilitated CS which may help to better foster a variety of learning outcomes.

Extension of learning and supporting civic science education

We found Levy et al.'s (2021) typology of civic science education (CSE) provided a helpful framework for understanding the different forms of civic science engagement which occurred through the GS Journey (Table 5). This typology places participation in most CS projects in the *exploratory* stage of CSE, which "involves the collection and analysis of data on science-related civic issues" (Levy et al., 2021, p. 1057). As discussed above, steps 1 and 2 of the Journey provided opportunities to achieve these types of skill- and process-focused science learning.

The third step of the Journey – the TAP – proved to be a unique feature of this facilitated CS experience which paved the way for extensions of learning beyond the typical focus on scientific skills, content knowledge, and process knowledge. The TAP served as a bridge to propel girls from the *exploratory* category of CSE to the *purposefully active* category, defined by Levy et al. (2021) as "experiences that involve raising awareness, advocating, organizing others, designing solutions, and/or purposefully participating in efforts to address science-related public matters" (p. 1057). Experiences such as these are critical foundations to prepare youth to be more engaged in civic issues related to science and the environment in the future (Ballard et al., 2017; Tidball & Krasny, 2010).

There were no explicitly stated learning outcomes for the TAP step of the Journey; the goal was simply to “Do a Take Action Project to address an issue in your community” (GSUSA, n.d.a., p. 1). Perhaps due to the broad guidelines for this step of the Journey, the TAP therefore created the potential for many unintended learning outcomes. In particular, the emphasis on action paved the way to the types of behavioral outcomes often only hoped for in CS and environmental programming more broadly (Haywood et al., 2016; Lewandowski & Oberhauser, 2017; McKinley et al., 2017; Phillips et al., 2018).

While the Journey curriculum provided examples of ways to connect a TAP to the previous steps in the Journey, the topic of the TAP was ultimately left open to the discretion of each girl or GS troop. Despite this, 81% of troops still chose to address a problem related to a science or environmental topic. Among this 81% (198 projects), a high proportion (66%) involved efforts to educate and inspire others. This process of sharing findings and information with others who can act upon it – particularly with civic leaders – could itself be considered a form of civic environmental action (Haywood et al., 2016). Furthermore, the act of demonstrating expertise and sharing findings has been shown to reinforce learning and boost youth CS participants’ environmental science agency, therefore promoting their confidence in taking future civic environmental action (Ballard et al., 2017). These opportunities therefore likely supported the development of STEM confidence and science identity captured in some open-ended responses.

Such efforts to educate and inspire others also had the potential to further the learning impacts of the Journey by providing *foundational* CSE to the girls’ audiences, characterized by “exposure to, discussion of, and/or peer interactions around science-related public matters…” (Levy et al., 2021, p. 1057). Given their engagement of outside audiences and the breadth of scientific skills and both science and environmental content knowledge girls were exposed to throughout the Journey, there was great potential for the diffusion of knowledge through the girls' social networks and broader audiences. This phenomenon has been described previously in relation to CS participation, including the spreading of environmental knowledge and skills by CS participants in a 2014 country-wide study in India (Johnson et al., 2014). The authors identified a three-step process of dissemination wherein individuals – typically those with pre-existing interest and concern for environmental issues – seek out opportunities to participate in CS; develop a degree of expertise and self-efficacy on related issues through this participation; and in turn engage in advocacy by encouraging members of their social networks to participate, educating members of the public on related topics, or pursuing a related career or educational path. In the case of the Girl Scout Journey, we see that even young individuals who may be newly exposed to environmental and scientific topics of societal importance are able to spread knowledge and inspire actions through their social networks.

GS troops accomplished this via both peer-to-peer and inter-generational learning through their efforts to educate their peers, the public, and adults in their lives. Previous research has demonstrated the potential for peer-to-peer learning to encourage environmental action among youth (de Vreede et al., 2014). Additionally, youth-led action on environmental issues has been shown to influence concern and policy support among adults, including civic leaders and members of the public outside their immediate family (Hartley et al., 2021). In all its forms, the ways in which the Journey facilitated the sharing of knowledge and outlets for engaging in CS and science more broadly makes it an excellent example of the potential for CS participation to foster community science literacy, an area of emerging interest in CS and STEM education research (Gibson et al., 2022; NASEM, 2016; NASEM, 2018).

Limitations and future research

We know that girls who completed the Journey were exposed to a variety of science and environmental topics, participated in a CS project, and took community action. Yet, while we observed extensive evidence of fulfilled learning outcomes among troop leader responses to our open-ended questions, we were not able to directly or quantitatively measure girls' learning within the scope of the current work. Additionally, although girls and their GS troop leaders documented extensive efforts to "educate and inspire others," we did not have the ability to quantify the impact on their audiences. Finally, while we only saw evidence of direct engagement with civic leaders in nine Journeys, we expect that older troops may have a greater capacity for such engagement, as a few open-ended responses specifically noted that due to the girls' ages (roughly 5-11), their ability to change a rule or a law (one of the suggested ways of making a TAP 'sustainable') was limited. Wichmann et al. (2022) recently noted the influence of age on behavioral outcomes of CS participation, with increasing participant age positively affecting students' ascription of harm for plastic marine debris (PMD), but negatively affecting their perceived behavioral control, awareness of consequences, ascription of responsibility, and self-reported behaviors surrounding PMD. Future research could examine and compare outcomes across the extended age range for the Journey (grades K-12) and similar programs and could aim for a more quantitative assessment of learning outcomes and civic engagement, perhaps working in partnership with older girls to measure impacts of their TAPs.

This case study demonstrates the potential for a facilitator organization to promote learning outcomes and civic action through a CS learning experience. Beyond this single instance of facilitated citizen science, there is still much to be learned about the roles these organizations play in the CS ecosystem, including what their motivations are for engaging with CS and the types of common outcomes these organizations can achieve in pursuit of their own goals and those of science learning more broadly (multi-project participation, pro-environmental behaviors, etc.). For example, in the case presented here, the GSUSA focus on hands-on learning and STEM education made CS programming a good fit for achieving their organizational goals, while the Girl Scouts' emphasis on STEM leadership and existing programs to promote learning and action provided important structures to support and extend learning outcomes from CS participation. Examination of a greater variety of facilitator organizations will help inform future program management by further elucidating the contexts and features that can best promote desired outcomes. One contextual piece which also may be of interest is examining the role of specific individuals within a facilitator organization in supporting participant learning outcomes. We emphasized earlier that we were interested in the role of the organization as a whole, but it is worth noting that key individuals (such as Girl Scout troop leaders) may still have a critical role as learning brokers in a CS experience (Barron et al., 2009).

A final area of future research with broad implications for the CS community at large is the potential for facilitator organizations to foster greater inclusion of individuals from groups that may have been historically under-represented in CS and the STEM sphere more broadly. CS has roots in efforts to democratize science (Bonney et al., 2016), yet current participant demographics poorly reflect such aspirations (Allf et al., 2022; Mahmoudi et al., 2022), leading to recent calls to make CS more inclusive and aligned with community interests (Cooper et al., 2021; Pandya, 2012). While demographics have not been a large focus of this case study, and specific demographics of participating girls were not available, it is worth emphasizing the geographic diversity of participants from across the US, including rural and urban areas in 43 states and DC. This geographic diversity likely also reflects a diversity of economic, social, political, and other backgrounds which would be worth exploring further. By fostering participation of individuals who may not otherwise self-select to participate in CS, facilitator organizations like the Girl Scouts and others – such as employers, formal and informal educational institutions, and community groups – could have an important role to play in enhancing inclusion in CS.

Conclusion

This case study of the Girl Scouts' Think Like a Citizen Scientist Journey on SciStarter demonstrates the potential for facilitator organizations to promote learning outcomes that might arise from participation in citizen science and associated learning activities. In particular, the structured progression of activities from content-and-skills based learning to action-based outcomes facilitated an extremely diverse array of cognitive, affective, and behavioral outcomes being reported, including the acquisition of STEM content knowledge and skills, development of science confidence and identity, and the adoption of civic action and advocacy behaviors. Furthermore, this case provided a unique example of how pairing CS with community engagement activities can foster peer-to-peer learning, intergenerational learning, increasing levels of civic science education, and civic action related to science and the environment, paving the way to increased community science and environmental literacy. Future research related to the role of facilitator organizations in CS should focus on developing a better understanding of the motivations of these organizations in employing CS, the specific contexts and organizational features which promote successful outcomes, and the role facilitator organizations play in enhancing inclusion in CS.

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Declaration of interest statement

SH, AM, KM, and LT were involved in this work as part of their employment with Girl Scouts of the USA. DC is the founder of SciStarter.org and helped to develop SciStarter's partnership with GSUSA and the Think Like a Citizen Scientist Journey.

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Table 1 Question 1 codes representing expected learning outcomes (see Appendix B for code definitions, sample quotes, and additional details).

Code Abbreviation	**Full Name & Description aligned to LSIE strands and GSUSA outcomes**
Strand 1	LSIE Strand 1 - Sparking Excitement and Interest
Strand 2	LSIE Strand 2 - Understanding Scientific Content and Knowledge
Strand 3	LSIE Strand 3 - Engaging in Scientific Reasoning
Strand 4	LSIE Strand 4 - Reflecting on Science
Strand 5	LSIE Strand 5 - Engaging in Scientific Practices
Strand 6	LSIE Strand 6 - Identifying as a science learner
GSLE1	GS Leadership Experience Outcome 1 - Develop a strong sense of self
GSLE2	GS Leadership Experience Outcome 2 - Display positive values
GSLE3	GS Leadership Experience Outcome 3 - Seek challenges and learn from setbacks
GSLE4	GS Leadership Experience Outcome 4 - Form and maintain healthy relationships
GSLE5	GS Leadership Experience Outcome 5 - Identify and solve problems in the community
GS STEM1	GS STEM Outcome 1 - STEM Interest
GS STEM2	GS STEM Outcome 2 - STEM Confidence
GS STEM3	GS STEM Outcome 3 - STEM Competence
GS STEM4	GS STEM Outcome 4 - STEM Value

Table 2 List of question 2 codes characterizing relevance of girls' Take Action Projects to science and environmental themes.

Code	Sample Quotes
Participated in another citizen science project	"The girls chose to do another Citizen Scientist Observation Project. They chose the Nature's Notebook. The girls walked around the wooded area by our meeting space and collect data on the birds in the area."
Encouraged others to participate in citizen science	"Citizen Science projects are fun and help the scientific community, but our friends and family don't know about citizen science. We made a video to share with family and friends. We explained what citizen science is and how to get involved. In our video we also shared what project we did & how much fun it was! We encouraged others to take on a citizen science project too!"
Related to an environmental theme	"We wanted to protect our ocean from plastic trash that hurts wildlife by teaching our friends to stop using single use plastics (like straws, plastic bags, and water bottles). We created a game called "Beach Cleanup" that teaches about not using plastics and caring for our ocean in a fun way."
Related to citizen science project subject	A troop that completed ANT-vasion said:"We really enjoyed learning how natural ant repellents are safe and effective! We wanted to share our findings with others, so that they may try them out where they may need ant control. We made an educational video showing how we did the experiment, and the results. We obtained permission to post it to our own Girl Scout Troop…YouTube channel."
Related to science literacy	"We wanted to provide more opportunities for kids in our area to learn about STEM. We assisted in building and donating a STEM backpack for the Frisco Library available to all kids in our area."
Not related to science or the environment	"The Troop wanted to help the residents of the nursing home by providing small throw blankets to help keep them warm. The residents needed the small throw blankets because the larger blankets get caught in the wheels of their wheel chairs. The Troop provided one small throw blanket to each resident of the nursing home (60 blankets)."

Table 3 List of question 3 codes characterizing the types of actions performed through Take Action Projects.

Code	
Educate and Inspire Others	A troop that completed Globe at Night said: "We wanted to teach others about the stars and constellations. Also about lights out times to view the stars. Our troop made 5 informational posters that are on display in several local schools, at our local library, and we're displayed at our cookie booths." "Not enough people are aware of Citizen Science…[We made] a presentation and handouts for the public that explains Citizen Science and encourages others to engage in projects."
Improve environment or habitat	"The girls wanted to create areas that would attract 'good' native bugs and insects. The girls planned and planted raised garden beds at the local YMCA"
Participate in more citizen science	"We wanted to contribute to another citizen science project. We chose Project Squirrel."
Take civic action	"The girls would like to limit the amount of school supply waste by recycling used and worn out items that are being thrown in the trash. We will partner with Crayola and other companies to place recycling bins through out the school for markers, crayons, and paper and send them to be repurposed. By partnering with the school district they will be implementing this program every year by educating the teachers and reminding students of the location and purposes of the bins."
Promote science literacy	"There were many students in our schools that didn't know much about science and couldn't find any age appropriate books to read about science. We decided to raise money and buy science books to donate to our school library."
Project unrelated to science or environmental theme	"The Hedgehog…at [a local] Nature Center keeps getting [sic] wearing out his sleep sacks. The girls sewed 8 new sleep sacks, using techniques from their research into making hedgehog bags."

Table 4 List of question 4 codes characterizing the audiences engaged throug.h Take Action Projects.

Code
Peers
Adults
General Public
Civic Leaders
Unspecified Audience
Project unrelated to science or environmental theme

Table 5 Activities from the Think Like a Citizen Scientist Journey mapped onto Levy et al.'s (2021) typology of civic science education (CSE).

Levy et al. (2021) CSE Category	**Levy et al. (2021) Definition**	**Relevant GS Journey Activities**
Foundational	"CSE experiences that involve exposure to, discussion of, and/or peer interactions around science-related public matters, with a focus on the development of related knowledge, skills, and values."	Interactions with various audiences through efforts to educate and inspire others provided foundational CSE experiences to these audiences.
Exploratory	"CSE experiences that involve asking questions and collecting and/or analyzing data and/or evidence related to science-related public matters."	Participating in a citizen science project provided exploratory CSE experiences for GS participants and those who participated with them.
Purposefully Active	"CSE experiences that involve raising awareness, advocating, organizing others, designing solutions, and/or purposefully participating in efforts to address science-related public matters."	Enacting a TAP (including sharing or discussing science and/or environmental topics; reaching out to a civic leader; improving the environment or creating habitat; encouraging others to participate in citizen science, etc.) provided GS troop members with purposefully active CSE experiences.

Figure 1 Image depicting the three scaffolded steps or phases of the Girl Scouts Think Like a Citizen Scientist Journey.

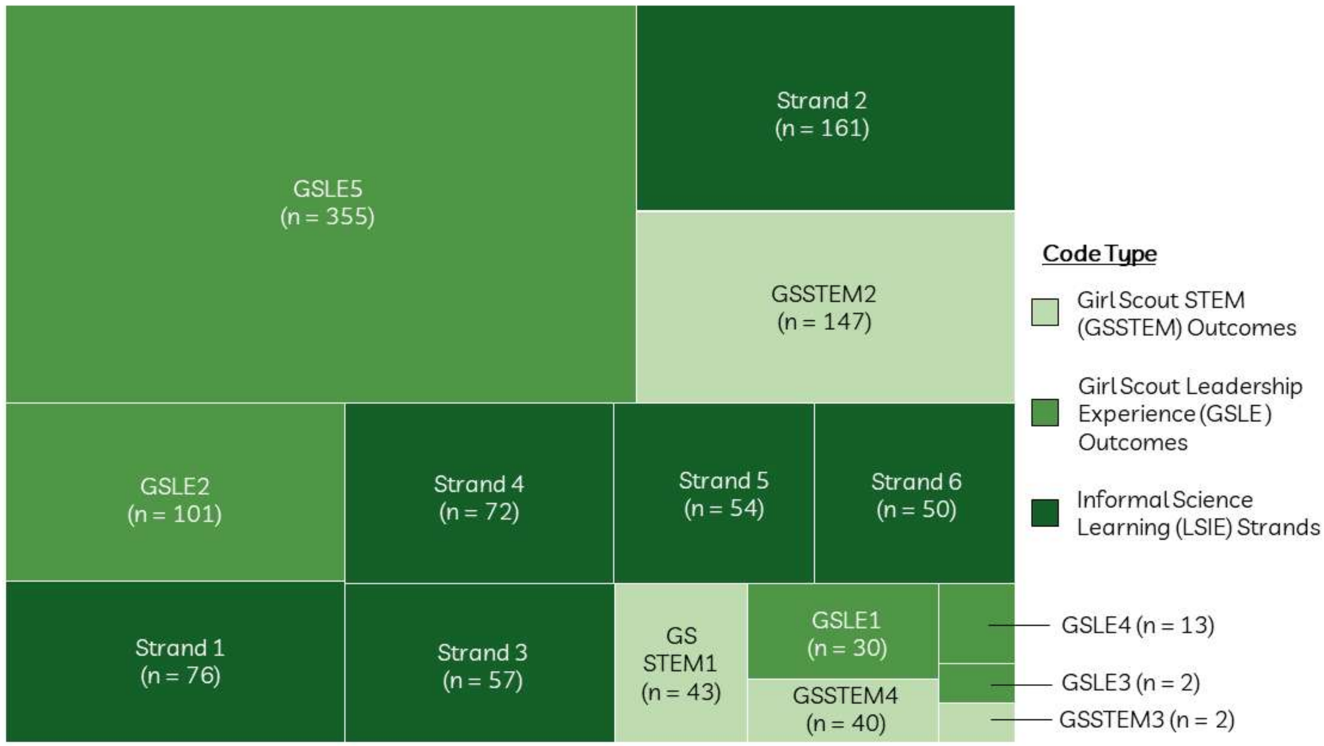

Figure 2 Treemap depicting comparative frequencies of occurrence of each code for analytic question 1.

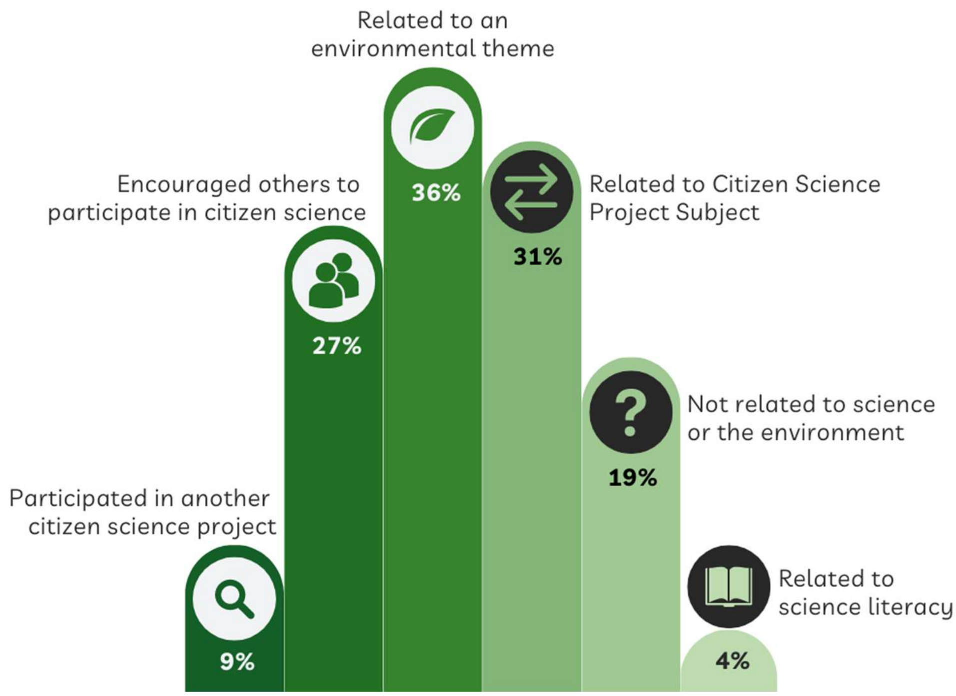

Figure 3 Bar graph depicting how TAPs related to science and the environment. Categories are non-exclusive with the exception of "Not related..." Percentages therefore add up to more than 100%. Percentages are rounded to the nearest percent.

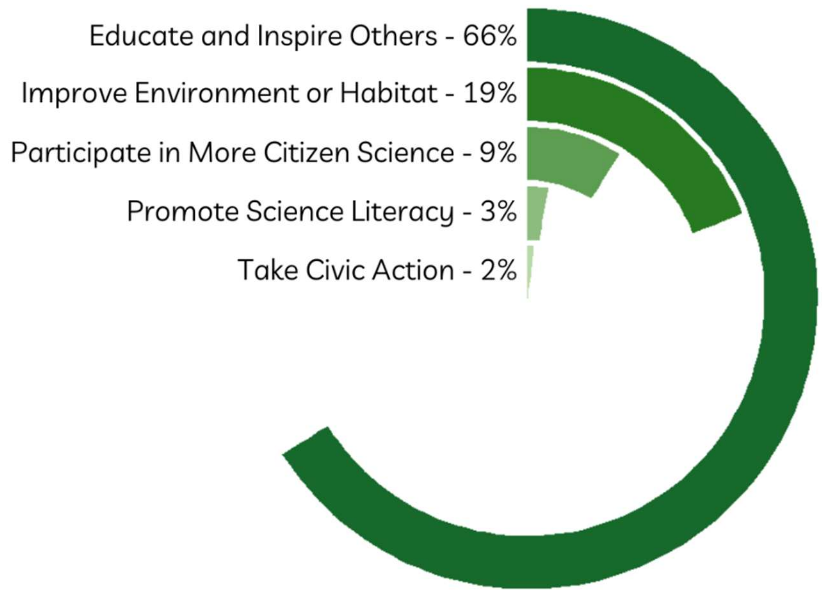

Figure 4 Circular bar graph illustrating the percentages of Take Action Projects in which girls took each coded type of action. Percentages are rounded to the nearest percent. Projects unrelated to science and environmental topics are not included. All categories are non-exclusive, therefore percentages add up to more than 100%.

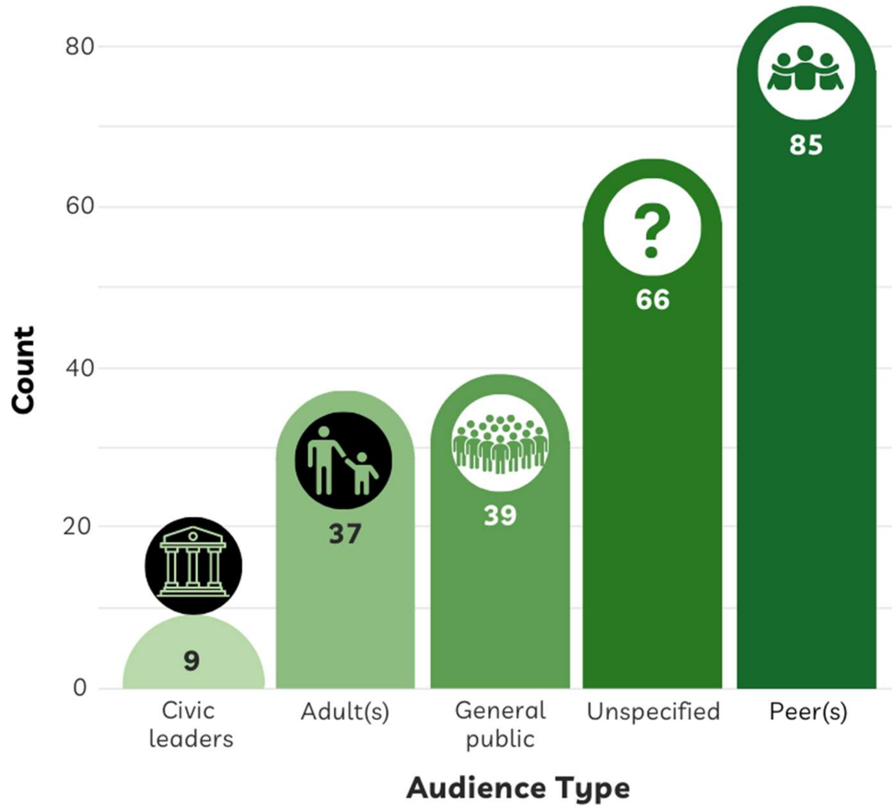

Figure 5 Bar graph demonstrating the frequency with which girls engaged different audiences through their Take Action Projects. Projects unrelated to science and environmental topics are not included. All categories are non-exclusive, therefore percentages add up to more than 100%.

CHAPTER 4: Facilitated Citizen Science in Public Libraries as a Context for Science Socialization

Abstract

Citizen science projects are widely recognized as contexts for a variety of informal science education outcomes. However, much of the previous research on learning in citizen science has taken place in single-project contexts and has not considered individuals' experiences outside of that project. Learning is, however, a highly individualized and contextual process. In this chapter, I take a holistic, life-course view of learning to investigate the role that facilitated citizen science experiences in public libraries play in the lifelong process of science socialization. Using a multiple case study approach involving interviews with nine public librarians in rural, suburban, and urban locations across the US, I adapted the five domains of socialization identified in Bixler et al.'s (2011) environmental socialization theory work to explore how library-based facilitated citizen science programming supports *access, accumulation of experiences, competency development, social support, and identity formation.* Libraries provide a unique community-based context for lifelong STEM learning, and librarians offer unique insights thanks to their familiarity and deep understanding of their patrons' experiences with their programs. My findings validate the use of this framework in citizen science contexts and demonstrate that libraries are supporting all five domains of socialization - most notably access, accumulation of experiences, and social support. This supports prior work indicating that facilitated citizen science has the potential to engage more diverse audiences, and my findings suggest specific opportunities for libraries (and other facilitators) to better support the socialization process, for example by offering more directly facilitated citizen science programs

rather than just opportunities for independent engagement, and by designing recurrent or series-based programs to encourage repeated participation.

Introduction

Citizen science and learning

Citizen science (CS) is a term referring to various forms of public participation in scientific research. It is a practice that has not only made valuable contributions to numerous scientific disciplines – perhaps most notably to biodiversity research (Chandler et al., 2017) – but that also leads to demonstrated impacts for participants and society more broadly. In the context of CS, such impacts are typically referred to as “learning outcomes.” Following modern theories of learning, CS research generally interprets learning quite broadly, including not only cognitive outcomes such as knowledge and skill acquisition but a wide range of affective, attitudinal and behavioral inputs and outputs, and the interactions among these factors (NASEM 2018). Examples of noted learning outcomes associated with CS include: increases in science literacy or understanding of science (Bonney et al., 2009; Bonney et al., 2016; Crall et al., 2012; McNew-Birren and Gaul-Stout, 2022), increased interest in science (Schneiderhan-Opel and Bogner, 2020; Smith et al., 2021), development of science agency (Ballard et al., 2017; Smith et al., 2021), and behavior changes following participation in environmental CS (Forrester et al., 2017; Jordan et al., 2011; Toomey and Domroese, 2013), among others (Phillips et al., 2018).

Learning is also known to be a continuous and contextual process that occurs constantly throughout a person’s life and is impacted by socio-cultural and other contexts (e.g. formal vs. informal learning environments) (NASEM, 2018). Learners come to an experience with highly variable pre-existing interests, knowledge, motivations, concepts of and experiences with science, all of which are socially and culturally mediated (NASEM 2018). Additionally, in thinking of a CS experience as a single encounter within an "ecosystem" of other experiences with science, CS, and learning (Allf et al 2022, NASEM 2018), the outcomes of one CS experience will (hopefully) become the inputs to another experience in the future. Therefore, so-called learning "outcomes" are not necessarily end points in and of themselves, but instead can serve as springboards to continued engagement in CS or science more broadly and to ongoing science learning over the course of a lifetime (NASEM, 2018; Phillips et al., 2018).

Theoretical framework

Taking a view of science learning as a continuous and culturally-mediated process, I propose "science socialization" as an appropriate framework for exploring the learning outcomes associated with citizen science. Socialization refers to a life-long process of exposure to ideas and experiences which can lead to the adoption of specific norms and practices (Carlone and Johnson, 2007; DiBenedetto and Bembenutty, 2013). Drawing on environmental socialization theory (James et al., 2010; Bixler et al., 2011), Figure 1 depicts five key "domains" of socialization which contribute to the process of socialization and identity development. In the present study, I will extend these domains to the realm of science.

The concept of socialization is foundational to the field of sociology, but also has roots in social and developmental psychology (Elder, 1994; Guhin et al, 2021). Studies of *science socialization* have typically focused on career retention in STEM fields and seem to lack any existing formal framework (for example, DiBenedetto and Bembenutty, 2013; Jahn and Myers, 2015; Laursen et al., 2012; Levine et al., 2021). Because citizen science is by definition a non-professional endeavor with roots in the context of natural history and is widely present in a variety of environmental science fields today, I instead turn to *environmental socialization theory* for a relevant framework within which to consider science socialization through citizen science.

Environmental socialization emerged in the early 2000s as a model to examine the impact of "significant life experiences" in nature on natural history professionals and hobbyists. Within this context, James et al. (2010) presented a "developmental model" of environmental socialization, consisting of four stages. In their model, individuals throughout their life course move through stages characterized by direct experiences with nature, emergence of formalized skills, role awareness (characterized by crystallization events that begin to have an identity association), and finally natural history and ecology identity formation. The authors generally align each of these stages with corresponding life stages, from childhood to adulthood.

Building on the same study of natural history enthusiasts and professionals, Bixler et al. (2011) used grounded theory to identify 5 key domains of socialization opportunities which influenced the environmental socialization process. Paraphrased to remove the environmental emphasis, these domains were: *access, social support, accumulation of experiences, development of competencies, and identity formation*. Most importantly, the authors concluded that the socialization process is created through "repeated and diverse experiences…within supportive social worlds" (Bixler et al., 2011, pg. 60). They emphasized the importance of regular and repeated experiences and the need for facilitated connections to be made between experiences.

The majority of citizen science research to date takes a narrow view of participants as statically engaging in a single project to assess project outcomes. Using science socialization as a theoretical framework allows me to instead take a life course or process-based approach (Elder,

1995) to understanding participants' experiences with and outcomes from citizen science participation.

Learning contexts and facilitator organizations

Following an understanding of learning as a highly contextual phenomenon, there has been a growing interest in developing a better understanding of the contextual factors that lead to learning through citizen science. Although participant learning outcomes have been demonstrated in individual citizen science project contexts, evidence supporting the achievement of such outcomes is mixed. Several studies in recent years have pointed to inconsistent outcomes and have made calls for improved evaluation across CS projects (Bela et al., 2016; NASEM, 2018; Peter et al, 2019). These works have clearly demonstrated that sweeping outcomes cannot be assumed to occur without intentional learning supports and have emphasized the need for a better understanding of the specific contexts and factors which lead to certain participant outcomes, particularly those of a more transformative nature (Bela et al., 2016; Peter et al., 2021). This recognition aligns with previous research on environmental behavior change, which has demonstrated that acquiring knowledge does not directly translate into attitude or behavior changes due to a number of internal barriers and external influences (Kollmuss and Agyeman, 2002). It also aligns with the definitions of learning discussed above, and an understanding of learning as being culturally and contextually-mediated.

One unique context for CS participation which is gaining recognition is that of "facilitated" citizen science, which involves an organization such as a museum, school, church, employer, or nonprofit organization laying the groundwork for participation (Golumbic et al., 2025; Lin Hunter et al., 2023; Smith et al., 2023). The idea of such third parties playing a role in the citizen science landscape transcends the traditional conception of citizen science as occurring only within siloed projects and involving only project scientists and participants (Allf et al., 2022). Facilitator organizations not only have the potential to bring new audiences to CS who may otherwise not engage with science in an authentic research context (Lin Hunter et al., 2023), they also have great potential for enhancing participant learning outcomes through existing infrastructure and learning supports, such as supplemental curricula and guides for taking action (Smith et al., 2023).

Libraries as facilitators of citizen science

Libraries are one type of facilitator organization that is increasingly adopting citizen science tools and projects as a means to achieve their own STEM education goals (Ignat et al., 2019; Shtivelband et al., 2017). Libraries have long been hubs for lifelong learning within their respective communities (Mumelas and Martek, 2024; Shtivelband et al., 2017), and – with the onset and evolution of the digital age – continue to expand beyond their traditional roles as repositories for books and knowledge to offer a variety of technological and information services, as well as simply a gathering space within the communities they serve (Cigarini et al., 2021; Mumelas and Martek, 2024; Santos Pimentel and Esteves Gomes, 2024). The public also has a deep-rooted trust in both libraries as institutions and librarians as individuals that seems to withstand the growing divides and institutional distrust in other areas of society (Adle, 2025).

Both public libraries and research libraries in the US and elsewhere are increasingly making use of citizen science projects and tools in alignment with these shifting goals. While a swath of research has been dedicated to the role of libraries in helping to launch citizen science projects and support principles of open science, particularly in a European context (Ayris and

Ignat, 2018; Kaarsted et al., 2023; Liu and Liu, 2023; Martek et al, 2022; among others), more recently there is an emerging focus on the role of public libraries in particular encouraging participation and facilitating learning among the public. Public libraries – in contrast to research libraries – are more well-suited to such outreach and community engagement goals due to their pre-existing connections to diverse audiences (Tautkeviciene and Pranckute, 2024). Like other facilitator organizations, public libraries also have the potential to reach more diverse audiences, including rural, low-income, and ethnically diverse populations, than those typically engaged in citizen science (Lin Hunter et al., 2023; Tawfik et al., 2023; Verbeke et al. 2019). Based on the growing use of citizen science in public libraries and current shortage of peer-reviewed literature on the subject, our study seeks to further explore learning associated with citizen science experiences facilitated by public libraries, specifically within a US context.

Therefore, applying a socialization lens to citizen science experiences facilitated by public libraries allows exploration of citizen science participation as one element in a lifelong process of navigating one's relationship with science. Building on Bixler et al.'s (2011) domains of *environmental socialization theory*, I aim to answer the following research question: How do US public librarians perceive that facilitated experiences with citizen science contribute to the five domains of socialization (access, social support, accumulation of experiences, competency development, and identity formation) and support the lifelong process of science socialization?

Methods

I employed a multiple case study approach (Stake, 2005), with the case study unit of analysis (Lashua, 2022) defined as an individual librarian who has engaged with citizen science programming at their library. Selecting individual librarians as the unit of analysis allowed me to compare and contrast both individual and contextual features associated with the process of science socialization through library-based citizen science programming. It also provided the opportunity for librarians to speak to heir own experiences with sciences socialization as well as their perceptions of their patrons' experiences.

A case study approach is appropriate to answering "how" questions, such as the one I pose in my research question (Lashua, 2022; Schwandt, 2007; Yin, 2002). Furthermore, "case study research…aims to grapple with the intricacy of a context in all of its multifaceted and glorious details" (Lashua, 2022, p. 104), making it an excellent choice for my intended objective of understanding both the individual and contextual factors that influence participant outcomes in library-based citizen science. A multiple case study approach allowed me to examine each library and librarian's individual experiences with citizen science in parallel and look for both commonalities and unique factors influencing learning outcomes. As Brown (2017) stated, a multiple case study methodology allows the researcher to "gain information on how each lived experience is unique, yet in some ways similar to others."

Case study research does not dictate any specific method(s), and in fact embraces almost any qualitative research method appropriate to the phenomenon under study (Lashua, 2022). Given that citizen science participation is not always long-term, happens sporadically, and frequently occurs in an online-mediated fashion, it is not an activity which lends itself to direct participant observation, for example. The flexibility allowed in case study research is therefore beneficial in the context of this research. The primary method of data generation for this study was semi-structured interviews, which used an "interview guide approach" (Schwandt, 2007), generally following an interview guide that was intentionally structured around the five domains of science socialization (see Appendix D for interview guide).

Recruitment

Participants were recruited using purposive (theoretical) sampling (Schwandt, 2007) to identify individuals engaging with citizen science through public libraries in the US. An existing research partnership with SciStarter allowed us to collaborate with their team for recruitment purposes. My initial intent was to recruit both librarians and library patrons to interview, but the latter proved to be extremely challenging. Librarians were recruited during the spring of 2024, primarily from among libraries across the US that have implemented SciStarter's "Libraries as Community Hubs of Citizen Science" programming, or who have completed the associated training on SciStarter. SciStarter assisted in sending recruitment announcements via email and newsletter to prospective librarians and patrons, as well as identifying specific partner librarians who they thought would be willing to participate and who the research team emailed directly. Interested individuals were asked to contact me via email. I also worked with recruited librarians to ask for assistance in recruiting patrons to interview.

Ultimately, only a single patron responded to recruitment emails and upon interviewing, I discovered that they had not actually participated in a citizen science project. However, I was able to recruit nine public librarians from across the US through the purposive sampling strategy outlined above, as well as snowball sampling through interviewed librarians (Parker et al., 2019) and assistance from library network partners. Although there is no perfect sample size, and indeed Schwandt (2007) states that an ideal sample size is "simply not quantifiable" for purposive sampling techniques, Brown (2017) citing Stake (2005) suggests that the number of cases for a multiple case study should remain small – somewhere between 4-10 cases. Indeed, nine interviews proved to be more than satisfactory for achieving data saturation, as common themes and repetition of data began to be apparent during the later interviews (Saunders et al., 2018). The librarians also represented libraries from across all four US Census Divisions and provided perspectives from libraries serving rural, suburban, and urban populations.

Each participating librarian was contacted via email and asked to complete a one-on-one semi-structured interview up to approximately 60 minutes in length, via Zoom. All interviewees were provided with a copy of the informed consent document and a choice of participation via phone or video call during planning email correspondence. They were asked to provide verbal consent at the beginning of the interview and were given an opportunity to ask any questions they might have, as well as reminded that they were welcome to terminate their participation, abstain from responding to any question they preferred not to answer, and ask questions at any time. Interviews took place between February 23rd, 2024 and May 6th, 2024. The study, including the interview protocol and consent process, were approved under NC State University IRB Protocol #26488.

Data collection and analysis

Interviews took place over Zoom, were recorded, and lasted between 32 minutes to 1 hour and 21 minutes. The audio recordings were then imported into Otter.ai for transcription, and each transcription was manually checked and cleaned prior to being exported. I used Quirkos as a computer-assisted qualitative data analysis software tool to help visualize and organize my manual thematic analysis process. This analysis included a combination of deductive and inductive coding (Nowell et al., 2017) to allow for the addition of key emergent factors not included in the original science socialization framework. Deductive coding was focused around the five domains of socialization (Figure 1) and followed working definitions of each domain adapted from Bixler et al. (2011) as well as other literature on STEM identity development and socialization into science careers. After initial coding, I exported codes and quotes into a spreadsheet for creating the final codebook and finalizing themes and subthemes (Appendix E).

Case comparison

Table 1 provides an overview of the unique context of each library represented in this study. This table highlights some of the unique features of each library which might have led to specific opportunities and challenges at that site. These opportunities and challenges are noted in the final column of the table.

Results

Common themes

Analysis of the nine librarian interviews demonstrated evidence that citizen science (and other science) programming in libraries supports all five domains of science socialization: *access, accumulation of experiences, competency development, social support*, and *identity formation*. However, certain domains were much more prominent than others, with access being the most commonly mentioned. Appendix E shows the final codes and corresponding frequencies. Overall, these conversations revealed both opportunities and challenges related to how library programs can support each domain.

Access

Access, or "…[m]echanisms that create opportunities for [individuals] to have access to and interact with" the tools, processes, norms and body of knowledge that comprise science

(Bixler et al., 2011, p. 41), appeared as the most prominent domain during coding. Major sub-themes related to access to science included: the variety of programs offered, with a particular focus on hands-on experiences; opportunities to connect with diverse audiences; providing access to scientific tools and experts; providing access to spaces to engage with science; existing library infrastructure that supports access; resources; partnerships; the easy entry nature of citizen science; and finally librarians "putting things out there."

The program offerings theme highlights an opportunity in the variety of programs offered by libraries, which can appeal to various audiences (and ages) or connect people to science in different ways. While some of the programming discussed was general STEM programming and not explicitly citizen science, these other STEM programs were often described as good jumping-off points for introducing citizen science to a community. One librarian described their programming as follows:

> *And so that was-, just introducing folks to the kits especially. And then having the programming that we did from the kits, really was eye opening to a lot of folks. A lot of people really got interested in that. They did it as family groups. We had Bug Bags that we put together where they could go out on the hiking trails, and they're looking for different types of bugs that they can identify. And then there's another ongoing experiment that they could, you know, submit their data to, and then cleaning up the trails as they were going along. So we had trash bags and we had those picker-up, trash picker upper things that were in those bags as well. And then we had like a bingo game. So they identified different types of bugs and filled the bingo card and brought it back then they got a book, a free book that*

talked about nature and, and the importance of nature in our lives and stuff. So it-, different ways to reach different audiences.

As demonstrated by the activities described above, a particular area of emphasis from librarians related to opportunities for access to hands-on experiences with science provided by citizen science programming and STEM programming more broadly. Another librarian elaborated:

I think it does, has changed the way that they think, because of programming. I think that most people learn by seeing and doing, not by reading and listening to someone lecture. I think they need to get their hands dirty, they need to be involved in it, they need to play a part in it. And I think, bringing in citizen science along with STEM programming, just making it all the same kind of program has opened people up to the fact that they can participate in science.

Another distinct sub-theme related to access to science had to do with how libraries provide opportunities to connect with diverse audiences, or audiences who may not otherwise have or seek out those opportunities. This sub-theme included quotes related to everything from explicitly doing outreach to marginalized communities and offering program materials in multiple languages to simply offering programming at no cost.

Many librarians distinctly referenced how citizen science programming in libraries increases access to tools and interactions with scientific experts. In describing the citizen science kits available for checkout, one librarian shared:

The kits are great, because they have too-, more tools for people to actually do these things. Like some people might not have the binoculars or the clip-on camera that goes on, or the magnifiers that go on your camera for better macro pictures of insects. I think that was a cool draw for some of them too.

Another described a unique opportunity provided to participants at their annual moth night program:

And like I said it was really, really fun to see him [a local scientist] invite people who specialize in moths or Lepidoptera or whatever, working with kids who may not be from affluent families or have that opportunity, and to kinda walk over to their parent and say, I want to let you know that that man talking to your kid right now is the number one scientist, you know. So it was a great opportunity to bring the-... kids who are less fortunate, you know, who may not have these experiences, together with people who are the top people in their field, or scientists, while at the same time they're doing this study that may have never been done before.

Related to tools, another theme identified was how the nature of citizen science itself promotes easy entry to engaging with science, particularly due to the minimal or low cost of equipment needed. As one librarian stated, "the great thing about citizen science projects is not all of them are super equipment-intensive. And, and like some of them, you just need an app for."

Another common theme emerged around how libraries provide spaces where people can engage with science. Different librarians emphasized different elements of what was unique about their spaces, with some highlighting how the outdoor spaces where their libraries were situated allowed easy access to places to engage with nature and do citizen science. Others simply emphasized the library itself as a place that welcomes people to come and gather, as well as a place that provides space for partners to offer programming: "I mean, I think libraries are amazing places to have this because if they can do it somewhat regularly, they are creating that hub and a place for people to go."

In addition to the spaces offered at libraries, many interviewees highlighted other existing library infrastructure that supports access to and engagement with their programs. One common example shared were social media accounts, newsletters, and mailing lists that let libraries share opportunities with their communities. One specifically mentioned how eager their community was to come to programs, and that they could easily get a crowd of 100 people to come out to almost any program they share with their mailing list.

Related to existing infrastructure, resources available to libraries was a major theme that emerged as something supporting their ability to offer programming and enhance access to science. Resources mentioned included financial resources (for example grants they have received); training resources from sources like SciStarter, STARnet, and individual citizen science projects; staff resources and expertise; partner resources; and community resources, including volunteers or community members sharing tools and materials.

Partnerships were a related major theme that provided enhanced access in various ways, such as creating pathways for experts to connect with library audiences, libraries sharing resources with community partners, and partners providing or collaborating on program offerings. Across the nine librarians interviewed, at least 30 different partner groups were mentioned, including local and state government groups, nonprofit organizations, citizen science projects or platforms, universities, informal educational centers like museums and botanical gardens, and more. One particularly notable example of a partnership that enhanced access was this story one librarian shared of their library system loaning air quality sensors to a local environmental justice group (some pieces excerpted for space, indicated by ellipsis):

> *However, that being said, I want to share this with you is that one of our local environmental justice group…it's all women, they actually they started collecting doing their own citizen science project…because they are-, their community is is is having facing the problem with noise pollution, because they live next to the freeway, they're dealing with extreme heat, with no trees in their neighborhoods, and then also air pollution. So they're like, you know, they have a lot of kids with you know, health problems related to you know, the air quality. So they were trying to figure out how to get the City Council the city planners' attention so they can help them do to make the community better…And then they found out that our library actually have air beam sensors. So they're like, they reached out to us and said…they really would love to get these units to the hands of you know, people who come and participate in their meetings. So they can also help them collect data that's around where they live. And so I said, Well, we do have these sensors*

that you know each branch that have it they only have one sensor for loaning. But what we ended up doing is we create a special loaning kit that has SIX sensors in there with instructions in both Spanish and English. We translate our spent-, instructions, and then we loaned it to them. They're still using it, actually. We- I told them, yeah, they can keep it until they finished a project. So now, they had a very, they had a great successful story to tell for the first one that they did, they were, actually they got, able to get the city planner to replan the things in their area by adding more trees, putting colors, adding the the paint to the pavement, the the asphalt, and then they add the padding to the freeway. So you know, so based on that success stories, that now they're doing it for another community…

A final theme related to opportunities for enhancing access to engaging with science was expressed by several librarians, and had to do with "putting things out there." After creating citizen science kits and programs, librarians emphasized the importance of continuing to advertise programs and remind people to participate in order to encourage them to take advantage of the resources and programs on offer.

So they invested a lot of money in these tools. But if you don't promote them, and that's what I'm going to tell this Brooklyn Library is you just can't have them there. You have to keep them out in front of people just like story times, you're consistent. You know, for the kids, they know, they can come at this or this time and get a story. You need to let people know that, hey, we've got these kits, let's do something together to train you. Or, you know, we still need they still need your *help, you know, it just can't be put in a back room and left there because it will stagnate. So yeah, that's that for any kind of program. You know, at a library, you've got to keep it elevated and in front of people. So they're aware it's there, because you always have new people coming in as well. You gotta just let people.*

Another set of subthemes emerged around things which create barriers to access, including: technological barriers; general citizen science barriers; difficulty keeping kits furnished or kits getting stolen; age barriers (both perceived and actual; challenges with staffing and turnover; lack of interest, awareness, or comfort with science among patrons; librarians lacking comfort in facilitating or teaching about citizen science; and challenges with terminology and appealing to diverse audiences.

Technology barriers related either to difficulty using apps, or - for rural libraries in particular - lack of access to reliable technology:

No and you know, the reason why is because, and again, I-, I'm not going to say this is the case everywhere, but in my experience, rural and small libraries, the community members, they do not, they're not receptive to virtual webinars, and- they're just not, and if you if you brought them all to the library and and had something set up, you might get some attendance. If you send them a link and have them look it up at home, you're not going to get anything, especially those who live further out and don't have reliable broadband that can't always log in. And so, you know, in a big urban community, internet's not an issue. I can't even tell you how many times we lost internet when we were up in [town] because of *one issue or another, and folks who don't have access at all, you know, so virtual type programming, webinars, um podcasts, they don't go over very well in rural and small, at least in my experience.*

General citizen science barriers represented barriers that are commonly-known challenges to many citizen science programs and are not specific to libraries, including issues of field safety, training and protocol challenges, competing priorities among prospective participants, seasonality challenges, and more. A related barrier that was mentioned frequently enough to warrant its own sub-theme is the perception that citizen science programming is just for kids and not adults. These age barriers to making citizen science (and all) programming more accessible to adults were raised repeatedly by the librarians I spoke to. One said: "My own library system is interested–again, their focus is on youth and have teens and they don't do a whole lot for adults. In fact, I talked to another staff member, they're the same feeling. So it's kind of hard to break through some of those barriers."

Another shared the following exemplar:

And the one experience that sets out more than any of them is at this pollinator party, we had an older lady who was extremely interested in the ZomBee Hunter kit. And she was asking me all kinds of questions about it. She was, if I remember, right, she was 83/84 years old, something like that, and just enjoyed the whole event. And told me she was going to come in and check out that kit. And so I said, great, you know, I'm happy to see when you come in. And she did! The very next day she came in to get that kit and one of my staff members came back to my *office and said, "[interviewee's name], there's this older lady here and she's insisting that she wants the kit that talks about zombies. And I think she's so confused, I don't think that's what she wants." And they were-, they were just totally, what's the word, stereotyping her because she was older that there because she couldn't possibly be interested in that kit. And I went out there and it was her and I knew it was her it was exactly what she was interested in. So it's eye-opening to my staff that it doesn't matter what age you are, you can be, you know, very interested in what's happening in nature around you and how it impacts you. And the lack of pollinators has a huge impact. And so it was very interesting to me how they just assume because of her age that that wasn't what she wanted, when that really was what she wanted.*

Among the librarians I spoke to whose libraries offer citizen science kits for check out, a common challenge they identified was that items in the kits often get damaged, lost, or stolen. One librarian mentioned that in response they have taken efforts to laminate and make materials as durable as possible for all items included in the kits. Another librarian from a suburban library discussed the difficult balance between keeping the kits on display where they will spark people's interest and not having the items or backpacks containing the kits get stolen.

This need to spark people's interest segues into another broad challenge for librarians related to a lack of interest, awareness, or comfort with science among patrons. A few interviewees who offer citizen science kits mentioned that they are still struggling to get people to check out the kits they offer, although others said their kits are almost always checked out. One opportunity that was identified to help combat a lack of interest or awareness was the theme of “putting things out there,” or the idea of continuing to advertise programs and incentivizing or encouraging people to participate in citizen science discussed above.

The lack of awareness of citizen science kits being available at the library may also translate more broadly into a lack of awareness of the diversity of programs and resources offered at libraries. Librarians seem very proud of the variety of services they offer for their communities. For example, one stated: “I often say that libraries are not the place for books anymore. It's more like a community center. And I think that middleman that draws this and this together, to educate, and and I think that's a really fun thing.” However, clearly not everyone among the general public is aware of these offerings. Another librarian described her struggles in getting the public to recognize that her library offers STEM programming:

> *The way I see it is... people don't see library don't connect library with science, no matter. Even though we've been doing STEM program back in 2013…* [some content omitted]. *I'm telling you when I go out people are just like "What? Libraries have science program?" I still get this from people here in local [city]. And I still get when I go out and present at conferences, I still have people looking at me like "What are you doing here? You're a librarian. This is a science conference." You know, people give me all that look. And I'm like, "well, that's why I'm here to try to tell you we are we are promoting science."*

While some libraries have had greater success with citizen science kits getting checked out (one librarian even said that they were almost constantly in circulation), some librarians also expressed doubt about how many people are actually doing the citizen science project associated with each kit. However, as described by one librarian, an associated opportunity is offering more hands-on facilitation, as described in the opportunities section:

> *Some of our librarians, like couple of them are really into citizen science, then they would actually very purposely walk them through the, the app itself, and then take the time, you know, when they do the program in the library, take them take the time to, you know, go out with them to have that really hands on engagement. Now, when you do just, you know, have the DIY kits, people just go and do it on their own. It is, it is true that I would say most of them probably just try things out. They don't necessarily really download the app, and there's no way we can gauge it, unfortunately. So we can-, only thing is we can see how often they get checked out. But whether they actually contribute data to data to any of these, we don't know. And people, you've probably heard this many, many times, people are so adamant about downloading another app, or registering with their email, because people are so-, so concerned about your privacy.*

As demonstrated by the end of the preceding quote, a lack of comfort with or trust in science is the final piece of this theme. Several librarians raised the issue of data privacy concerns among their patrons, including how their data would be used if they did contribute it. However, some librarians also extended this to a general lack of understanding and comfort in participating in science, but suggested opportunities to frame projects so they are less about data and more about fun:

One thing that we learned is not everyone loves science. Sometimes when you throw things out, like say, hey, come and help, you know, real scientists gather real data and stuff and they're like, "Well, how do I know my data is real? How do I know my data is correct?" So you kind of scare them away. So like I said, one way we really always try to do is we try to emphasize on the fun of the program. So for example, when we do the BioBlitz challenge, we don't tell them. I mean, you know, on the official media release, we said, we're doing this word "research," blah, blah, because going to the general public, but when we do the promotion in branches, or when we teaching the librarians say what are some of the buzzwords that you can use, as I said, Hey, you know, we want them to, you know, like, refine their photographing skills. So we're like, "Come in and join us, if you are-, you love selfies" or something like that, you know, kind of pivot towards that direction, pick the fun part of, of the citizen science project that people were doing, you know, the, the key fun part that people enjoy the most, and then really elaborate on that part and put the spotlight right on that one. And if people who are interested, you know, once they get in, they will be asking, like, "so why are we doing this?" Then you can say, We're doing this because scientists wants to these, you know, you can, they can use these use these data for research and stuff. And they're like, "Oh, that's great."

This idea of framing also relates to the next barrier that several librarians identified, which is challenges with terminology and appealing to diverse audiences. When I say diverse audiences, I mean both rural and urban, young and old, conservative and progressive, etc.

Regardless of the terminology chosen, all librarians expressed a desire to choose terminology that would make citizen science-based programming more appealing and accessible to the populations they serve. However, for many of them, the terminology of “citizen science” or even “science” did not feel like the best way to do that. Some chose to rebrand their programs as “community science” or “neighborhood science.” Others leaned away from citizen science because it seemed to be an unfamiliar term that deterred participation:

> *Well, originally, I did have a hard time getting people on board with anything called Citizen Science. And when I started using that term here, it actually-, attendance went down. Registration wasn't as robust as, as, as opposed to calling it you know, an environmental science type of thing, or an Environmental Day or Science Day or you know, Earth Day type of programming. And that's where I had to lean a little bit back on to SciStarter and said, "Hey, I know we're really concentrating on this term and I-, the focus was citizen science, but I need you guys to help me break this down even better for my community.*

Regardless of the terminology being used, a few librarians also noted that they still struggle to reach beyond their “core group” of participants to more diverse audiences, which again is a challenge observed more broadly across the citizen science landscape:

> *I'm just going to throw it out there is that even though when we do the citizen science programs or the neighborhood science programs in different branches throughout our city? You It's not hard for you to see that the program and these*

programs tend to have better attendance when they're in the more affluent communities. And they are indeed majority white, or Asian. It's very, it's been very, very tough to do it in the central southern area. We have a librarian there who's doing this program monthly basis. At best she will get maybe 10 people, max, but every- every month it's different people, it's she never gets the same people coming back. So and it just, it's just tough.

Turning to barriers associated with librarians and libraries, many librarians I interviewed noted that they themselves (at least initially) and fellow librarians lack familiarity with citizen science or comfort facilitating citizen science programming (and STEM programming more broadly). One stated:

I just think we've run across some staff that were kind of interested in it, sounded fun, but when they heard the commitment to it, and maybe didn't have-, they were even afraid of science, because they didn't have the background. They shied away from it.

Similarly, many of the interviewees noted how challenging it can be to support citizen science programming with limited resources and high staff turnover in libraries. Given that not all librarians are comfortable facilitating citizen science programming, programming sometimes ends when a “champion librarian” leaves.

One librarian said: “I don't know what's happened since I left. I know my department has pretty much almost done a complete turnover in personnel. I think one person who wasn't as interested in supporting citizen science may still be there.” Another shared:

> *…Really, I'm the only one doing this. And, you know, I'm looking at retirement. So, you know, I, I'm hoping that somebody on staff will become as excited about this as I am. Or at least somebody in the community will. And I know I have a lot of excited people that show up. But that might want to take even that leadership role on as a volunteer.*

Despite the challenges mentioned, each of these librarians has offered successful citizen science and STEM programs at their library over the years, and (even for those now retired) are continuing to promote these types of programs in their communities.

Accumulation of experiences

Following access, accumulation of experiences was the next most common science socialization domain referenced in the interviews. Accumulation of experiences refers to the impact of repeated, “frequent and long-term participation in…activities [that] reinforc[e], rene[w], and expan[d] interests” in science (Bixler et al., 2011, pg. 53; Levine et al., 2021).

Major themes that emerged as opportunities to support accumulation of experiences with science within libraries were: scaffolding, series and recurring programming, and paired reading for patrons. Related to librarians’ individual experiences with science, lifelong interests, accumulation of experiences with citizen science specifically, and prior exposure or proximity to science emerged as common themes. As with access, I also identified a theme related to barriers to accumulation of experiences.

The scaffolding theme highlighted program design elements that are intended to help participants continue to explore a subject on their own (Belland, 2017). One librarian explained how they would use STEM programs on a related topic as a way to introduce the citizen science kits:

> *Once the project kits came out, and I physically had instruments and directions to support a project, those programs were segues to introduce the kits. So you know, I always said to people, "and now time for a word from our..." you know, an, an, or-, I'd say, "now it's time for a commercial break." And I, you know, introduce the kit availability.*

Perhaps unsurprisingly for a study on libraries, a related major theme emerged specifically around paired reading. This theme related to programming that was built to supplement reading programs as well as reading suggestions that were offered as additional information following a program. For example, one librarian was planning how she could incorporate Globe at Night into a summer reading program about constellations:

> *And and I saw that the one that was brought up yesterday on light pollution. They're supposed to be doing a Constellation program for our summer reading program and I was gonna kind of approach them and see if they knew about this study on light pollution and if we could include that with with their constellation*

night, so and there probably is an importance of light pollution, you know. But it would be kind of nice to know, in our rural area, how much that affects it also.

One more directly facilitated way that libraries can support accumulation of experiences with science that was discussed by many librarians was offering series and recurring programming. This allows experiences to build upon one another and encourages participants to commit to coming on a recurring basis. One librarian shared how her library had been offering "Citizen Science Saturdays" the first Saturday of every month in an effort to keep momentum and engagement around citizen science:

What I basically just put down on that was hosting Citizen Science Saturdays, and having that be a regular thing. And we had decided we were gonna start that this past October with the annular eclipse, and I think, as a team, and even under the direction of my director, now, she, her button is like, keep going on this, if you know, we have people coming up. And I have developed solar science kits to go out to be used for like, early elementary and families. And right on the end of, you know, the eclipse and those circulating, we're going to start circulating pollinator kits that were developed through SciStarter, we'll start those circulating in the beginning of May. So we're not gonna, you know, let any dust settle.

Another discussed a themed series they had offered that involved a citizen science day as a component among other STEM-related programming:

Uh the series-es that we do. Those– those– those tend– people tend to like that. They're like, "Oh, I'm gonna participate in this series," you know. And, and "I'm gonna go to the book discussion, and I'm gonna do the film, and I'm gonna," you know that, you know the people that we see at those, at those programs are, are repeats. Like, I see people over and over again.

Interviewees also spoke about their own accumulated experiences with science and citizen science. For many, their interest in science programming grew out of a lifelong interest in the environment. For example:

Sure, I have no formal science background. So, but I have a very strong interest in the environment. So I've been involved in things like starting a recycling program. In a town I lived in Connecticut years ago, while I was in [city], I was part of land conservation group that was working to protect the [omitted for de-identification] mountain preserves, I served in leadership roles there as a treasurer and President. I've in within that group and the help of others, we tried to stop a freeway from cutting through part of one of the mountain preserves. So you know, I just have a very strong interest in trying to protect our environment. I got involved in yet another environmental group up here, we're trying to keep our rural areas rural and stop developmental housing sprawl, from changing, you know, habitats destroying habitat. So yeah, that that kind of sums it all up is, I understand why it's important to gather data for science and, and help make good data points for possible change within the scientific community.

Several also described the repeated experiences they have had by participating in various citizen science projects both through work and in their free time:

> *The very first project, I can remember, knowing that it was citizen science, was the Great Backyard Bird Count through Cornell. And I forgot how I heard about it. But I was working at the Conservation Department. And, you know, probably online, somehow I heard about the Great Backyard Bird Count. And I thought, "well, that sounds fun." And, and now that I think about it, I can't remember if I did it... before? No, I think it was after I worked there. Well, I thought that would be something fun to do with the citizens in where I worked. So first, I just did it with my volunteers. And we had a little volunteer crew. And I said, "Hey, you guys want to join me? We'll just do this from the office." And then I also-, that's right. And then I also did it at home. So like since it was a whole weekend, I would do one count at the office for work. And then I did one count for my house. And after I left the Conservation Department, I kept doing it at home just with my-, I have two daughters. So I liked it so much that I just kept doing it on my own.*

While most of the librarians I spoke with did not have a formal science background, some attributed their interest in or willingness to pursue citizen science and STEM programming at their library to previous exposure to science, for example through family. One shared: “That's, you know, I, my family has technical and I have, you know, somewhat of a little teeny bit of a technical background. And I don't-, I think if you don't have those kind of experiences, you're going to be less likely to embrace something like this."

Finally, a few references were made to barriers to accumulation of experiences, or things that deter repeated experiences with science in libraries. Specifically, librarians referred to a lack of consistency in programming, either by not offering citizen science regularly enough, or not having the capacity to facilitate programming as frequently as is needed by a project. One librarian admitted:

> *It's been a while since we've had-, I just thought about this. We haven't had a citizen science project since-, might have been last spring, we had some other things going. And I thought I should have more–it'd be kind of fun if we could have more to keep it going. Kept-, keep the interest going in the community.*

Several librarians also discussed the difficulty of not having a "captive audience." For example:

> *Well, yeah and also because, I mean, I'm glad to be in a public library, but I don't have a captive audience, and so I can't guarantee that the kid who came on Tuesday will come next Tuesday, you know? And we have done registrations pre-COVID, but even then, people were starting to not register. So you know, the culture is just that people don't-, either they register and they don't come, or they come and they haven't registered, so we just don't do registration anymore.*

Social support

Social Support - ways in which an individual's social system (comprised of peers, parents, teachers, etc.) provide external recognition of one's abilities in science, and/or support "further discoveries, opportunities and choices" related to engagement with science (Bixler et al., 2011, p. 44; Carlone and Johnson, 2007; Jahn and Myers, 2015; Levine et al., 2021) – was the next most common domain. Major social support themes identified were: familial support and the related idea that "we're going to do it together." The familial support theme included references to families doing activities and learning together, for example:

> *Yeah, parents come to our programs, and they're almost as excited, if not, sometimes I think they're more excited than the kids because the kids can be really little, and the parents are like, "Oh, my gosh, we get to walk through the creek and find salamanders?! This is so much fun." So the adults really love the programs. And they're almost always with their kids.*

parents or adults encouraging learning among youth:

> *There's this one little boy he comes to every single program either his dad brings him his mom brings him or his grandma brings him. He comes to my volunteer workdays, and he's only eight. But he's like, into botany and entomology. And he's just this amazing kid. He's really, really smart. And he'll come out and work on volunteer workdays, he's, he knows the invasive plants and which ones are native so but he's always he always has a parent with him. But But that's, that's just him.*

He's really, you know, just a special kid. But there are a lot of kids like that at [town] Public Library, whose parents, bring them and stay for the program and have a blast.

and instances of intergenerational learning (IGL):

Because I know especially with the kids, it's hands-on, if we're not doing something active, you're really not getting participation, having it stick with them, and they'll enjoy it. And then they want to take that home and continue on with it. So that's any of my youngster stuff, it's all hands on, and repetitive and to see that excitement with the kids wanting to take something home or build collaboratively to leave it here at the library to be show off and bring other aunts, uncles, whatever back to see what they've created.

While some references to familial support discussed families doing things together, the “we’re going to do it together” theme centered around learning experiences with a group or community, in particular those that are directly facilitated by a librarian or content expert:

Sure, yeah, I think we kind of had like a, we did like a two-hour session when they first came in, we took them downstairs, and we had a screen up. And we kind of just did what is citizen science kind of starting 'em out that way and showed 'em a few videos, actually, from one of them might have been from SciStarter, talked about some different sites and saying, "This is what we're going to do today, but *here are some other sites that you could go to after today, and, you know, explore," you know, and then after a little bit of that, then talking about what we're going to do say like for the bird count, or something like that, we went over, we had a sheet for them, and some field guides out on the tables for them. Also, you know, showed them eBird and everything and Merlin, and, and showed them that they could use those to identify the birds too. Then we went upstairs in our library and first we kind of did it together out the windows. And I kind of walked around and saw how they were doing. We have had experiences where we didn't make them get on the app, some, well, I shouldn't say we didn't make them get on, I let them all get on, but- if they wanted to. But then I was also doing my own tally, like on paper. And, and so some people might have tallied, but we had a great group, I remember that last time that all of them were able to get on, get the app and and use it. And that was to me feeling good, because then it makes it more likely they're going to use it again, if they actually install the app, you know. And then we'll bird for a while. And then I also can tell them go out, you know, go out and about. And if we were doing a BioBlitz, I'd even say you don't have to come back. Because it's all on your phone. Go for it. If you want to come back for anything or ask anything, go ahead. But if not just keep entering all your stuff.*

More minor but notable social support themes related to using social networks to spread the word about citizen science and the opportunity for programs to provide relatable role models. The first involved patrons, members of the public, or even librarians themselves leveraging their social system to encourage others to participate in citizen science. For example, one librarian discussed how they view patrons as partners in helping to spread the word about their citizen science offerings:

> *For us, I'm still trying to get more checkouts. That's the hard part. But for the checkouts we've had I do feel kind of going back to the-, I think the folks who check them out, they look at things differently the way-, you know, when they bring it back. Like that was pretty cool. And I you know, I hadn't thought of this before. So yes, I think I'm looking at them as as more of a maybe a partner in teaching others about science. So that's kind of kind of how I feel, then they can pass that information on too and say, "Hey, you should try this. We did this." So they become a partner with us in helping teach about science.*

Although only mentioned by one librarian, a particularly poignant example of the support provided by a relatable role model was shared by one librarian whose moth night programs were co-led by a professional scientist who had grown up in their rural community and was working to get youth in the area engaged in science:

> *But if we can get these kids interested and excited, having that person there, with their collection, shows them that they can do that too. And if [Scientist's Name] can be the top [species] expert in the nation and he grew up in [town] and graduated from the school that they graduated from. Again, that just shows them that you know, what they want to do, they can they can achieve, even though they*

grew up in tiny little [town name], you know, so so if we can bring those two together, I'll definitely do that.

No clear themes emerged related to barriers to social support.

Competency development

Major themes identified within the competency development domain - the development of scientific knowledge, skills, and understanding which support both conceptual and intellectual competence (Bixler et al., 2011; Carlone and Johnson, 2007) - were: engaging with scientific practices, curiosity and knowledge acquisition, science and data literacy, training, and the relevance and real-world applications of science. Engaging with scientific practices related to participants using scientific instruments and engaging in scientific inquiry (regardless of whether the specific activity was directly contributing to research or not). One librarian provided an example of patrons using all of the tools included in their citizen science kits:

It's but they're going out. And people are using, you know, the– the binoculars and the bird, you know, has a identification book, or, you know, for the butterflies it's got a butterfly, you know identification book with you know, with a magnifier. You know there's all these different things that you know we do it for bats and bee– you know lady beetles and– and pollinators.

The curiosity and knowledge acquisition theme encompassed instances where participants (including librarians themselves) expressed excitement about and/or interest in science and a desire to learn more. For example, one library's pollinator party program was very successful in generating interest and excitement:

> *We were talking about the importance of pollinators. And we talked about the ZomBee Hunter kit where we got this fly that's killing pollinators and whatnot. And, and people had no idea and I was shocked at this, and maybe I shouldn't have been but that bees were not our only pollinators. And that's what everybody always thinks that bees are the pollinators. And they are, but there are so many other pollinators out there as well. And we were able to share that and educate folks on that that hummingbirds were pollinators and butterflies were pollinators and moths were pollinators. And they really got excited about that.*

Science and data literacy was a theme that largely emerged as a motivator for librarians in wanting to offer citizen science programming:

> *To me, science literacy is very important to, you know, the democracy of our communities, you know, being knowledgeable, being educated, whether they realized it or not, you know, they were learning about different issues and could actively participate, which is a great thing about citizen science.*

Librarians also discussed the value of the data coming from their citizen science experiences, both in terms of its impact and the information it provides:

Oh, yeah, that's a good question. Yes, I think that I actually have more tools, for data to tell the students or the homeschool families or my programs about. And I notice the tools. For example, when I, one of the most exciting things when I did the Great Backyard Bird Count was when you get to see your little dot pop up on your city, and you're like, "that's me!" And then, and then you get to track and then all of a sudden, you can start looking at all the lists. And that's how I kind of found out that the cardinal was, like, found in every state in the United States, and like one of the most common and I was like, "Oh, I never thought about that." So looking at the data collected from everywhere was just very interesting to me.

Most librarians discussed training most explicitly in the context of their own training experiences with citizen science, learning to use the apps, protocols, and any necessary equipment. While many discussed training members of the public on how to participate in projects, they rarely used the terminology of “training,” but instead typically talked about “teaching” or “showing” their patrons the process.

The final theme within the competency development domain centered around how citizen science experiences supported competency development by helping people understand the relevance and real-world applications of science. One librarian shared:

Now, why do we want to do citizen science or a neighborhood science program in the library? In 2018, that was the year we already have five years of STEM programs going on in our library system. And we were sort of feeling like, it's not really connecting with participants. Some, you know, meaning that kids come in, I *mean, kids or adults, whoever, when they walk in these participants, they have fun doing the hands-on activities, but we have no way of gauging whether or not they are seeing the connection between this and what's happening in real life. Are they able to take what they learn in terms of these STEM concepts, and they are able to apply to their everyday life? We can't see it. Now, so at that moment, we were thinking, well, we need to pivot this somehow to make that connection with real life, you know, something that's relevant to people in [city]? So actually, it was my division director read about citizen science. And she said, why don't we try citizen science?*

No explicit themes emerged related to barriers to competency development.

Identity formation

The identify formation domain (defined as the emergence of a scientifically-oriented identity as an individual develops "a robust set of…competencies, preferences, and values" related to science (Bixler et al., 2011, p. 57)) manifested around four major themes: (1) the idea of "contributing to knowledge about the place that I live," (2) a highly related theme of action and sense of agency, (3) citizen science as helping to challenge non-science identities, and (4) for librarians themselves, developing an identity as "the STEM or citizen science person" among their co-workers and community.

The in vivo code "contributing to knowledge about the place that I live" clearly described a common theme around place-based identity and participants being able to contribute to scientific knowledge related to that place through citizen science. One librarian described a program that helped participants become more aware of and connected to their own backyards:

> *And we did a program where a biologist came and talked about her project that was a, you know, citizen science project on pollinators in your backyard. And one of the things that I think was really galvanizing for people, and I think more people will per– probably participate in that particular science, citizen science project around pollinators is that you can have a real…You can see real, you know, changes in your own backyard. Like if you plant, you know, if you plant native, you know native species of plants, and you don't use Chemlawn on your lawn, you know– you do these various things that are fairly easy and fairly low cost. You can create a, an environment just in your backyard that is really healthy. And so you, you know, that will bring in more– more insects, that brings in more birds, you know it's– it's like, even just within your own backyard. You can ha–, you can see a tangible difference, and that is something that really resonated with people they're like, "Oh!" [laughter] "I have some agency with how things you know, you know, you know, how, how better things can be in my community.*

A highly related theme, though not exclusively place-based, was the theme of taking action and a sense of agency, in which participants feel that they are able to use science as a tool to drive change. Librarians shared their own experiences with this, such as one who said in relation to their own participation in citizen science: "I understand why it's important to gather data for science and, and help make good data points for possible change within the scientific community." Several librarians also mentioned their patrons feeling more of a sense of being able to influence change, such as one who spoke about how citizen science programming, beyond their traditional STEM programming, allowed patrons to feel that they could make a difference:

> *And, and so for us, you know, our traditional programming prior to all this has been mostly like some, you know, lectures or workshops where an expert is telling you, you know, what's– what's happening, you know, like, "Oh, you know, you know, there's this terrible thing happening, you know, like we're killing off the bats or or the bees, or whatever it is." And, and the citizen science projects move that needle away from like the, I–, you know, that sort of sense of hopelessness like, "Oh, I can't really do anything about this, it's way bigger than what I'm able to do." It moves that needle to "Oh, actually, I can do this.*

Another identity forming experience that seemed to be shared by both librarians and patrons alike was having their "non-science" identities challenged by participating in citizen science. These were experiences related to someone's concept that they are not a "science person'' being counteracted by participating in citizen science, or simply ways in which participating in citizen science makes people be able to feel like they are scientists. One librarian shared their perspective:

Well I think it opens up a whole new world for people who, who some of them who think that they're, they would never be smart enough to participate in a science program of any kind, you know, especially when you are introducing it as a STEM program. And we know, you know, science, technology, engineering, and math, people think, well, that's not for me, that's way over my head, and these types of programs and this type of project, brings it to the fact that that anybody can be a scientist. Anybody that's interested enough can be a scientist, and it's not all lab work. It's not all, you know, wearing this fancy lab coat and doing all of these experiments that are gonna save the world necessarily, it's learning about science and the impact it has on our everyday lives and, and how you can contribute to that.

Finally, for librarians specifically, many of the individuals I interviewed had developed identities as “the STEM person” or “citizen science person” at their library, both among their coworkers and their community. For example, one interviewee described their role at their library:

And it covers, you know, just about any program from storytimes to STEM/STEAM, which is usually my favorite. Even though my degree is in history. I have three children, which has really pushed me into the STEM/STEAM arena, and I've loved it ever since. And that's something I really enjoy. And I've taken the lead on that for all the departments within the library. So that's usually when anything like that creeps up, it's handed off to me.

As with social support and competency development, there was no explicit discussion of barriers to identity formation during citizen science programming within my conversations with librarians.

Emergent themes

While some of the subthemes identified in each domain of science socialization were arrived at in an emergent fashion, many aligned well with a specific domain of science socialization. However, a handful of emergent codes appeared as major themes across interviews but lacked a direct relation to one of the domains. These emergent themes included: both opportunities and challenges around the COVID-19 pandemic, opportunities and challenges in working with different types of school audiences, and librarians' knowledge of and connections to their audiences.

Five of the nine interviewees brought up COVID in our conversations, even though it wasn't explicitly asked about. A couple librarians mentioned challenges related to COVID impacting their momentum and flow of programming, with one stating: "Trying to just get everybody back on track was kind of a challenge." Another librarian mentioned the challenges that COVID posed related to her community's relationship with science. She felt that the pandemic almost caused her community to lose some of the progress that had been made through STEM programming at the library:

> *I want to say the pollinator party was after COVID. And it was. It was after COVID. During-, during that timeframe, when we were dealing with COVID, it*

was almost like the community I was in up in [town] went backwards. They you know, we were making some progress. We were talking about science and and we were talking about STEM and we were talking about you know how these things impact your everyday life and, and that and then COVID hit and I it almost like we went backwards a little bit because there were so many people that were denying that it was as bad as it was.

Interestingly, this same interviewee also perceived some opportunities that were afforded by COVID where bigger questions about science were raised and spurred in-depth conversations with patrons:

Oh, yeah. Oh, yeah. There was a lot of questioning, well, scientists don't know everything. And you're right. They don't, they don't know everything. And they're learning about this, as we're going along. And, you know, we would have people say all the time, why are things changing? Why did protocols change? Why are there-, changing so frequently? You know, don't they know what they're talking about? And it would be, you know, they're, they're learning, they're having to do experiments, they're having to do research to figure out what's going on with this virus? And what how do they take care of it? And how do we impact it? And how to, you know, how do we get better if someone gets sick, I mean, it's- scienc is ever changing all the time. And we're always learning about it. So it did bring science way to the forefront.

For the next major emergent theme, six of the nine interviewees discussed working with school or homeschool audiences. The overwhelming consensus among all of these librarians was that working with homeschool groups was an opportunity to have a recurring audience. One librarian even shared that they had used their homeschool group as the test audience for their citizen science kits:

> *We tried to target all audiences. Um, the homeschool group, in particular, we kind of had their undivided attention because we were doing already a homeschool program for them regularly every month. And so they were who we first started this citizen science kits with they, when we first introduced citizen science, it was to the homeschool group.*

Conversely, while the librarians I spoke to seemed interested in working more with non-homeschool school groups, they had generally encountered challenges in collaborating with these audiences. One librarian explicitly mentioned the challenges of having to align programming with school curricula. Another discussed successfully working with high school students for volunteer events in the park adjacent to their library. Yet another mentioned briefly that they did "school days for the Monarch Watch."

Eight of the nine librarians mentioned the final major emergent theme of librarian's knowledge of and connections to their audiences. Some expressed this theme simply in relation to knowing that their community was interested in scientific topics and programs. For others, this theme was connected to the access theme of terminology, and the importance of knowing what terminology would be appealing and accepted by their communities when introducing citizen science. However, while these themes are highly interrelated, this additional theme was added to emphasize not so much the framing and programming choices made by librarians to bring patrons into programs, but the skills and strengths of librarians in having a strong knowledge of their audience(s). This was stated very well by one librarian who said:

But in this particular case, it was trying to be sensitive to the community that I was in, and the fact that they're very conservative and very much, you know, not necessarily want to say that there is climate change. So you got to figure out a way to do it without, you know, totally getting them upset at you or turning them away or something like that. So... And I think every librarian that knows their job knows their community and knows how to go about doing that.

Discussion

Findings demonstrate that all five domains of science socialization (access, accumulation of experiences, competency development, social support, and identity formation) can be – and often *are* – supported through citizen science programming in libraries. Science socialization as a framework fits well in the citizen science context, and the domains and overarching process are not only relevant but actively occurring in facilitated settings such as libraries. The socialization process is also occurring both among library patrons and librarians themselves, supporting findings by Tautkeviciene and Pranckute (2024) that librarians can hold multiple roles with citizen science, including as participants and facilitators. In considering how citizen science experiences are supporting the socialization process, each domain presented its own opportunities and challenges within the library context.

It is perhaps unsurprising that access (both opportunities for and barriers to) was the most prominent of the domains to appear in my interviews with librarians. In essence, access is the necessary-but-not-sufficient domain which must occur first in order for the other domains of science socialization to be possible. Without access to experiences with science, none of the other domains are likely to occur. Therefore, access must come first. My results suggest that - while there are certainly challenges that libraries or individual librarians may face when implementing citizen science (or other STEM) programming in their libraries – there are ample opportunities for libraries to provide access to opportunities for patrons to interact with science - including among individuals who may not otherwise have such opportunities. These results support previous studies indicating that libraries, among other facilitator organizations, hold the potential to engage more diverse audiences in citizen science experiences (Lin Hunter et al., 2023; Tawfik et al., 2023; Verbeke et al. 2019). Although some librarians specifically noted challenges in engaging ethnically diverse audiences, many suggested opportunities for continuing to expand the populations they reach, including through direct outreach, adjusting terminology and framing, offering programming targeted at specific audiences, and designing programs that are relevant and help patrons build place-based connections to issues they care about.

Despite the challenges that exist for libraries in supporting accumulation of experiences with science – including not having a captive audience like in formal learning environments, or not always having the staffing or other resources to provide consistent programming – numerous opportunities were presented that can facilitate this domain of science socialization. In particular, scaffolded programming, series and recurrent programs, and paired readings were all methods commonly mentioned by librarians. These are approaches that could easily be translated to other libraries, or perhaps other facilitated environments as well (perhaps with the exception of paired reading). The series and recurrent programs in particular provide the opportunities not only for repeated experiences, but for librarians to help facilitate connections across these experiences, as called for by Bixler et al. (2011).

Additionally, librarians were able to provide personal accounts of how they had accumulated experiences with science across their life courses (Elder, 1995), from early exposure to technical or scientific terminology due to having a family member in a scientific field, to recognizing that their interest in citizen science stemmed from lifelong interests in nature and/or the environment - therefore demonstrating a clear connection for the application of environmental socialization theory to the citizen science context. Furthermore, many librarians discussed how they have participated in many citizen science projects over time - typically starting with just one project (which often marked their first recognition of the term citizen science) to evolving participation in various projects over time.

Libraries also appear to have great potential for fostering social support as a domain of science socialization, particularly in providing opportunities for familial and community or facilitator support. Peer support, on the other hand, went largely unmentioned - perhaps because of the often multi-generational audiences present at library programs, or the informal nature of even all-youth or all-adult programs. The themes of familial support and “we’re going to do this together” are evocative of the idea of learning partners (Barron et al., 2009), in which parents (or other adults) facilitate learning by either encouraging interests or pursuing interests alongside youth. However, these themes emerged as being beneficial to both adults in peer environments and both youth and adults in mixed-age programs. Similarly, the familial support and inter-generational learning themes both featured instances of intergenerational learning, including examples of multi-directional collaborative learning among generations as well as uni-directional knowledge transfer between generations, and both intra- and "extra-familial" learning (Newman and Hatton-Yeo, 2008). One library's use of a local scientist as a role model in encouraging youth from their rural town to develop interest in science is also a promising idea. Although my interview did not provide data on the outcomes of that experience, literature on role models in STEM education indicate the value and effectiveness of providing a role model who appears to be "meaningfully similar" to their audience (Gladstone and Cimpian, 2021).

Although the subthemes under the competency development domain were initially coded organically and in an inductive manner, they align well with previous literature on learning through citizen science, in particular the LSIE (Learning Science in Informal Environments) strands identified by the National Research Council (NRC, 2009), which have often been applied to citizen science contexts (NASEM, 2018; Phillips et al., 2018; Smith et al., 2023). For example, the subtheme of "engaging with scientific practices" was ultimately named after LSIE Strand 5 (NRC, 2009) due to strong alignment with the subtheme definition of using scientific instruments and engaging in scientific inquiry (Appendix E). Strand 5 states that learners "participate in scientific activities and learning practices with others, using scientific language and tools, and engaging in collective activities" (NRC, 2009, pg. 4). The remaining competency development themes also each demonstrated alignment with one of more of the LSIE Strands: curiosity and knowledge acquisition (Strands 1 and 2), training (Strands 2 and 5), data literacy (Strand 4), and relevance and real-world applications of science (Strands 2 and 4). The final domain - identity formation - aligns with LSIE Strand 6 - Identifying as a Science Learner. Identity formation was the least prevalent domain coded for, perhaps in part because identity formation is such an individual experience, making it difficult for my interviewees to speak to the identity formation processes of their patrons. However, librarians were able to speak about their own identity-forming experiences, as well as share some specific instances or opportunities for identity formation in their public programming. Interestingly, while the original environmental socialization work by James et al. (2010) on which I based this study implied that socialization experiences begin in childhood, and indeed I embrace the concept of science socialization as a lifelong process, most of the librarians I spoke to identified as a non-science person well into adulthood, prior to their exposure to citizen science. This demonstrates the true power of citizen science in helping to "democratize science" and engage non-experts in the processes of science.

Science identity formation through citizen science has been a growing area of research in recent years, although the path(s) by which it occurs remain complex and often hard to decipher (Phillips et al., 2025; Williams et al., 2021). However, my results align well with existing literature on the subject. The first identity subtheme - "contributing to knowledge about the place that I live" alludes to the importance of place-based connections in identity formation. The importance of place connection is well-established in the citizen science literature broadly (Haywood et al., 2016; Haywood et al., 2020; Toomey et al., 2020) as well as in more recent research on identity development in citizen science (Dixon et al., 2022; Haywood et al., 2024). Previous work has also identified the interactions between community action, agency, and identity formation in STEM education contexts (Calabrese Barton and Tan, 2010) as well as "nested purposes" - or ways that engagement in science has meaning and impact beyond their immediate learning environment - contribute to identity formation (Dixon et al., 2022; Harris et al, 2019). Ultimately, by introducing science socialization as a process in which identity formation is the final step, the opportunities associated with all five domains in some ways contribute to the lifelong process of science identity formation.

Barring another global pandemic, the emergent themes around COVID-19 may not be as applicable in future contexts. However, the idea of opportunities related to COVID-19 was an unexpected finding. This theme highlights potential opportunities for librarians to engage their communities in discussions about other science-related current events, capitalizing on the immediacy of the topic to help “bring science to the forefront.” For the audience-based subthemes, homeschool groups seemed to be a successful audience to work with, so other libraries looking for audiences to pilot citizen science programming might turn to their own similar audiences if they have them. The challenges related to working with school groups might be addressed by focusing more on projects that curate their own curriculum-alignment resources. Alternatively (or in addition), organizations like SciStarter and STARnet who curate resources for librarians might consider developing more curriculum-aligned facilitation materials.

The final emergent theme related to librarians’ knowledge of and connections to their audience is a unique strength of libraries as potential facilitators of citizen science. This strength aligns with competencies identified as necessary to support citizen science programming and already existing among interviewed librarians in many contexts, in large part due to their unique ability to communicate with and reach many different audiences (Tautkeviciene and Pranckute, 2024). We would extend that by saying that librarians in our study emphasized not only the product of audience-appropriate communication, but also the inherent knowledge librarians have of their audiences based on being embedded within and frequently interacting with their communities.

The strong alignment between our findings and existing literature in various areas related to citizen science outcomes indicates the value of taking a deep dive into understanding how a specific context can support these various outcomes. While individual studies have explored the potential for one or two domains at a time, this study provides depth into the ways in which libraries offer a unique context for supporting all five domains at once. Perhaps the most encouraging takeaway of this study is that, despite some noted challenges and the highly varied contexts and resources across the libraries examined, each was able to find ways to successfully incorporate citizen science programming in ways that demonstrated opportunities for supporting a process of science socialization among their patrons. Hopefully the lessons shared by these librarians can help to inform more successful and transformative citizen science experiences in public libraries and beyond. Resource hubs like SciStarter, STARnet, and individual projects that curate training materials can also support the success of library-based and other facilitated programs by curating resources that intentionally support certain domains of socialization, such as materials for series-based or repeat programming. Ultimately, all facilitators of citizen science could likely improve their impact by assessing their programming and considering how they could more intentionally design programs that support each domain of science socialization.

Limitations and future research

Although interviewing librarians directly provided a valuable opportunity to understand both librarians' own processes of science socialization and their perceptions of these processes among their patrons, a valuable extension of this work would be to interview and/or observe patrons directly. I found librarians to be fiercely protective of their patrons' privacy, as noted in research about public trust in libraries and librarians (Adle, 2025). One reason several some of the interviewed librarians said it would be difficult to advertise the study to audiences who have specifically participated in citizen science programming is that they often do not keep records of who attends programs for privacy reasons. Perhaps through a more long-term relationship with an individual library or librarian, it might be possible for future researchers to have the opportunity to learn about library patrons' experiences through interviews and/or by conducting participant observation(s) of citizen science programming at a library. This might also be achieved in partnership with researchers in library and information sciences, a field in which ethnographic research is historically popular yet some argue still underutilized (Hider, Wakeling, and Garner, 2025).

Furthermore, there is the challenge of socialization being a lifelong process, whereas my research only offers a snapshot in time. Being able to talk to individuals who have participated in citizen science over longer periods would also be beneficial. However, while not having the opportunity to interview library patrons to gain this perspective on life-course experiences with citizen science, many of the librarians themselves exhibited strong examples of socialization in action - and identity formation in particular. While their experiences may not translate exactly to their patrons, it does at least indicate that there is clear potential for citizen science participation to have a long-term influence on the socialization process, leading to development of a STEM identity.

Conclusion

In this study, we provided evidence that public libraries in the US present a context with ample opportunities for supporting science socialization through citizen science programming, among both patrons and librarians. To best support this process, librarians (and other facilitators) can lean into some of the strengths and opportunities mentioned in this study that specifically foster each domain of socialization. For example, to improve access, librarians and other facilitators can leverage resources and partnerships to offer a wide variety of hands-on citizen science programs geared at various audiences. Groups can also foster repeated engagement with science by creating scaffolded experiences and offering repeated programs (like Citizen Science Saturdays) as well as programs that are part of a series. These types of programs also create opportunities for librarians to draw direct connections between accumulating experiences, helping to build competencies and support identity formation. These are only a handful of the opportunities shared by the librarians in this study for supporting science socialization through citizen science. One major limiting factor for these and other libraries is staff time and turnover. Having district- or administrative-level support for these types of programs is critical and may be able to help bolster some of these efforts even in the face of turnover. Leaning on existing resources like SciStarter, STARnet, and the training provided by individual projects or project teams can also help. These resource hubs might also consider intentionally curating resources designed to address some of the domains of socialization, such as materials for series-based or repeat programming.

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Table 1 Library Case Comparison.

Interview #	Library Location (US Census Division)	Librarian's Tenure at Library	Number of staff	Population Served by Library (or Lib. System)	Unique Features/ Summary of Programs
1	Northeast	Not stated	Not stated but mentioned at least one other staff member who works on development (grants, etc.). Likely more than that given size of population served.	Suburban (city population under 50,000; county population over 150,000)	This librarian worked at the only library branch serving the city. Librarian's focus was adult programs. Part of SciStarter network and citizen science kits grant. Library had seen success with science-themed series involving a citizen science day. Proximity to universities and general progressiveness of the state made people interested in and open to science and environmental topics. Struggled to balance interest in kits with kits getting stolen from the library. Terminology was something they had thought a lot about due to a large refugee resettlement community in the town. Felt that the place-based nature of citizen science was a good opportunity to help newly relocated people connect to their new home.
2	West	Not stated, retired	Not stated but mentioned at least a couple fellow staff members who had been excited to support citizen science programming at the library. Likely more than that given size of population served.	Urban (county has a population over 1 million)	Librarian had served at the district level for an urban county with several library branches. Was involved with the SciStarter *Libraries as Community Hubs for Citizen Science* pilot. Retired in 2020 but had been continuing to consult with libraries across the country. Had been focused more on adult programming. Felt that their community was generally very interested in learning about science. Had been offering astronomy and pollinator-related programming prior to implementing citizen science. Introduced citizen science kits as part of the pilot program. Discussed the value of resources provided by SciStarter and the

Table 1 (continued).

					challenge of dealing with turnover and losing "champion" librarians.
3	Northeast	17 years, approaching retirement	Not specified, however mentioned having multiple departments, and at least one other person in charge of children's programming.	Rural (town population under 5,000)	Successes included offering Monarch Watch and hatching monarchs annually; eclipse programming in '23 and '24. Has used SciStarter, Globe Observer, and SEALnet resources. Began Citizen Science Saturdays (recurring monthly program) in October 2023 and so far had been successful. Had offered solar science kits starting around the eclipse and was soon to roll out SciStarter pollinator kits. Pending challenge noted was that citizen science programming was this librarian's passion project and they were likely be retiring soon.
4	West	Recently moved to new library (within last year) - experiences shared were primarily from old library	At current library: seven. Not the only person at previous library, but probably a smaller team.	Rural (as defined by librarian; city population between 10-15,000)	A lot of direct involvement with SciStarter. Pollinator party was a highlight. Had citizen science kits at their previous library, but was not sure if they are continuing after leaving. Was actively working on getting kits in circulation at the new library. Challenges at the previous library had included how to frame topics to make them appealing to their audience, and how to offer programs that were interesting and accessible for rural audiences.
5	Northeast	11+ years	"Staff of 1.5" Presumably one full-time, one part-time.	Rural (population under 5,000)	Primary involvement with citizen science has been an annual moth night logging observations in iNaturalist with a local scientist. This program ran from about 2013-2018. Librarian was also interested in incorporating Globe at Night into their summer reading program. Mentioned opportunities for engagement with local citizen science efforts related to monitoring recently

Table 1 (continued).

					reintroduced wildlife species in the region.
6	West	Not explicitly stated. Doing STEM in libraries since at least 2013.	Not stated, part of huge urban library system (over 70 branch locations)	Urban (county has a population over 1 million)	Extremely robust programming. Have used SciStarter kits and gone through extensive training to facilitate GLOBE Observer programs. Large library system with lots of staff. A “champion” librarian who has become extremely dedicated to incorporating citizen science. Role is specifically focused on STEM programming. The library and its citizen science tools have been able to serve as a resource to local nonprofit partners, such as an environmental justice group documenting noise and air pollution. Mentioned challenges with engaging more diverse populations in less affluent areas of the city.
7	Northeast	11.5 years	Six when fully staffed	Rural (population under 7,500)	This library is early in their citizen science journey. Librarian had participated in a biodiversity monitoring project before, but the state’s library system is just starting to roll out kits. The librarian was a children’s librarian and had done other STEM programming with youth audiences.
8	Midwest	7 years	Staff of four at their branch, soon to be five	Urban (metro population over 1 million)	Library is located in a county park. All programming at the branch is focused on science and nature. Interviewee has a formal library background but also environmental background. Other staff all have biology or environmental backgrounds. Have done a lot of Cornell Lab of Ornithology Projects (GBBC, Project Feederwatch) on site, as well as BioBlitzes with iNaturalist. More recently have introduced SciStarter kits. Were struggling to get interest in checking out kits, wondered if it might be because they already

Table 1 (continued).

					had so many other science and nature-themed offerings. Had only done limited formal programming around citizen science. Discussed concerns about terminology and having a large Spanish-speaking population, so leaned more into advertising around "anyone can do science.'
9	South	Part-time since 2018 or 2019	Library itself has other staff, but interviewee noted they are typically the only one supporting citizen science programming like BioBlitzes.	Suburban-Urban. (Town population over 50,000. County population around 150,000)	Librarian herself is a trained environmental educator. Library is set within a wooded park that is over 30 acres. Have an engaged volunteer population, but the reality of the interviewee being the only person on staff coordinating these programs and it being a half-time role was a challenge. University town - fairly educated and engaged population, so they get great attendance and citizen science kits are almost always in circulation. Many, many partnerships with other local and state-wide organizations to offer unique programming. Have done a lot of BioBlitz-style programming with iNaturalist. Also mentioned challenges with reaching audiences beyond their typical "core group" of attendees, in particular "black and brown" folks. However, discussed some intentional outreach the library and its partners are doing to try to reach more underserved populations (bookmobile, programs targeted at specific audiences, etc.).

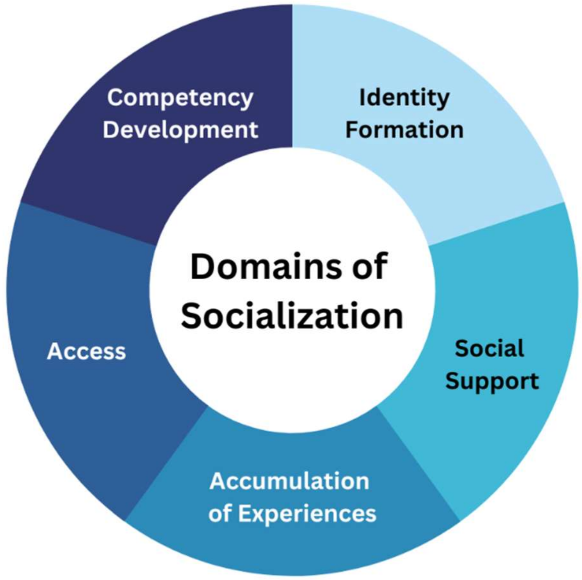

Figure 1 Domains of socialization, adapted from Bixler et al., 2011.

CHAPTER 5: Conclusions and Recommendations

Key Takeaways from All Chapters:

- Multi-project participation is not uncommon (16+% of SciStarter users participate in 2+ projects)
- “Initial dropper” behavior (joining but not contributing) is extremely common (almost 50% of SciStarter users)
- Affiliate projects on SciStarter get almost 10x more joins than non-affiliate projects
- As reported by other researchers before us, participation is highly skewed, with 1% of SciStarter users making 86% of total contributions to affiliate projects
- Activity patterns are also heavily skewed, with most participants contributing sporadically or only a little before dropping out of a project
- Facilitation impacts participation in citizen science, but the impact seen depends on the nature of the facilitated experience. Based on my research, there is evidence that more highly-structured experiences that are opt-in (ie Girl Scouts) are more likely to result in more contributions over longer periods of time as opposed to “captive audience” facilitation with minimal support and scaffolding, and perhaps more extrinsically motivated participation (corporate volunteer programs, students)
- Providing structured facilitation of a series of activities supports a wide array of learning outcomes and actions among citizen science participants
- Pairing citizen science with community engagement activities can foster community-level outcomes, including interpersonal learning and increased community science and environmental literacy.
- Public libraries in the US implementing citizen science programming provide a facilitated context for increasing access to science, accumulation of experiences with science, science competency development, social support for doing and learning science, and science identity formation.
- Librarians and other facilitators can intentionally take advantage of opportunities to support these areas to foster interest and engagement with science, and science identity development

Recommendations for Future Research

- Further exploration is needed between the interactions between facilitation, motivations and participation
    - This could include a combination of digital trace data and either survey data or qualitative investigation to understand the individual and contextual factors that lead to the participation trends observed
- Continued research on HCI and platform design would be beneficial to understand how and why specific design factors influence participation within and across projects
- Future research on facilitators might seek to understand the motivations of facilitator organizations in employing citizen science with their audiences, as well as the specific contexts and organizational features which promote successful outcomes
- Additional research on library-based citizen science might benefit from developing deeper relationships with a single library with the goal of connecting with patrons about their experiences with citizen science programming, and how that fits into their life course of experiences with science. This could also allow for participant observation of citizen science programs occurring at the library.
- Continuing to learn more about how citizen science fits into lifelong experiences with science for participants from a variety of contexts would also be beneficial in further exploring how citizen science can support the process of science socialization at a variety of life stages and for people with varied experiences with science throughout their lifetimes.

Recommendations for Facilitators

This will also be turned into an infographic or other type of informational document for librarians and/or other facilitators.

- Facilitators (librarians, scout leaders, formal and informal educators, etc.) employing citizen science should consider the motivations of their audience(s) and craft experiences intentionally to fulfill these motivations and encourage continued participation beyond the facilitated experience.
- Facilitators could also suggest next steps or additional projects that participants might try when the facilitated experience comes to a close to help bridge

- Highly structured facilitation involving a progression from science learning activities to citizen science participation, to open-ended community action projects seems to lead to positive learning outcomes and continued engagement with citizen science, at least for certain audiences. Facilitators who believe this approach is appropriate for their audiences should consider testing out intentionally scaffolded experiences that are developmentally appropriate for the age of the audience

- Public libraries who have yet to consider offering citizen science programming are encouraged to consider implementing citizen science and offering citizen science kits for checkout to achieve any STEM or environmental education goals they may have. Librarians who do not feel comfortable with the idea of facilitating citizen science are encouraged to take advantage of training opportunities such as those offered by SciStarter, STARnet, and individual citizen science projects. Alternatively, libraries could benefit from partnering with local scientists who may have knowledge to facilitate a citizen science experience at their library

- Libraries and other facilitator groups can increase science learning and STEM identity development by designing citizen science programs to provide intentional support in the following areas:

    - <u>Access</u>:

        - Strive to offer a variety of programs aimed at various audiences and ages and offering different ways to engage with citizen science

        - Offer hands-on experiences that employ citizen science tools

        - Consider terminology, framing, and resources needed to engage diverse audiences in citizen science programming (perhaps alternate terminology is needed to "citizen science;" perhaps materials in multiple languages are needed, etc.)

        - Provide access to scientific tools (such as through citizen science kits) and opportunities to engage with scientific experts

        - Take advantage of ways that existing library spaces can be leveraged to offer opportunities for patrons to engage with science and/or citizen science

        - Use existing library infrastructure (including communications platforms, volunteer resources, etc.) to support citizen science offerings

- Take advantage of training, financial, staff, and other resources available to support launching of a citizen science program. For example:
  - NSF and IMLS grants
  - SciStarter, STARnet, GLOBE observer, iNaturalist, and other resources hubs and projects offering facilitator resources
- Leverage partnerships to increase access to experiences with (citizen) science in your community, both by receiving and sharing resources
- Continue promoting citizen science kits once they are in circulation, and use programs to highlight and generate interest, and teach people about contributing to a project.

- Accumulation of Experiences:
  - Offer scaffolded experiences where participants are introduced to citizen science and then given opportunities to continue exploring on their own (such as through use of the kits)
  - Pair reading programs with citizen science experiences - either use reading programs (like summer reading) as a jumping off point for introducing a citizen science project, or offer reading suggestions for learning more about the topic of a citizen science project
  - Encourage repeated participation by offering recurring programs (like a "Citizen Science Saturday" each month) or by featuring citizen science in a series.
    - Intentionally build connections across programs for recurring attendees
  - Connect citizen science to other lifelong interests patrons may have (gardening, stargazing, birding etc.)
- Competency Development:
  - Encourage patrons to engage with scientific instruments and inquiry, through use of citizen science apps and kits, among other programming
  - Foster curiosity and interest by answering questions or providing resources where participants can learn more about citizen science or a particular science topic

  - Offer trainings in which participants can learn and practice the protocols and tools (including and app) for a citizen science project
  - Emphasize the relevance and real-world applications of citizen science to help participants gain understanding and interest
- Social Support:
  - Provide opportunities for families to engage in programs together. Ensure that there are learning elements geared at all ages in these multi-generational programs.
  - Provide opportunities for direct facilitation (either by a librarian or a content expert), in which the program leader walks through all parts of a project or activity with participants. It can be good to emphasize the value of failing and learning together.
  - Where possible, offer relatable role models to help encourage participation in science (for example, a professional scientist who grew up in the same town and went to the same school as youth in a program)
  - Lean on library patrons to help spread the word about citizen science
- Identity Formation
  - Design programs that have a place-based connection (in other words, that allow participants to contribute to knowledge about the place they live and learn more about that place).
  - Connect citizen science programming to the outcomes it may provide and to other tangible actions that patrons can take to make a difference (for example, planting pollinator-friendly plants in connections with a pollinator citizen science kit)
  - When facilitating citizen science programs, use language that helps participants see that they can and are doing science, and anyone can be a scientist.
- Other
  - Leverage real-world events as opportunities to engage in discourse about scientific topics (for example, COVID presented challenges but also

    brought science to the forefront and provided a venue for talking about the process of scientific discovery

    - Consider implementing citizen science programming with homeschool or other existing, recurrent audiences

    - Use your knowledge of your audience or community and their needs and interests to tailor programming that is appealing and will be received well by them. If at first you don't succeed, try something different!

- One major limiting factor for these and other libraries is staff time and turnover. Although only mentioned by one or two librarians in passing, having district or administrative-level support for these types of programs is critical and may be able to help bolster some of these efforts even in the face of turnover. Leaning on existing resources like SciStarter, STARnet, and the training provided by individual projects or project teams can also help. These resource hubs might also consider intentionally curating resources designed to address some of the domains of socialization, such as materials for series-based or repeat programming.

Recommendations for Platforms/Resource Hubs (like SciStarter)

- Advertise that featured/affiliate projects get more joins (almost 10x more joins on SciStarter)

- Since multi-project participation and natural lapses in participation are common, continue offering new opportunities to existing users that might spark new engagement

- Consider also offering additional connections for participants in citizen science projects, for example, actions they can take to support or promote the topic of their project or take action in their community

- Provide resources to encourage and help participants share their citizen science experiences with others to spark new participants

- Consider creating a repository of programming and resource guides for facilitators to use in hosting citizen science programs targeted at various ages and audiences. In particular, beginner-friendly guides to science content and FAQs related to particular program topics could benefit librarians or other facilitators who are hesitant about their ability to facilitate science programming.

- Include content in programming guides about the relevance and real-world applications of the project
- This repository might also include suggestions of unique uses of spaces and expertise found in libraries to increase access to science
- A repository cataloguing financial, content expert, and partnership resources available to libraries for launching or continuing citizen science efforts would also be beneficial
- This repository could also include suggested reading lists connected to citizen science projects
- Help develop marketing materials for libraries and other facilitators to use in promoting citizen science
- Develop documentation of the benefits of citizen science programming in libraries (or other contexts) to help get administrators on board
- Consider offering facilitation guides for progressive programming that builds up to and off of citizen science participation (similar to the Girl Scouts' Think Like a Citizen Scientist Journey)
- Create program guides that are framed around connections to common lifelong interests (like gardening, astronomy, etc.)
- Offer training to librarians, as well as guides for facilitating training among patrons
- Consider developing and offering programming guides that are geared towards multi-generational audiences
- Provide guidance for how librarians can frame citizen science to help participants realize that anyone can do science.
- Encourage librarians to develop place-based programming
- Develop and offer discussion guides about timely scientific topics (COVID-19, bird flu, lead pipes in the era of Flint, MI, etc.)
- Consider providing facilitation guides for working with school audiences that have built-in curricular for widely-taught science topics

- Support librarians in developing transition guides to help sustain programs when staff turnover occurs

APPENDICES

Appendix A

Comparison of frequencies of the top 10 project disciplines between 2018 data used by Allf et al. (2023) and affiliate projects in the 2024 data used in Chapter 2.

Top 10 Most Common Disciplines (2018 data):	**Percentage of total projects falling in this discipline (2018 data)**	**Top 10 Most Common Disciplines (current study, 2024 data):**	**Percentage of total projects falling in this discipline (current study, 2018 data)**
Ecology & Environment	56.76%	Ecology & Environment	57.63%
Pollution	11.34%	Pollution	11.53%
Geology & Earth Science	6.33%	Geology & Earth Science	8.14%
Health & Medicine	4.69%	Astronomy & Space	7.12%
Astronomy & Space	4.38%	Health & Medicine	4.41%
Cell & Molecular	3.13%	Cell & Molecular	2.37%
Psychology	2.58%	Psychology	2.37%
Computers & Technology	1.95%	Transportation & Infrastructure	1.36%
Anthropology	1.80%	Anthropology	0.68%
Pets	1.33%	Food & Agriculture	0.68%

Appendix B

Chapter 3: Analytic Question 1 Codebook

List of *a priori* codes used for manual deductive coding of analytic question 1, accompanied by their formal definitions from NRC (2009)[a], GSUSA (2017)[b], and GSUSA (n.d.b)[c]. This table also describes alignment between the selected codes and the stated learning goals of the Think Like a Citizen Scientist Journey (GSUSA, n.d.a)[d] where applicable, as well as representative quotes for each code.

Code	Full Name & Description	Formal Definition [a, b, c]	Alignment with Intended GSUSA Journey Outcomes [d]	Representative Sample Quote
Strand 1	LSIE Strand 1 - Sparking Excitement and Interest	Learners experience excitement, interest, and motivation to learn about phenomena in the natural, physical, constructed, and social worlds.	**Outcome 1:** "Explore how scientists do research and create solutions to some of the most important problems faced by people, animals, and the environment."	"We wanted other kids to know how much [fun] science could be and easy ways they could enjoy science."
Strand 2	LSIE Strand 2 - Understanding Scientific Content and Knowledge	Learners come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science (including both technical content and broader social, political, and cultural contexts of science).	**Outcome 1:** "Explore how scientists do research and create solutions to some of the most important problems faced by people, animals, and the environment."	"The girls wanted to inform the public about light pollution after completing the Stars at Night."
Strand 3	LSIE Strand 3 - Engaging in Scientific Reasoning	Learners manipulate, test, explore, predict, question, observe, and make sense of the natural, physical, constructed, and social worlds.	**Outcome 2:** "Practice making scientific observations and collecting data."	"We helped gather data for project squirrel, visited a wetland, and a forest preserve, observed and learned about a lot of plant and animal species, talked about conservation, invasive species, pollination and the monarch butterfly (we played pollinators with silk flowers and paper butterflies, and then laid our eggs on the monarch's host plant, milkweed)."
Strand 4	LSIE Strand 4 - Reflecting on Science	Learners reflect on science as a way of knowing: on processes, concepts, and institutions of science; and on their own process of learning about phenomena.	**Outcome 1:** "Explore how scientists do research and create solutions to some of the most important problems faced by people, animals, and the environment."	"We shared with our friends and family how we contributed to science by doing observations and recording data on the squirrels we saw."
Strand 5	LSIE Strand 5 - Engaging in	Learners participate in scientific activities and learning practices with	**Outcome 3:** "Participate in a citizen science project."	"We joined up with the National Park Service at Great Smoky Mountains National Park to work

Chapter 3: Analytic Question 1 Codebook (continued).

	Scientific Practices	others, using scientific language and tools, and engaging in collective activities.		the Citizen Scientist project "Solar Eclipse 2017: Life Responds." We looked at animal behavior 30 minutes before totality, during totality, and 30 minutes after totality, then sent our data to scientists so they can study it."
Strand 6	LSIE Strand 6 - Identifying as a science learner	Learners think about themselves as science learners—that is, as ones who CAN learn science—and develop an identity as someone who knows about, uses, and sometimes contributes to science.		"We wanted others to know what a citizen scientist was and how people of all ages could be one."
GSLE1	GS Leadership Goal 1 - Develop a strong sense of self	Girls have confidence in themselves and their abilities, and form positive identities.		"The girls talked with their classmates about science and being Citizen Scientist [sic]. They showed them their posters on the different foods ants like to eat and what they were not crazy about."
GSLE2	GS Leadership Goal 2 - Display positive values	Girls act ethically, honestly, and responsibly, and show concern for others.		"We spent an afternoon picking up litter along street [sic] as we traveled to and from a stream setting an example and making an impact."
GSLE3	GS Leadership Goal 3 - Seek challenges and learn from setbacks	Girls take appropriate risks, try things even if they might fail, and learn from mistakes.		"Educated friends and family on how and why to conduct fun science experiments, even when you don't get expected results!"
GSLE4	GS Leadership Goal 4 - Form and maintain healthy relationships	Girls develop and maintain healthy relationships by communicating their feelings directly and resolving conflicts constructively.		"The girls worked with another troop doing this experiment. They wanted to do more things with other Girl Scout troops."
GSLE5	GS Leadership Goal 5 - Identify and solve problems in the community	Girls desire to contribute to the world in purposeful and meaningful ways, learn how to identify problems in the community, and create "action plans" to solve them.	**Outcome 4:** "Do a Take Action project to address an issue in your community."	**Problem:** "The girls would like to limit the amount of school supply waste by recycling recycling used and worn out items that are being thrown in the trash." **Solution:** "We will partner with Crayola and other companies to place recycling bins through out the school for markers, crayons, and paper and send them to be repurposed."

Chapter 3: Analytic Question 1 Codebook (continued).

GS STEM1	GS STEM Leadership Goal 1 - STEM Interest	Girls are excited about STEM subjects and want to learn more about them.		"We did a [sic] education video for people on how to become a citizen scientist and the cool things you can do as a scientist."
GS STEM2	GS STEM Leadership Goal 2 - STEM Confidence	Girls have confidence in their STEM skills and abilities.		"The Daisies told many people what they did and shared how important it is to collect data and interpret results."
GS STEM3	GS STEM Leadership Goal 3 - STEM Competence	Girls think scientifically to solve problems.	**Outcome 2: "**Practice making scientific observations and collecting data."	"By participating in the USA National Phenology Network's Nature's Notebook we were able to collect data about plants and animals in our community and upload it to their organization through a downloaded application."
GS STEM4	GS STEM Leadership Goal 4 - STEM Value	Girls learn the importance and relevance of STEM to people and society.	**Outcome 1:** "Explore how scientists do research and create solutions to some of the most important problems faced by people, animals, and the environment."	"Educate family and friends on importance of science and observations around us."

Appendix C

Citizen Science Projects Featured on Girl Scouts Microsite on SciStarter

Project Name and Sponsoring Organization	Times Completed	Dates Featured on GS Microsite	Purpose, Goal, and/or Task
Ant Picnic, by Your Wild Life	70	2018 – present (Fall 2022)	“Inform scientists about global food preferences of ants. Create a picnic for ants, wait an hour, record number of ants.”
ANT-vasion, by the Backyard Biodiversity Project	9	2018 – 2020	"To get the ants out of your home without harmful chemicals! Test out a natural deterrent to see if it keeps the ants away!”
Girl Scouts SciStarter Project on iNaturalist, by iNaturalist	1	2020 – present	“Share the biodiversity that you and your troops explore.”
Globe at Night by NSF’s NOIRLab	20	2018 – present	“With Globe at Night, citizen scientists match the appearance of a constellation they see with 7 star maps of progressively fainter stars. They then submit their choice of star map online with their date, time and location to help create a light pollution map worldwide.”
GLOBE Observer: Clouds by NASA and The GLOBE Program	22	2018 – present	“GLOBE Observer is an international citizen science initiative to understand our global environment. Your observations help scientists track changes in clouds in support of climate research. Scientists also use your data to verify NASA satellite data. And by submitting your observations, you can help students of all ages do real scientific research as part of the GLOBE Program.”
GLOBE Observer: Trees by NASA and The GLOBE Program	2	2019 – present	“Observe trees to understand changes in biomass and effects on the carbon cycle.”
ISeeChange, by ISeeChange	3	2018 – present	“We're making a record of climate change impacts. What you see change in your backyard, neighborhood, and city is important to our understanding of how climate change and weather affect our communities. Your observations and insights can help scientists, engineers and local organizations advocate for and create solutions to climate challenges.”
Nature’s Notebook by the USA National Phenology Network	9	2018 – present	“Observe, share seasonal changes in plants and animals.”
Project Squirrel by Project Squirrel	49	2018 – present	“Help scientists better understand tree squirrel ecology.”
Stream Selfie by the Izaak Walton League of America	59	2018 – present	“Map streams across the country and start testing the waters. Simply snap a pic of your local stream and share it!”
ZomBee Watch, by the Natural History Museum of Los Angeles County	1	2018 - present	“Learn where in North America bees are infected by Zombie Flies. Collect honey bees; report easy-to-spot signs of infection.”

Appendix D

Chapter 4 Interview Guide

Background Questions

1. Can you tell me about your role at your library?
2. What types of previous experiences did you have with science throughout your lifetime?
    a. [*If examples are needed*: through school, work, other volunteering, relevance in everyday life, etc.]
    b. Are there, or were there, any areas of science that you have a particular interest in or feel you are particularly knowledgeable about?
    c. Are there, or were there, any areas that you don't feel as knowledgeable about or interested in?
3. How did you originally get involved with citizen science at your library?
4. Before working with citizen science at your library, had you previously heard of citizen science?
    a. [If so] Where had you heard of citizen science?
    b. [If participated previously] What other projects or types of projects have you participated in before?
    c. [If so] What effect, if any, did your earlier experiences with science have on your interest in getting involved with citizen science?
    d. [If heard of but had not participated] Had you considered participating previously? Why or why not?
5. [If interviewee is the one who initiated citizen science programming at their library]: Why did you think citizen science would be a good programming choice to bring to your library? Was there anything (or things) in particular that influenced your decision to implement citizen science programs?
6. What other types of science programming, if any, did your library already offer?
    a. [If any were offered previously]: How were you involved in that programming, if at all?

Questions about Individual Librarian Participation

7. Have you yourself participated in any citizen science projects through your role with the library?
    a. [if so] How much or how often did you (or do you) participate in citizen science through the program?
    b. [if so] Is there anything in particular that encouraged you to participate or made it easy for you to participate?
    c. [if no] Is there anything in particular that made it difficult for you to participate? Any specific barriers or challenges?
    d. [if no] Is there anything that would have allowed you or encouraged you to participate more/more often?
8. [If participated] Can you tell me about your experience doing citizen science through the library?
    e. What effect, if any, did your earlier experiences with science have on your interest in getting involved with citizen science?

    f. Is there anything in particular that you feel you have gained or taken away from the experience, as a participant?
9. [If participated] Do you feel that your participation in citizen science through the library has supported you in developing scientific knowledge, skills, and understanding?
    g. Are there any particular elements of the experience that have supported this? SciStarter materials? Project materials? Etc.
    h. If not, why not?
10. [If participated] Do you feel that doing citizen science with the library has provided community or social support for you to engage with science? If so, can you name specific ways you have felt this support?

Questions about Library Programs and Patron Experiences

11. Can you describe the citizen science experience(s) your library provides for its patrons and how you have been involved with these?
    a. Do you provide any programming, activities, educational content etc. to supplement participation in a citizen science project? If so, describe.
    b. Have there been any specific challenges or barriers that you as a facilitator or your patrons as participants have encountered while doing citizen science?
12. Are there any ways that you have tried to better support your library patrons in developing scientific knowledge, skills, and understanding with citizen science?
    a. Have there been any particular resources from SciStarter or individual projects that have made this easier for you?
    b. Is there anything specific you can think of that SciStarter or individual citizen science projects could provide that would better allow you to support your patrons' science learning?
13. Do you believe that your library's programming provides community and/or social support for its patrons to be able to engage with science?
    a. Can you name anything in particular that you as a librarian or library do to provide this support?
    b. Is there anything specific that SciStarter has done to provide this support?
    c. Anything individual citizen science projects have done to provide this support?
    d. Can you think of anything else that might provide a better sense of social support or community for participants?
14. Are there any ways that your library encourages patrons to repeatedly participate in citizen science or otherwise engage with science?
    a. How often and in what way?
    b. Is there anything else you think the library could do to encourage more repeated engagement?
    c. Is there anything you think SciStarter or individual projects do or could do to support repeated engagement?
15. Has your library's citizen science program (and your participation in it, if applicable) changed the way you think about your relationship to science, or the relationship of the public to science?
    a. Relationships with doing science?
    b. Relationships with science in everyday life?

16. Is there anything else you would like to share about your or your patrons' experiences with citizen science, SciStarter, or anything else related to this research?

17. ***Can you help put me in touch with 1-2 patrons from a library you work with who have participated in citizen science programming?***

Appendix E

Chapter 4 Codebook.

Science Socialization Codes		
Theme *Subtheme*	**Definition**	**Sample Quote**
Access	"…[M]echanisms that create opportunities for [individuals] to have access to and interact with" the tools, processes, norms and body of knowledge that comprise science (Bixler et al., 2011, p. 41).	N/A
Variety of programs	Opportunities within libraries to offer a wide variety of programs to appeal to various audiences (and ages) or connect people to science in different ways (including offering options for both adults and youth).	*And so that was-, just introducing folks to the kits especially. And then having the programming that we did from the kits, really was eye opening to a lot of folks. A lot of people really got interested in that. They did it as family groups. We had Bug Bags that we put together where they could go out on the hiking trails, and they're looking for different types of bugs that they can identify. And then there's another ongoing experiment that they could, you know, submit their data to, and then cleaning up the trails as they were going along. So we had trash bags and we had those picker-up, trash picker upper things that were in those bags as well. And then we had like a bingo game. So they identified different types of bugs and filled the bingo card and brought it back then they got a book, a free book that talked about nature and, and the importance of nature in our lives and stuff. So it-, different ways to reach different audiences.*
Hands-on experiences (possible secondary theme of the above)	Ways that libraries provide hands-on experiences with science, and the value of those types of experiences	*I think it does, has changed the way that they think, because of programming. I think that most people learn by seeing and doing, not by reading and listening to someone lecture. I think they need to get their hands dirty, they need to be involved in it, they need to play a part in it. And I think, bringing in citizen science along with STEM programming, just making it all the same kind of program has opened people up to the fact that they can participate in science.*
Connecting with Diverse Audiences	Ways that the library opens up access to science for audiences who may not otherwise have or seek out those opportunities	*They have! And we use that. And that was actually wonderful. And our team looked at that, and we're, we're super happy about that. So what we do is, we actually have printed both the English and the Spanish, and we put it in our booklets. So it's been great for that.*

Chapter 4 Codebook (continued).

Access to Scientific Tools and Experts	Ways that libraries provide access to the tools needed to do citizen science (or science more broadly) as well as venues for interacting with professional scientists.	*The kits are great, because they have too-, more tools for people to actually do these things. Like some people might not have the binoculars or the clip-on camera that goes on, or the magnifiers that go on your camera for better macro pictures of insects. I think that was a cool draw for some of them too.* *And like I said it was really, really fun to see him [a local scientist] invite people who specialize in moths or Lepidoptera or whatever, working with kids who may not be from affluent families or have that opportunity, and to kinda walk over to their parent and say, I want to let* you *know that that man talking to your kid right now is the number one scientist, you know. So it was a great opportunity to bring the-... kids who are less fortunate, you know, who may not have these experiences, together with people who are the top people in their field, or scientists, while at the same time they're doing this study that may have never been done before.*
Access to Spaces to Engage with Science	Ways in which libraries offer access to physical spaces in which people can engage with science.	*I often say that libraries are not the place for books anymore. It's more like a community center. And I think that middleman that draws this and this together, to educate, and and I think that's a really fun thing. And I think that's what I really like doing and to see our summer reading program speaker-, be scientifically or professionally directed kinda gives those kids that opportunity to to be more inspired than just having [me] up there trying to teach them something that I know less about than, than somebody who really knows what they're doing.*
Existing library infrastructure that supports access	Non-physical infrastructure that libraries already have that can support science programming (for example, communications platforms and volunteers).	*Sure. What we'll do, we have, through our social media, we have a lot of social media networks with our library system. For us, we have a calendar, online calendar for all our branches... And if we have an event, we'll put it on [that site]. So that'll let them know. We also do social media posts throughout the week, and our site gets to do them every Friday. So, on- if we have an event coming up close to that, they might hear from it on Facebook, Instagram. What else do we have? And then our website, I guess, too. We also have mail- flyers that we mail to people. So if people aren't tech savvy, they might get a flyer in the mail that might have that program listed. So those are ways. Of course, if they come into the library too we usually have something on a bulletin board that would tell them about it.*

Chapter 4 Codebook (continued).

Resources	Financial, training, staff, and other types of resources that make it possible to provide opportunities for patrons to engage with science	*A lot of the materials come like right from SciStarter, or from some of the activities through SEALnet. If you're familiar with SEALnet or not, that's a-, if you Google it, it's it's right here, aha on my water bottle, Solar Eclipse Activities for Libraries. And it's a website specifically designed for libraries and librarians to help us you know, come up and have great vetted activities. And so I use them for adults too, because they work really well sometimes too.* —- *Because we had gotten a grant for these citizen science kits.*
Partnerships (highly related to above)	Ways in which partnerships promote access to science. Related to resources in that often these partnerships involve a sharing of resources.	*However, that being said, I want to share this with you is that one of our local environmental justice group…it's all women, they actually they started collecting doing their own citizen science project…because they are-, their community is is is having facing the problem with noise pollution, because they live next to the freeway, they're dealing with extreme heat, with no trees in their neighborhoods, and then also air pollution. So they're like, you know, they have a lot of kids with you know, health problems related to you know, the air quality. So they were trying to figure out how to get the City Council the city planners' attention so they can help them do to make the community better…And then they found out that our library actually have air beam sensors. So they're like, they reached out to us and said…they really would love to get these units to the hands of you know, people who come and participate in their meetings. So they can also help them collect data that's around where they live. And so I said, Well, we do have these sensors that you know each branch that have it they only have one sensor for loaning. But what we ended up doing is we create a special loaning kit that has SIX sensors in there with instructions in both Spanish and English. We translate our spent-, instructions, and then we loaned it to them. They're still using it, actually. We- I told them, yeah, they can keep it until they finished a project. So now, they had a very, they had a great successful story to tell for the first one that they did, they were, actually they got, able to get the city planner to replan the things in their area by adding more trees, putting colors, adding the the paint to* the *pavement, the the asphalt, and then they add the padding to the freeway. So you know, so based on that success stories, that now they're doing it for another community…*

Chapter 4 Codebook (continued).

Nature of Citizen Science (Easy Entry)	How citizen science promotes access to science by having a low barrier to entry (requiring no, minimal, or free/inexpensive tools).	*…the great thing about citizen science projects is not all of them are super equipment-intensive. And, and like some of them, you just need an app for.*
"Putting things out there"	Ways that libraries advertise programs or otherwise continue to incentivize or encourage people to take advantage of resources and programs on offer.	*So they invested a lot of money in these tools. But if you don't promote them, and that's what I'm going to tell this Brooklyn Library is you just can't have them there. You have to keep them out in front of people* just *like story times, you're consistent. You know, for the kids, they know, they can come at this or this time and get a story. You need to let people know that, hey, we've got these kits, let's do something together to train you. Or, you know, we still need they still need your help, you know, it just can't be put in a back room and left there because it will stagnate. So yeah, that's that for any kind of program. You know, at a library, you've got to keep it elevated and in front of people. So they're aware it's there, because you always have new people coming in as well. You gotta just let people.*
Barriers to Access	Barriers that reduce or hinder mechanisms for creating access to science.	N/A
Technological barriers	Ways in which lack of access to technology impedes interactions with science	*No and you know, the reason why is because, and again, I-, I'm not going to say this is the case everywhere, but in my experience, rural and small libraries, the community members, they do not, they're not receptive to virtual webinars, and- they're just not, and if you if you brought them* all *to the library and and had something set up, you might get some attendance. If you send them a link and have them look it up at home, you're not going to get anything, especially those who live further out and don't have reliable broadband that can't always log in. And so, you know, in a big urban community, internet's not an issue. I can't even tell you how many times we lost internet when we were up in [town] because of one issue or another, and folks who don't have access at all, you know, so virtual type programming, webinars, um podcasts, they don't go over very well in rural and small, at least in my experience.*

Chapter 4 Codebook (continued).

General Citizen Science Barriers	Barriers that would be challenges for any citizen science experience, not just those facilitated by libraries - for example, issues of field safety, training and protocol challenges, competing priorities, seasonality, etc.	*Honestly, I don't like going out in my backyard, I'm up against a forest. And I know [unintelligible] a coyote or a deer and it'll scare the wits out of me. So, you know, it-, those are the kind of goofy things that maybe stop me from doing something, you know, making sure all the lights in our house are turned out. So I can get a, you know, accurate reading.* —- *The people that tend to show up for those programs are retired, you know, a lot of retired people, and then people in their twenties, you know, before they have families, before they have a lot of other commitments.*
Difficulty Keeping Kits Furnished/Kits Getting Stolen	Challenges encountered by librarians related to citizen science kits being stolen, materials getting lost or broken, or the cost of creating new kits	*And we've had pretty good luck with people, you know, returning things in, in good shape, and we get everything back. We do have to be a little bit careful about where we put the kits in the library proper, because we are a city library, and there's a homelessness crisis right now, and, and people will steal them. So, so we've had to kinda shift, you know, how we, you know, deal with them.*
Age barriers (perceived or actual)	Ways in which age may pose a barrier to participation, including a lack of programming for certain age groups, or assumptions that citizen science programming is mostly for kids.	*And the one experience that sets out more than any of them is at this pollinator party, we had an older lady who was extremely interested in the ZomBee Hunter kit. And she was asking me all kinds of questions about it. She was, if I remember, right, she was 83/84* years *old, something like that, and just enjoyed the whole event. And told me she was going to come in and check out that kit. And so I said, great, you know, I'm happy to see when you come in. And she did! The very next day she came in to get that kit and one of my staff members came back to my office and said, "[interviewee's name], there's this older lady here and she's insisting that she wants the kit that talks about zombies. And I think she's so confused, I don't think that's what she wants." And they were-, they were just totally, what's the word, stereotyping her because she was older that there because she couldn't possibly be interested in that kit. And I went out there and it was her and I knew it was her it was exactly what she was interested in. So it's eye-opening to my staff that it doesn't matter what age you are, you can be, you know, very interested in what's happening in nature around you and how it impacts you. And the lack of pollinators has a huge impact. And so it was very interesting to me how they just assume because of her age that that wasn't what she wanted, when that really was what she wanted.*

Chapter 4 Codebook (continued).

Staffing and turnover	Ways in which limited staff/staff time or staff turnover reduce a library's ability to offer citizen science programming.	*…Really, I'm the only one doing this. And, you know, I'm looking at retirement. So, you know, I, I'm hoping that somebody on staff will become as excited about this as I am. Or at least somebody in the community will. And I know I have a lot of excited people that show up. But that might want to take even that leadership role on as a volunteer.*
Lack of familiarity with Citizen Science	This subtheme generally relates to any ways in which the public may resist or shy away from participating in citizen science due to a lack of familiarity with the term, a lack of comfort with science, or concerns about sharing data with a project.	*One thing that we learned is not everyone loves science. Sometimes when you throw things out, like say, hey, come and help, you know, real scientists gather real data and stuff and they're like, "Well, how do I know my data is real? How do I know my data is correct?" So you kind of scare them away. So like I said, one way we really always try to do is we try to emphasize on the fun of the program. So for example, when we do the BioBlitz challenge, we don't tell them. I mean, you know, on the official media release, we said, we're doing this word "research," blah, blah, because going to the general public, but when we do the promotion in branches, or when we teaching the librarians* say *what are some of the buzzwords that you can use, as I said, Hey, you know, we want them to, you know, like, refine their photographing skills. So we're like, "Come in and join us, if you are-, you love selfies" or something like that, you know, kind of pivot towards that direction, pick the fun part of, of the citizen science project that people were doing, you know, the, the key fun part that people enjoy the most, and then really elaborate on that part and put the spotlight right on that one. And if people who are interested, you know, once they get in, they will be asking, like, "so why are we doing this?" Then you can say, We're doing this because scientists wants to these, you know, you can, they can use these use these data for research and stuff. And they're like, "Oh, that's great."*
Lack of interest or awareness	Librarians have difficulty generating interest about or awareness of citizen science at the library	*The way I see it is... people don't see library don't connect library with science, no matter. Even though we've been doing STEM program back in 2013…*[some content omitted]. *I'm telling you when I go out people are just like "What? Libraries have science program?" I still get this from people here in local [city]. And I still get* when *I go out and present at conferences, I still have people looking at me like "What are you doing here? You're a librarian. This is a science conference." You know, people give me all that look. And I'm like, "well, that's why I'm here to try to tell you we are we are promoting science."*

Chapter 4 Codebook (continued).

Getting people to actually do a project with the kits	Some librarians observed that - although they have no way to officially track participation - they suspect that most people who check out the kits are more interested in borrowing the supplies like binoculars than participating in the project.	*Some of our librarians, like couple of them are really into citizen science, then they would actually very purposely walk them through the, the app itself, and then take the time, you know, when they do the program in the library, take them take the time to, you know, go out with them to have that really hands on engagement. Now, when you do just, you know, have the DIY kits, people just go and do it on their own. It is, it is true that I would say most of them probably just try things out. They don't necessarily really download the app, and there's no way we can gauge it, unfortunately. So we can-, only thing is we can see how often* they *get checked out. But whether they actually contribute data to data to any of these, we don't know. And people, you've probably heard this many, many times, people are so adamant about downloading another app, or registering with their email, because people are so-, so concerned about your privacy.*
Librarian comfort with facilitating/ teaching about citizen science	Lack of comfort or confidence among librarians in leading citizen science or STEM programming more broadly	*I just think we've run across some staff that were kind of interested in it, sounded fun, but when they heard the commitment to it, and maybe didn't have-, they were even afraid of science, because they didn't have the background. They shied away from it.*
Terminology barriers and appealing to diverse audiences	Ways that the terminology of "citizen science" may itself be a barrier to participation.	*Well, originally, I did have a hard time getting people on board with anything called Citizen Science. And when I started using that term here, it actually-, attendance went down. Registration wasn't as robust as,* as*, as opposed to calling it you know, an environmental science type of thing, or an Environmental Day or Science Day or you know, Earth Day type of programming. And that's where I had to lean a little bit back on to SciStarter and said, "Hey, I know we're really concentrating on this term and I-, the focus was citizen science, but I need you guys to help me break this down even better for my community.*
Accumulation of Experiences	The impact of repeated, "frequent and long-term participation in…activities [that] reinforc[e], rene[w], and expan[d] interests" in science (Bixler et al., 2011, pg. 53; Levine et al., 2021).	N/A

Chapter 4 Codebook (continued).

Scaffolding	Program design elements that are intended to help participants continue to explore the subject on their own	*Once the project kits came out, and I physically had instruments and directions to support a project, those programs were segues to* introduce *the kits. So you know, I always said to people, "and now time for a word from our..." you know, an, an, or-, I'd say, "now it's time for a commercial break." And I, you know, introduce the kit availability.*
Paired Reading	Programming that is built to supplement reading programs or reading suggestions that are offered as additional information following a program.	*And and I saw that the one that was brought up yesterday on light pollution. They're supposed to be doing a Constellation program for our summer reading program and I was gonna kind of approach them and see if they knew about this study on light pollution and if we could* include *that with with their constellation night, so and there probably is an importance of light pollution, you know. But it would be kind of nice to know, in our rural area, how much that affects it also.*
Series and recurring programming	Programming that facilitates repeated participation by being featured as a series or by occurring at a recurring common time	*Uh the series-es that we do. Those– those– those tend– people tend to like that. They're like, "Oh, I'm gonna participate in this series," you know. And, and "I'm gonna go to the book discussion, and I'm gonna do the film, and I'm gonna," you know that, you know the people that we see at those, at those programs are, are repeats. Like, I see people over and over again.*
Lifelong Interests	Repeated engagement with certain types of experiences out of personal interest and/or enjoyment.	*Sure, I have no formal science background. So, but I have a very strong interest in the environment. So I've been involved in things like starting a recycling program. In a town I lived in Connecticut years ago,* while *I was in [city], I was part of land conservation group that was working to protect the [omitted for de-identification] mountain preserves, I served in leadership roles there as a treasurer and President. I've in within that group and the help of others, we tried to stop a freeway from cutting through part of one of the mountain preserves. So you know, I just have a very strong interest in trying to protect our environment. I got involved in yet another environmental group up here, we're trying to keep our rural areas rural and stop developmental housing sprawl, from changing, you know, habitats destroying habitat. So yeah, that that kind of sums it all up is, I understand why it's important to gather data for science and, and help make good data points for possible change within the scientific community.*

Chapter 4 Codebook (continued).

Accumulated Experiences with Citizen Science	(For librarians specifically) - Accumulated experiences with citizen science through role with library	*The very first project, I can remember, knowing that it was citizen science, was the Great Backyard Bird Count through Cornell. And I forgot how I heard about it. But I was working at the Conservation Department. And, you know, probably online, somehow I heard about the Great Backyard Bird Count. And I thought, "well, that sounds fun." And, and now that I think about it, I can't remember if I did it... before? No, I think it was after I worked there. Well, I thought that would be something fun to do with the citizens in where I worked. So first, I just did it with my volunteers. And we had a little volunteer crew. And I said, "Hey, you guys want to join me? We'll just do this from the office." And then I also-, that's right. And then I also did it at home. So like since it was a whole weekend, I would do* one *count at the office for work. And then I did one count for my* house*. And after I left the Conservation Department, I kept doing it at home just with my-, I have two daughters. So I liked it so much that I just kept doing it on my own.*
Prior exposure/ proximity to science	Ways that an individual has developed comfort with science by proximity, such as having a family member in a science field	*"That's, you know, I, my family has technical and I have, you know, somewhat of a little teeny bit of a technical background. And I don't-, I think if you don't have those kind of experiences, you're going to be less likely to embrace something like this."*
Barriers to Accumulated Experiences.	Things that prevent or deter repeated experiences with science in libraries. Include lack of consistency and non-captive audiences	*Well, yeah and also because, I mean, I'm glad to be in a public library, but I don't have a captive audience, and so I can't guarantee that the kid who came on Tuesday will come next Tuesday, you know? And we have done registrations pre-COVID, but even then, people were starting to not register. So you know, the culture is just that people don't-, either they register and they don't come, or they come and they haven't registered, so we just don't do registration anymore.* *It's been a while since we've had-, I just thought about this. We haven't had a* citizen *science project since-, might have been last spring, we had some other things going. And I thought I should have more–it'd be kind of fun if we could have more to keep it going. Kept-, keep the interest going in the community.*

Chapter 4 Codebook (continued).

Competency Development	The development of scientific knowledge, skills, and understanding which support both conceptual and intellectual competence (Bixler et al., 2011; Carlone and Johnson, 2007).	N/A
Engaging with scientific practices	Using scientific instruments and engaging in scientific inquiry, even if the activity doesn't directly contribute to new research.	*It's but they're going out. And people are using, you know, the– the binoculars and the bird, you know, has a identification book, or, you know, for the butterflies it's got a butterfly, you know identification book* with *you know, with a magnifier. You know there's all these different things that you know we do it for bats and bee– you know lady beetles and– and pollinators.*
Curiosity and knowledge acquisition	Participants (including librarians) express excitement about and/or interest in science and a desire to learn more.	*We were talking about the importance of pollinators. And we talked about the ZomBee Hunter kit where we got this fly that's killing pollinators and whatnot. And, and people had no idea and I was* shocked *at this, and maybe I shouldn't have been but that bees were not our only pollinators. And that's what everybody always thinks that bees are the pollinators. And they are, but there are so many other pollinators out there as well. And we were able to share that and educate folks on that that hummingbirds were pollinators and butterflies were pollinators and moths were pollinators. And they really got excited about that.*
Science/Data Literacy	Librarians reflect on the importance of science and/or data literacy and how citizen science participation can contribute to that. Generally expressed as a motivation for offering citizen science programs at their libraries.	*To me, science literacy is very important to, you know, the democracy of our communities, you know, being knowledgeable, being educated, whether they realized it or not, you know, they were learning about different issues and* could *actively participate, which is a great thing about citizen science.*
Training	Participants and librarians engage in training to learn about citizen science in general and to learn and practice the protocols and tools associated with individual projects.	*Like with the Alzheimer's, we did do a practice session, it was also to kind of test up the setup, we had, you know, could we have all these computers? Actively able to, you know, get those little video clips from the stock cut-, catchers site at the same time, you know, was our equipment and internet available to handle that? So, you know, we tested and we trained people at the same time.*

Chapter 4 Codebook (continued).

Relevance and Real-World Applications of Science	Ways that the real-world applications of citizen science help participants to related to and understand scientific content or ideas.	*Now, why do we want to do citizen science or a neighborhood science program in the library? In 2018, that was the year we already have five years of STEM programs going on in our library system. And we were sort of feeling like, it's not really connecting with participants. Some, you know, meaning that kids come in, I mean, kids or adults, whoever, when they walk in these participants, they have fun doing the hands-on activities, but we have no way of gauging whether or not they are seeing the connection between this and what's happening in real life. Are they able to take what they learn in terms of these STEM concepts, and they are able to apply to their everyday life? We can't see it. Now, so at that moment, we were thinking, well, we need to pivot this somehow to make that connection with real life, you know, something that's relevant to people in [city]? So actually, it was my division director read about citizen science. And she said, why don't we try citizen science?*
Social Support	Ways in which an individual's social system (comprised of peers, parents, teachers, etc.) provide external recognition of one's abilities in science, and/or support "further discoveries, opportunities and choices" related to engagement with science (Bixler et al., 2011, p. 44; Carlone and Johnson, 2007; Jahn and Myers, 2015; Levine et al., 2021).	N/A
Familial support	This includes families doing activities and learning together, parents/adults encouraging learning among kids, or IGL, where youth take what they have learned home to family	*Because I know especially with the kids, it's hands-on, if we're not doing something active, you're really not getting participation, having it stick with them, and they'll enjoy it. And then they want to take that home and* continue *on with it. So that's any of my youngster stuff, it's all hands on, and repetitive and to see that excitement with the kids wanting to take something home or build collaboratively to leave it here at the library to be show off and bring other aunts, uncles, whatever back to see what they've created.*

Chapter 4 Codebook (continued).

"We're going to do it together"	Learning with a group or community, or having direct facilitation from a librarian or a content expert (but not within-family together)	*Sure, yeah, I think we kind of had like a, we did like a two-hour session when they first came in, we took them downstairs, and we had a screen up. And we kind of just did what is citizen science kind of starting 'em out that way and showed 'em a few videos, actually, from one of them might have been from SciStarter, talked about some different sites and saying, "This is what we're going to do today, but here are some other sites that you could go to after today, and, you know, explore," you know, and then after a little bit of that, then talking about what we're going to do say like for the bird count, or something like that, we went over, we had a sheet for them, and some field guides out on the tables for them. Also, you know, showed them eBird and everything and Merlin, and, and showed them that they could use those to identify the birds too. Then we went upstairs in our library and first we kind of did it together out the windows. And I kind of walked around and saw how they were doing. We have had experiences where we didn't make them get on the app, some, well, I shouldn't say we didn't make them get on, I let them all get on, but- if they wanted to. But then I was also doing my own tally, like on paper. And, and so some people might have tallied, but we had a great group, I remember that last time that all of them were able to get on, get the app and and use it. And that was to me feeling good, because then it makes it more likely they're going to use it again, if they actually install the app, you know. And then we'll bird for a while. And then I also can tell them go out, you know, go out and about. And if we were doing a BioBlitz, I'd even say you don't have to come back. Because it's all on your phone. Go for it. If you want* to *come back for anything or ask anything, go ahead. But if not just keep entering all your stuff.*
Role models	Providing relatable role models who can encourage (youth especially) to participate in science	*But if we can get these kids interested and excited, having that person there, with their collection, shows them that they can do that* too. *And if [Scientist's Name] can be the top [species] expert in the nation and he grew up in [town] and graduated from the school that they graduated from. Again, that just shows them that you know, what they want to do, they can they can achieve, even though they grew up in tiny little [town name], you know, so so if we can bring those two together, I'll definitely do that.*

Chapter 4 Codebook (continued).

Spreading the word about citizen science	Using social networks to encourage others to participate in citizen science	*For us, I'm still trying to get more checkouts. That's the hard part. But for the checkouts we've had I do feel kind of going back to the-, I think the folks who check them out, they look at things differently the way-, you know, when they bring it back. Like that was pretty cool. And I you know, I hadn't thought of this before. So yes, I think I'm looking at them as as more of a maybe a partner in teaching others about science. So that's kind of kind of how I feel, then they can pass that information on too and say, "Hey, you should try this. We did this." So they become a partner with us in helping teach about science.*
Identity Formation	The emergence of a scientifically-oriented identity as an individual develops "a robust set of…competencies, preferences, and values" related to science (Bixler et al., 2011, p. 57).	N/A
"contributing to knowledge about the place that I live"	element of place-based identity connected with agency/ability to contribute to scientific knowledge related to that place	*And we did a program where a biologist came and talked about her project that was a, you know, citizen science project on pollinators in your backyard. And one of the things that I think was really galvanizing for people, and I think more people will per– probably participate in that particular science, citizen science project around pollinators is that you can have a real…You can see real, you know, changes in your own backyard. Like if you plant, you know, if you plant native, you know native species of plants, and you don't use Chemlawn on your lawn, you know– you do these various things that are fairly easy and fairly low cost. You can create a, an environment just in your backyard that is really healthy. And so you, you know, that will bring in more– more insects, that brings in more birds, you know it's– it's like, even just within your own backyard. You can ha–, you can see a tangible difference, and that is something that really resonated with people they're like, "Oh!" [laughter] "I have some agency with how things you know, you know, you know, how, how better things can be in my community.*
Community action/ sense of agency	Feeling that one is able to use science as a tool to drive change	*And, and so for us, you know, our traditional programming prior to all this has been mostly like some, you know, lectures or workshops where an expert is telling you, you know, what's– what's happening, you know, like, "Oh, you know, you know, there's this terrible thing happening, you know, like we're killing off the bats or or the bees,*

Chapter 4 Codebook (continued).

		or whatever it is." And, and the citizen science projects move that needle away from like the, I–, you know, that sort of sense of hopelessness like, "Oh, I can't really do anything about this, it's way bigger than what I'm able to do." It moves that needle to "Oh, actually, I can do this.
Identifying as the STEM or Citizen Science Person	(For librarians) How their role at the library has helped them to develop an identity as a STEM or citizen science person among their peers and/or community	*And it covers, you know, just about any program from storytimes to STEM/STEAM, which is usually my favorite. Even though my degree is in history. I have three children, which has really pushed me into the STEM/STEAM arena, and I've loved it ever since. And that's something I really enjoy. And I've taken the lead on that for all the departments within the library. So that's usually when anything like that creeps up, it's handed off to me.*
(Challenging) Non-Science Identities	Ways that citizen science can counteract someone thinking they are not a "science person." For example, ways that participants feel that they are able to be a scientist through participation in citizen science	*Well I think it opens up a whole new world for people who, who some of them who think that they're, they would never be smart enough to participate in a science program of any kind, you know, especially when you are introducing it as a STEM program. And we know, you know, science, technology, engineering, and math, people think, well, that's not for me, that's way over my head, and these types of programs and this type of project, brings it to the fact that that anybody can be a scientist. Anybody that's interested enough can be a scientist, and it's not all lab work. It's not all, you know, wearing this fancy lab coat and doing all of these experiments that are gonna save the world necessarily, it's learning about science and the impact it has on our everyday lives and, and how you can contribute to that.*
Emergent Codes		
Theme	**Definition**	**Sample Quote**
COVID-19: Opportunities	Ways in which the COVID-19 pandemic provided opportunities for the public to engage with science	*Oh, yeah. Oh, yeah. There was a lot of questioning, well, scientists don't know everything. And you're right. They don't, they don't know everything. And they're learning about this, as we're going along. And, you know, we would have people say all the time, why are things changing? Why did protocols change? Why are there-, changing so frequently? You know, don't they know what they're talking about? And it would be, you know, they're, they're learning, they're having to do experiments, they're having to do research to figure out what's going on with this virus? And what how do they take care of it? And how do we impact it? And how to, you know, how do we get better if someone gets sick, I mean, it's- science is ever changing all the time. And we're always learning about it. So it did bring science way to the forefront.*

Chapter 4 Codebook (continued).

COVID-19: Challenges	Ways in which the COVID-19 pandemic introduced challenges to the public engaging with science	*I want to say the pollinator party was after COVID. And it was. It* was *after COVID. During-, during that timeframe, when we were dealing with COVID, it was almost like the community I was in up in [town] went backwards. They you know, we were making some progress. We were talking about science and and we were talking about STEM and we were talking about you know how these things impact your everyday life and, and that and then COVID hit and I it almost like we went backwards a little bit because there were so many people that were denying that it was as bad as it was.*
Audience: Challenges to working with schools	Challenges that arise when working with formal school audiences	*But working with the schools is difficult, because they have their curriculum and– and we have to figure out a way* how *to, you know how to, you know, get those, you know, incorporated*
Audience: Opportunities for working with homeschool groups	Opportunities provided by working with homeschool groups, particularly on a recurring basis	*We tried to target all audiences. Um, the homeschool group, in* particular*, we kind of had their undivided attention because we were doing already a homeschool program for them regularly every month. And so they were who we first started this citizen science kits with they, when we first introduced citizen science, it was to the homeschool group.*
Knowledge of/Connections to Audience	Ways that librarians' unique knowledge of and/or connections to their audience allow them to tailor programming to their community's needs and interests	*But in this particular case, it was trying to be sensitive to the community that I was in, and the fact that they're very conservative and very much, you know, not necessarily want to say that there is climate change. So you got to figure out a way to do it without, you know, totally getting them upset at you or turning them away or something like that. So... And I think every librarian that knows their job knows their community and knows how to go about doing that.*