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## THE CONTEXTS OF LEARNING IN CITIZEN SCIENCE

Holly K. Rosser

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THE CONTEXTS OF LEARNING IN CITIZEN SCIENCE

By

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# The Contexts of Learning in Citizen Science

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The University of Nebraska at Omaha, 2023

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## **Abstract**

In citizen science, project leaders rely on volunteer contributors to collect, classify, and analyze data in both natural and digital environments. To be successful, volunteers are often provided with specialized training that supports the learning goals of the project. Yet, little is understood regarding the contextual influences of both the project *and* the volunteer that affect what those learning goals are and how they are supported. Additionally, the use of technology to deliver and support learning opportunities to volunteers is increasingly relied upon regardless of the project's physical setting. However, the degree to which the transition to digital supports for volunteer learning has been successfully leveraged by projects to meet their unique goals and the needs of their volunteers has not been thoroughly examined.

Unlike much of the research that is available, this exploratory study examined volunteer learning from a different perspective, that of the citizen science project leader, and investigated the influences at play that impact the project's volunteer learning goals and the project's ability to support those objectives. Through semi-structured interviews with project leadership and the analyses of digital and physical documents, this study revealed the need for a new framework to better understand how the personal, social,

organizational, and physical contexts of the project and their volunteers impact a citizen science project's approach to volunteer learning. This dissertation introduces the Contextual Model of Citizen Science Learning to meet this need.

**Keywords:** Citizen Science, Volunteer Learning, Informal STEM Learning, Contextual Model of Citizen Science Learning

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## 1 Introduction

There are any number of reasons why including the public in scientific research is a good idea. It allows for the collection, classification, and analysis of huge amounts of data on a budget (Celino et al., 2018), creates community awareness of social, environmental and conservation efforts (Graham et al., 2015), and provides the broader public with volunteer opportunities that support science learning (Roche et al., 2020). These opportunities to participate in citizen science are diverse and include activities such as collecting environmental specimens outdoors, identifying flora and fauna from camera trap images, and even discovering new stars and planetary formations from astronomical images online. By participating in such activities, volunteers can gain science literacy skills such as improved understanding of the nature of science as well as an increased comprehension of the scientific research they are a part of (Bonney et al., 2016; T. Phillips et al., 2018).

While these and other volunteer learning outcomes have been more or less well-defined in the literature, the dynamics that influence a project leader's understanding of volunteer learning or how projects can foster their own objectives for volunteer learning remain unclear (National Academies of Sciences, Engineering, and Medicine, 2018; Peterman et al., 2022). If the project leader does not have a clear understanding of how to incorporate mutually beneficial learning opportunities into the design of their project, the disconnect between the two may be detrimental to project outcomes, the volunteer experience, or both (Jennett et al., 2016; Kosmala et al., 2016). Bringing the project leaders' definitions of and mechanisms to support volunteer learning into better focus may

therefore help project leaders with creating and maintaining an engaging participation experience.

Notwithstanding a project team's ability to include supports for specific learning goals within their project, some learning naturally occurs from participating in citizen science (Mugar et al., 2015). Often considered a mainstay of citizen science, this learning starts with new scientific and technical skills necessary for the completion of a required task (Law et al., 2017; Schulze et al., 2011). As an example, participants who analyze and classify data presented to them in an online project such as Galaxy Zoo may learn new pattern recognition skills that can be transferred to other activities or projects (Jennett et al., 2016; Kloetzer et al., 2013). However, deeper understanding of scientific processes and outcomes can also occur as participants become more engaged and they seek learning opportunities beyond the available artifacts within the project (Kloetzer et al., 2013; Mugar et al., 2015; Nguyen, 2020). Opportunities at this more academic level of learning and engagement may include interacting with others in online forums and talk spaces, engaging in independent research (both on and off topic), or possibly even becoming a more contributing and collaborative member of the research team (Jennett et al., 2016; Mugar et al., 2015).

With any one of these outcomes, however, the personal and sociocultural characteristics of the volunteer have a direct influence over the type and depth of the learning that takes place through engaging in science-related projects and programs such as citizen science (J. H. Falk & Dierking, 2018; National Academies of Sciences, Engineering, and Medicine, 2018). Yet, it remains a bit of a mystery to what degree project managers can take advantage of what they know about their volunteers—who they are,

where they come from, or why they decided to participate in the project in the first place—despite evidence that being able to utilize such information can directly impact the design, management, and overall success of the project itself (J. Falk & Storksdieck, 2005; National Academies of Sciences, Engineering, and Medicine, 2018; Peterman et al., 2022).

Naturally, citizen science projects take advantage of the resources that are readily available to them and their volunteers and using technology to support a project's learning goals is not a new phenomenon; but the reliance on technology as a primary resource for volunteer learning has been a point of emphasis in recent years (Becker-Klein et al., 2016; Herodotou et al., 2018; Roche et al., 2020). More prominently, community lockdowns, social isolation, and other COVID-19 protocols forced many projects' hands in adopting online resources for volunteer training and development (Dwivedi, 2021; Van Haeften et al., 2021). Even when technology is not the primary platform to support learning in a citizen science project, its presence (or lack thereof) may have an effect on the volunteer experience, which in turn may adversely affect project success (Cappa et al., 2018; Skarlatidou et al., 2019).

## **1.1 Purpose of Study**

Although many projects can and do rely on intermittent and sporadic participation from volunteers where a high level of science literacy may not be necessary (Eveleigh et al., 2014), maintaining a skilled and knowledgeable volunteer population *is* vital to the success of many other citizen science projects (Law et al., 2017; Wiggins & Crowston, 2011a). As more projects incorporate technological tools and online platforms, keeping participants engaged in activities that support desired learning outcomes are likely to include access to online tutorials and training materials, discussion spaces and online

communities, as well as access to other resources for further engagement and learning experiences outside of the project (H. K. Rosser & Wiggins, 2019). Consequently, looking at how project managers are defining learning outcomes and providing access to learning opportunities that support those outcomes can bring new insight into the citizen science project design space.

Fundamentally, project design for citizen science can be a complicated endeavor, and incorporating the tools needed to guide participant learning toward intended outcomes can make the process daunting for project managers (Bonney et al., 2009; T. Phillips et al., 2018). Identifying the factors that affect learning outcomes is often complex, and designing citizen science projects that provide opportunities of intended science learning takes careful planning and evaluation (Bonney et al., 2016; Shirk et al., 2012; Stylinski et al., 2020). With its foundation in situated and experiential learning theories, the Contextual Model of Learning (introduced in further detail in Section 2.4) should be a useful framework for project managers to consider as they develop activities that support volunteer learning (J. H. Falk & Dierking, 2018; Liu & Falk, 2014). To that end, this dissertation work explored the following research questions:

- RQ1: How do a citizen science project's organizational, sociotechnical, and physical contexts impact their learning goals?*
- RQ2: How do a citizen science project's contexts impact the types of learning opportunities provided for volunteers?*
- RQ3: How do a citizen science project's learning opportunities align with volunteers' personal and sociocultural contexts?*

## 1.2 Characteristics of Learning – Definition of Key Terms

Learning can be defined as the product *and* process of acquiring “knowledge, understanding, or skill” through exposure to education, training, or experience (Merriam-Webster, n.d.). Being both a verb and a noun, *learning* is one of those words that is sometimes difficult to figure out its intended meaning in a sentence. To complicate matters more, *learning* can be used in the compound like an adjective to enhance the meaning of the primary object. The phrase *learning processes* is such an example where in isolation, *learning*, could be used to convey the meaning intended when *learning* and *processes* are combined. As a compound noun, *learning processes* become a more meaningful description of the specific characteristic that describes the activities of learning being referenced. In the case of citizen science, three primary characteristics of learning are prevalent that describe both the action and the result of skills training, development, and transfer: *learning goals*, *learning opportunities*, and *learning outcomes* (Jordan et al., 2011; National Academies of Sciences, Engineering, and Medicine, 2018; T. Phillips et al., 2014). Throughout this dissertation, these three terms are used to specifically identify the inter-connected, yet unique characteristics of learning related to a project’s ability to support meaningful volunteer contribution while maintaining the rigors of scientific research.

*Learning goals* are the knowledge and skills a project leader/team wants their volunteers to acquire as they participate in the activities of the project. They are the intended consequences of a project’s training efforts and educational supports and include content knowledge, data collection, monitoring, submission skills, and nature of science knowledge (T. Phillips et al., 2014; Roche et al., 2020). While recognizing that volunteers

also have personal goals for learning new things through citizen science participation, the focus of this dissertation work is on the learning goals established by project managers.

*Learning opportunities* are the materials, resources, and activities provided by a project to support a project's learning goals. They are the physical and digital supports created to foster volunteer learning. Examples of learning opportunities can include events like in-person training and related solo or group participation activities (in person or online), and artifacts like printed and online tutorials and instructional materials, resources, discussion spaces, etc. (Hein, 2009; National Academies of Sciences, Engineering, and Medicine, 2018).

*Learning outcomes* are what volunteers take away from their experience with a citizen science project. These outcomes can include the skills and knowledge intended as a project's learning goals, or they can be more personal to the volunteer and include interest, behavior and attitude changes toward science content, processes and policies (Kloetzer et al., 2013; T. Phillips et al., 2018). When learning outcomes do not align with project learning goals—which can happen when volunteers do not learn what project leaders meant for them to learn—they can still be useful for the project and provide incentive to redirect training efforts or influence revisions to the project's learning goals (J. H. Falk & Dierking, 2018; Robinson et al., 2018).

Figure 1.2 shows the relationship among learning goals, learning opportunities and learning outcomes. As demonstrated in that image, the ideal is for learning goals and opportunities to work together to create outcomes that are mutually beneficial to the project and the volunteer. Although learning outcomes are important for citizen science projects to understand—especially as they develop learning opportunities to support those results—



they are not a subject of this dissertation. This study is only examining learning goals and the approaches citizen science projects are taking to support them.



Figure 1.2: Learning goals plus the opportunities offered to support those goals can turn into learning outcomes that may or may not be intended by the citizen science project

### 1.3 Overview

Thus far, Chapter One has offered the rationale and purpose of this dissertation, including research questions and definitions for key terms. The remainder of this chapter will look ahead and provide a brief synopsis of the literature review, methods, as well as summaries of the significance, findings, and contributions of this work.

#### 1.3.1 Literature Review

The literature review focuses on four main areas of interest: citizen science, volunteers and participation, informal science learning, and the Contextual Model of Learning (CML). More specifically, this work looks at the characteristics of citizen science related to learning and how they are currently identified in the literature. This topic also includes a discussion of what the literature specifically says about project learning goals, volunteer skills training directed at those goals, and the tools used to achieve them. Next, the focus turns toward the volunteers themselves where the conversation is centralized around the ideas of identity, prior knowledge and experience, as well as motivation—all well-studied topics in citizen science that are synthesized here to give a sense of who the volunteers are (a key component of the CML). This section also provides insight regarding

how these factors can and do impact learning—often in profound ways. To round out the literature review, a more general discussion of informal science learning characteristics and outcomes is provided as a backdrop to a deeper review of the CML. The section on the CML discusses the framework’s theoretical influences, its overall premise and the key concepts that make the model unique and well-suited to apply in citizen science. The discussion of the CML moves from overview toward methods as the factors and characteristics that make up the personal, sociocultural, and physical contexts of the CML are identified and defined.

### ***1.3.2 Methods***

This study took an interpretive approach to make sense of how the contextual influences of the project and the volunteer affect learning (Elliott & Timulak, 2015). The research itself was completed in two parts: document analysis of project artifacts of both field-based and technology-based citizen science projects and semi-structured interviews with project leadership. The interviews included respondents from 22 citizen science projects, programs, and agencies (projects). The protocol investigated how and to what extent projects use what they know about their volunteers when identifying learning goals and also explored how these projects foster these learning goals with the resources available to them. Following manual content extraction, document analysis of the digital and physical artifacts was completed in three phases in order to sort, identify, and analyze data retrieved for each of the projects that participated in the interviews (Bowen, 2009; J. T. Morgan, 2013). Iterative qualitative content analysis of the interview transcripts and project artifacts was completed to examine the contextual influences of the project and volunteer on learning.

### *1.3.3 Significance*

Some of the volunteer learning that happens in a project is intentional, some not so much. Nevertheless, learning is fundamental to scientific endeavors; and having a clearer understanding of the different ways learning can be supported in a citizen science project can not only improve the volunteer learning that is taking place, but it can also improve the science that results from it as well (Kelling et al., 2015). We have seen the significance of this idea before—a multitude of resources are widely available that describe the learning volunteers experience by being a part of a citizen science project (Becker-Klein et al., 2016; T. Phillips et al., 2018). However, that research focuses on learning from the volunteers' perspective, i.e., what citizen science researchers say volunteers learn or what volunteers themselves say they learn (Kloetzer et al., 2013; Mugar et al., 2015; National Academies of Sciences, Engineering, and Medicine, 2018). The research in this dissertation takes a different approach and explores volunteer learning from the project leaders' point of view to develop a more holistic and complementary understanding of how volunteer learning might influence project design. With this change of perspective, results from this research should appeal to the very subjects of this study, those project managers who are interested in better understanding the myriad of influences that impact volunteer learning in both positive and negative ways.

To move the study of learning (and its potential impact on citizen science projects) to the next level, it is important to look at the factors at play when learning is inherently informal, and participation is freely chosen. In this regard, it may prove beneficial for projects to understand the personal, sociocultural, and physical factors that influence volunteer learning and the tools needed to support it (J. Falk & Storksdieck, 2005; Hein,

2009). The Contextual Model of Learning (CML) can provide a framework that guides this investigation into the specific characteristics of volunteer learning—likely of interest to the project leader and the citizen science researcher alike.

Inspired in large part by Lave & Wenger’s theory of situated learning, the CML argues that what and how much a person learns in any one environment is largely dependent upon a myriad of interrelated factors unique to the person, place, and time in which the learning is taking place (J. H. Falk & Dierking, 2018; Hong & Song, 2013). These factors, though undoubtedly significant in traditional education settings, come into even greater play when the opportunity to learn is freely chosen, such as when visiting museums, zoos, and science centers—or when volunteering in citizen science (Bamberger & Tal, 2007; J. Falk & Storksdieck, 2005). Understanding how a project can leverage the motivations, experiences, and beliefs that influence informal learning has been invaluable to designers and managers of exhibits and programs that support learning in other like-minded institutions (J. H. Falk & Dierking, 2018; J. Falk & Storksdieck, 2005; Hein, 2009). It was hoped that moving the CML beyond the museum and into citizen science would prove equally worthwhile. As such, this research examined the novel application of this framework to the research of citizen science and explored how adaptations and extensions of the CML (particularly related to how technology is harnessed to support learning) could benefit the practice of citizen science.

#### ***1.3.4 Findings***

Findings from this research found that in many respects the CML could be applied to learning in citizen science. Many of the same contexts and characteristics identified in the model were likewise identified in the data in this study. More specifically, the project’s

physical context and the personal and sociocultural contexts of the volunteer were shown to be influences on a project's learning goals and the opportunities provided to support them. However, findings from this study also showed that additional characteristics of the project and the sociotechnical mediation of volunteer learning were highly influential in how projects approached learning, both of which were findings outside of the CML. Additionally, many of the definitions provided by the CML did not quite match their application in citizen science. Thus, it was decided to use the CML as inspiration and develop a new framework, the Contextual Model of Citizen Science Learning, to explain the contextual influences of volunteer learning found in this study.

### ***1.3.5 Contributions***

This dissertation work makes contributions to both citizen science theory and its practice. Looking first at theoretical contributions, this work introduces a novel framework, namely the Contextual Model of Citizen Science Learning (CMCSL), to the study of citizen science. It introduces the idea of contextual influences to the study of volunteer learning that is capable of demonstrating the intertwined relationship of projects and their volunteers. Basically, the CMCSL describes the *who*, *what*, *where*, and *why* of learning that makes a difference in *how well* a volunteer meets a project's learning goals. When applied to volunteer learning goals, the CMCSL can provide project managers with an idea of which personal and social characteristics of the volunteer as well as the organizational and physical contexts of the project they need to take into consideration as they develop and manage their project learning goals. Additionally, this framework can be used to study the practice of citizen science (as is the case with this dissertation) by offering researchers with a framework to identify the characteristics of free-choice learning that appear to be as

important to citizen science as they are to the museum. While each contribution has strong potential to positively impact volunteer skills development and the learning outcomes that move beyond the volunteer's participation in citizen science, when combined, the contributions of this dissertation work may actually improve the quality of a project's contribution to science—and that's pretty cool.

## 2 Literature Review

### 2.1 Citizen Science

#### 2.1.1 *Definition of Citizen Science*

Citizen science is the practice of connecting the public with research across a wide variety of scientific disciplines (Celino et al., 2018; Haklay et al., 2021) allowing for varying levels of engagement (Heigl et al., 2019; Wiggins & Crowston, 2011a). Its mission is the co-creation of new knowledge spanning the natural, life, and social sciences through mutually beneficial research-related activities (Haklay et al., 2021; National Academies of Sciences, Engineering, and Medicine, 2018). The strength and uniqueness of citizen science is that it provides opportunities for the public to participate in and engage with the processes and data underpinning scientific endeavor (National Academies of Sciences, Engineering, and Medicine, 2018; Wiggins & Crowston, 2014). Further, citizen science provides researchers with the opportunity to effectively and affordably collect, classify, and analyze large amounts of data. It also offers them occasions to improve communications through community outreach and knowledge sharing to a broader, more generalized audience (Bonney et al., 2009; Celino et al., 2018).

Much of the public's participation in citizen science is field-based and focused on data collection where individuals are physically measuring, assessing, and engaging with scientific phenomena in the natural world (Haklay et al., 2021). In fact, involving volunteers in conservation and ecological research is a core practice of those disciplines that has been attributed to the success of such projects for decades (Catlin-Groves, 2012; McKinley et al., 2017). Despite citizen science being historically grounded in the physical

world however, within the last 15 years or so there has been an increased interest in crowdsourcing elements of scientific research using online resources (Lee et al., 2016; Wiggins & Crowston, 2014). In addition to streamlining administrative functions and data entry (Becker-Klein et al., 2016; Wiggins & Crowston, 2011a), the move to the cloud is advantageous for scientific research where online platforms provide support for processing and analyzing large amounts of data quickly and with project-wide accuracy is important (Prestopnik & Crowston, 2012; Trouille et al., 2019).

Additionally, including online social networking components like social media presence, chat rooms and discussion boards for all formats of citizen science projects keep volunteers informed and engaged in varying aspects of the project that may fall outside of the project's primary focus (Mugar et al., 2015; Reeves et al., 2017). To that end, web-based platforms such as Zooniverse, SciStarter, and CitSci.org have crafted an interesting hybrid of online community and distributed crowdsourcing platforms that are dedicated to the advancement of citizen science regardless of primary practice and participation of the project (Smith et al., 2013). These technologically-mediated characteristics of citizen science therefore provide projects with sociotechnical systems “that best take advantage of the efficiencies of the machine while acknowledging the complexity of human motivation and engagement” (Trouille et al., 2019, p. 1902).

### ***2.1.2 Characteristics Related to Learning***

Although citizen science may not necessarily be a well-bounded space with projects spanning any number of disciplines, venues, and contexts; extant literature shows that certain characteristics that support volunteer learning tend to be consistent from project to project (National Academies of Sciences, Engineering, and Medicine, 2018; Shirk et al.,



2012). One such characteristic is that citizen science can serve as a venue for volunteer participants to learn about science in context—meaning that all projects provide opportunities to learn about the phenomenon of project interest as well as learn how to engage in the various scientific research practices surrounding that phenomenon (Bonney et al., 2009; T. Phillips et al., 2018). Additionally, many of the activities that volunteers undertake as a member of a citizen science project involve data in some form or another, creating opportunities for volunteers to learn appropriate data collection, recording, and analysis skills (Herodotou et al., 2018; Shuttleworth, 2017). Finally, these experiences often take place within the context of any one of our lived-in or virtual worlds making the learning that takes place more relevant, meaningful, and long-lasting to the volunteer (J. H. Falk & Dierking, 2018).

Another characteristic of citizen science that supports learning relates to *how*, *where*, and *with whom* a volunteer participates, i.e., the infrastructure of the project itself (J. Falk & Storksdieck, 2005; Newman et al., 2012). Breaking this infrastructure down a little further, the technical and social structures of the project are key foundations for projects to build learning opportunities upon (National Academies of Sciences, Engineering, and Medicine, 2018). Looking first at technology, there has been a tremendous push in recent years to move project coordination and communications onto social media accounts and educational resources, training materials, record keeping, and the like onto project websites (Newman et al., 2012; Wiggins & Crowston, 2014). However, technologies are more than just computers and mobile phones. They also include the specialized tools and equipment needed to complete the project's research goals such as telescopes, microscopes, scanners, or any other piece of equipment a volunteer learns to

use in order to perform the tasks asked of them (Brenton et al., 2018; National Academies of Sciences, Engineering, and Medicine, 2018). Therefore, volunteers are provided with opportunities to learn about and build new skills related to science through the exposure of these various forms of technology (Hein, 2009; Kloetzer et al., 2013).

Additionally, providing access to sociotechnical supports such as online forums, chat rooms, discussion boards, and listservs not only enhance coordination and communication for the project itself, these supports also enable opportunities for volunteers to learn from project moderators and practitioners as well as from each other (Mugar et al., 2015; Wiggins & Crowston, 2014). Consequently, the social foundation of the project not only includes the project specialists (i.e., organizers, facilitators, and managers) that are available to assist volunteer participants, but it also includes the volunteers themselves as they engage with one another online or in the field (Causer & Wallace, 2012; Jackson et al., 2020; Oesterlund et al., 2014).

The social structure of a citizen science project may look different depending upon the environment from which it is experienced however (Wiggins & Crowston, 2011a). In some cases, (i.e., in-person outreach and training events for field-based projects) observation of and training from project leaders and more experienced volunteers can provide newer members with direct access to learning opportunities from others around them (Newman et al., 2010; Wiggins & Crowston, 2011a). In other cases, as evidenced in many online citizen science projects, this level of synchronous social interaction for learning is either not possible due to differences in locale, lack of personnel and resources, or eliminated entirely through deliberate design (Mugar et al., 2015). Still other projects offer asynchronous means of communication to engage volunteers and provide supports

for learning in more social ways (Jackson et al., 2020; Oesterlund et al., 2014). Regardless, socially-mediated learning is an inherent part of citizen science (Robinson et al., 2018).

### ***2.1.3 Common Learning Goals and Outcomes***

Through volunteer participation in authentic scientific research, opportunities for learning can include outcomes related to increasing knowledge and understanding of scientific concepts and phenomena; improving scientific interest and engagement; as well as developing the skills needed to actively participate in scientific activities (Hein, 2009; Shirk et al., 2012). To evaluate the success citizen science has had in achieving some of these goals, a number of tools and assessments have been developed for project managers and evaluators to use in measuring the learning outcomes achieved by their participants (Becker-Klein et al., 2016; Nelson et al., 2019; T. Phillips et al., 2018). However, outside of a few well-known projects (i.e., Planet Hunters, Galaxy Zoo, EyeWire, and FoldIt), evaluation of volunteer learning outcomes for online citizen science projects is generally limited (Bonney et al., 2016; Jackson et al., 2020; Mugar et al., 2015). Moreover, the learnings goals of these projects are often nebulous and ill-defined (Parrish et al., 2018; T. Phillips et al., 2018). This can be especially true for projects that follow an “open-call” approach where long-term engagement is not expected (Masters et al., 2016; Parrish et al., 2018), 2018).

While providing learning opportunities for volunteers is a key objective for many citizen science projects, volunteers often consider learning as a strong motivator to participate in a project as well (T. Phillips et al., 2018; T. B. Phillips et al., 2019; Stylinski et al., 2020). Moreover, volunteer motivation is one of the primary characteristics identified within the personal context of the CML (J. H. Falk & Dierking, 2018). However, examining

the learning goals volunteers may have for themselves is outside the scope of this dissertation; the focus of this work is on how project-specified learning goals are defined and supported.

## **2.2 Informal Science Learning**

Informal science learning can occur pretty much anywhere outside the classroom—from simple everyday experiences to clearly defined settings and well-organized programs (Bell et al., 2016; Hein, 2009). This learning is largely by choice and occurs naturally over time and across contexts (J. H. Falk & Storksdieck, 2005; Kisiel & Anderson, 2010). It is the learning that takes place through the participation of citizen science. While some aspects of informal science learning are more objective like knowledge about science, skills in using scientific tools and working with data, other components are much more personal and subjective making informal science learning difficult to define and even more difficult to measure (Hein, 2009; Sacco et al., 2014).

In citizen science, evidence of informal science learning may include volunteers acquiring knowledge of project-specific skills and processes that are then reported by the project as key learning outcomes of participation (Allen & Peterman, 2019; Jordan et al., 2011; T. Phillips et al., 2014). As with other activities of informal science learning, a few outcomes noted in the citizen science literature are less concrete and have been described as measurable improvements in participation and engagement as well as increased outlook and interest in science (National Academies of Sciences, Engineering, and Medicine, 2018; T. Phillips et al., 2018). More recently, outcomes of informal science learning have been developed into a framework that can serve as a guide for developing and evaluating learning and performance measures within citizen science projects (T. Phillips et al., 2018).

These outcomes include skills of science inquiry, behavior and stewardship, interest, self-efficacy, motivation, content, process, and nature of science knowledge. Although this framework was thoroughly considered and has inspired this dissertation work in many ways, the fit was not quite right for the context of this research, due to its focus on volunteer performance and not the reasons behind those outcomes.

### **2.3 Volunteers**

In the past, uncovering the population make up of volunteer participation has been somewhat tenuous for researchers (Alender, 2016; National Academies of Sciences, Engineering, and Medicine, 2018). However, recent literature on citizen science practices have begun reporting this demographic data of volunteer participants for both online and field-based projects (Curtis, 2015; Pateman et al., 2021). From these records, project volunteers tend to be older white males with college degrees (Pateman et al., 2021; Spiers et al., 2019). Although highly educated older white women have increased their level of participation in recent years, the lack of diversity among volunteers is a noted point of concern and has become a call to action by US science agencies (National Academies of Sciences, Engineering, and Medicine, 2018; Pateman et al., 2021).

When asked to describe their background as it relates to the project, volunteers have self-reported being ‘backyard experts’, concerned community members, or even scientists trained in other fields. Moreover, given the above characteristics, these volunteers bring years of prior knowledge and experiences with them to the project (Jennett et al., 2016; Liu & Falk, 2014). Not only does this background influence what the volunteer brings to the project, it undoubtedly guides what the volunteer gets out of the project as well (Alender,

2016; J. Falk & Storksdieck, 2005). It does not, however, necessarily explain what brought the volunteer to the project nor why they stay involved (West & Pateman, 2016).

Motivation to participate in citizen science can be for a whole host of reasons. The volunteer could be interested in the research topic or field of study; or they could enjoy contributing to science or completing the research task (Jennett et al., 2016; Kloetzer et al., 2013). They could be motivated by the social engagement and sense of community they feel when they participate (Oesterlund et al., 2014; Reed et al., 2013); or by the possibility of a serendipitous discovery and the accolades that follow (Jennett et al., 2016; Trouille et al., 2019). What may prove to be more substantive to this dissertation work, is that they could be motivated by the thrill of investigating a curiosity or the intellectual challenge of learning new information (Curtis, 2015). In any of these cases, however, the motivation that brings the volunteer to the project will also influence what a person learns and how well they learn it (J. H. Falk & Storksdieck, 2005; Heigl et al., 2019).

## **2.4 The Contextual Model of Learning**

The Contextual Model of Learning (CML) describes learning as a product of the unique interactions between an individual's personal, sociocultural, and physical worlds across time (J. H. Falk & Dierking, 2018). Consequently, learning changes and is different as the conditions under which it occurs change or are different (J. H. Falk & Storksdieck, 2005). Additionally, we *mostly* learn about things we almost already know; and it often follows one of two parallel pathways—the learning of high-level ideas or the learning of very specific, usually idiosyncratic facts and concepts (Sacco et al., 2014). Whichever direction it takes, however, the processes of learning are almost always personally motivated and intended to make meaning out of the ever-changing contexts of our lived-in

worlds (J. H. Falk, 2011). Learning is situated, synergistic, and (for the most part) freely chosen.

With the understanding that the study of learning is complicated, the CML was created to conceptualize some of the key factors routinely in play that influence learning when people visit the broadly defined museum (J. H. Falk & Dierking, 2018). Obvious examples of Falk's museum include art, history, natural history, and science museums. However, the definition moves wider still to include zoos and aquariums, botanical gardens, conservatories, and arboretums, making it an appealing consideration for studying learning in citizen science (J. H. Falk & Storksdieck, 2010). Moreover, the CML recognizes that learning is a fundamental goal of these institutions that should be broadened to include concepts also appreciated by citizen science, i.e., changes in attitudes and behaviors about science and science learning (Liu & Falk, 2014; T. Phillips et al., 2014). Thus, the type of learning that takes place in these environments is more holistic and personally driven than learning that takes place in more traditional settings (J. H. Falk et al., 2007).

#### ***2.4.1 Contextual Factors That Influence Learning***

The factors that make up the personal, sociocultural, and physical contexts are never static, stable, or constant—they are always changing and influencing how and to what degree something is learned (J. H. Falk, 2002). Accordingly, the learning can be viewed as an endless cycle of interaction of factors within these contexts across time that coalesce and integrate into meaningful experiences (Bamberger & Tal, 2007; J. Falk & Storksdieck, 2005). Thus, to be useful in understanding the intricate play each of these contexts has in free choice learning, the CML must also be capable of providing a framework that is flexible and capable of change. The rest of this section looks at each of

the contexts of the CML in greater detail and points out the key factors that are often influential in how learning can be supported.

**2.4.1.1 Personal Context:** When engaged in supporting environments that are motivating and meet expectations, people generally like to learn (Falk 2000, 2018). Essentially, there are three primary characteristics of the personal context that play an integral role in learning: a) motivations and expectations; b) prior knowledge, interests and beliefs; and c) choice and control (Falk 2000, 2005, 2018).

- a) *Motivations and Expectations:* learning is mostly intrinsically motivated, meaning that it is self-motivated, emotionally satisfying, and personally rewarding. Additionally, learning is bolstered when the expectations a person has regarding the experience are satisfactorily met (J. H. Falk, 2011).
- b) *Prior Knowledge, Interests, and Beliefs:* as learners, people actively self-select the programs and projects they want to participate in based on their past experiences and interests. The meaning they take away from these new experiences is framed (and constrained by) their prior knowledge, interests and beliefs (Liu & Falk, 2014).
- c) *Choice and Control:* learning is enhanced when there are choices and control over what and when a person learns. This is the essence of free-choice learning.

**2.4.1.2 Sociocultural Context:** Learning is both an individual and group experience (Arnseth, 2008). At a fundamental level, institutions like museums support the participation of others in a wide range of learning communities that are mediated either from within or from outside the group (J. H. Falk & Storksdieck, 2005; Liu & Falk, 2014).



When learning is socially mediated from within the group, the group uses their members to decipher information, reinforce shared beliefs, as well as for meaning making (J. H. Falk & Dierking, 2018; Henning, 2004). On the other hand, facilitated mediation can support learning when there is an encounter with a person perceived to be more skilled or knowledgeable in the activity taking place (Bransford et al., 2000; J. Falk & Storksdieck, 2005).

**2.4.1.3 Physical Context:** Learning is very much dependent upon context and does not necessarily transfer from one environmental context to another very well (Chang, 2006; J. H. Falk, 2005) In fact, absent these cues, little meaning is made of the patterns and associations the brain processes from one activity or experience to another (Anyfandi et al., 2014; J. H. Falk, 2011). Thus, while learning is more or less generalizable to new situations, contextual cues must be recognizable to the learner to support old learning in the new context (J. H. Falk et al., 2007). Physical contexts rely on the principal factors of orientation and design to support learning:

- a) *Orientation:* By providing artifacts and resources that are familiar, they can be used to guide the learner to build meaning from new activities and experiences (Lin, 2011). Basically, people learn better when they feel secure in their surroundings and know what is expected of them. This is also true when the physical space happens to be virtual, and the artifacts and resources are online (Aristeidou et al., n.d.; Kridelbaugh, 2016).
- b) *Design:* Spatial learning is integrated with all types of learning, i.e., all learning is influenced by the cognitive awareness of a physical space (Chuang & Liu, 2012; J. H. Falk & Dierking, 2018). Good design engages the senses, incites curiosity, and compels people to investigate the topic at hand in greater detail (Weible & Zimmerman, 2016).

**2.4.1.4 Time:** Although time was not a unique context of learning in the first edition of (J. H. Falk & Dierking, 2018), its importance to learning in general, and free-choice learning more specifically, is appreciated to a much greater extent in subsequent work of Falk including the second edition of *Learning From Museums*. Not only do prior experiences play a role in determining what is learned, subsequent experiences contribute to what an individual does or does not learn when engaged in an activity; it is what they find to be relevant and useful from their participation that stand the tests of time. These are the reinforcing events and activities that connect the pieces together and form deeper and longer lasting learning.

## 3 Methods

The primary focus of this research is to examine how citizen science projects use what they know about their volunteers and themselves to identify learning goals for their project and provide opportunities for learning that are beneficial to both the project and volunteer. It is a deeper investigation of informal science learning that originated with the study of task instruction and tutorial design in online citizen science spaces. As more citizen science projects incorporate technology into their project design (especially for training purposes), it has become evident that this research of informal science learning should include all citizen science projects, both field-based and online. This chapter discusses the approach this study took to explore this idea.

### 3.1 Research Approach

An interpretive approach was chosen for this research. When using an interpretive approach, meaning comes from the perceptions of those individuals involved in a socially constructed process (Elliott & Timulak, 2015). Learning is such a process, and is made meaningful through the collective understanding of shared interactions and artifacts (Anyfandi et al., 2014). In the case of learning in citizen science, evidence from the extent literature comes from the perspectives of the volunteer, the evaluator, and even the citizen science researcher, but not necessarily from the project's perspective—despite their role in creating the interactions and artifacts used to support volunteer learning. Learning in this context appears to be missing an important component to its meaning. Consequently, gathering the point of view of citizen science project leaders regarding how their projects approach volunteer learning “is a matter of content and intent, rather than procedure”

(Mankowski et al., 2011, p. 27) making the use of an interpretive lens an appropriate research approach.

Additionally, as a citizen science researcher that has studied volunteer learning for a number of years (Peterman et al., 2022; H. K. Rosser & Wiggins, 2019; H. Rosser & Wiggins, 2018), as well as my experience as a project lead for a technology-based citizen science project, I bring my own unique point of view regarding volunteer learning to this study. Moreover, this perspective is now also informed by a theoretical framework that other domains outside the broadly-defined museum are relatively unfamiliar with, i.e., the CML. Examining the CML's application to learning in citizen science--as perceived through my observations and experiences with the leaders and artifacts of citizen science projects--is well-informed but not necessarily objective nor easily replicated by others (Elliott & Timulak, 2015; Thorne, 2014). As such, by providing this study with a general framework to understand volunteers and project leaders in context, an interpretive research and analysis strategy allows for a more dynamic approach that can reveal compelling and powerful insights filled with subtleties not as easily observed using other qualitative methods (Mankowski et al., 2011; Putnam & Banghart, 2017).

### **3.2 Data Collection**

The data in this study was collected through interviews with citizen science project leaders, directors, and coordinators along with the manual extraction and analysis of online artifacts from partnering projects. When available, project leaders also provided me with physical copies of artifacts they offer to their volunteers during live in-person events. Additionally, to gain access to learning materials, contact information, etc. I became a member of two projects (NASA's Exoplanet Watch and Monarch Rx) and joined private

social media groups for two others (Nebraska Bumble Bee Atlas and Nebraska Friends of Pollinators). I am a non-participating observer in NASA's Exoplanet Watch, Nebraska Friends of Pollinators, and Monarch Rx, but am an active contributor to Nebraska's Bumble Bee Atlas—albeit with minimal involvement beyond my own posts. When combined, the interview and artifact data provided this study with deeper insight into the contextual influences at play in volunteer learning while also providing this research validity measures through triangulation of data.

### **3.3 Study Population and Sample Selection**

There are several databases and repositories of both technology-based and field-based citizen science projects. CitizenScience.gov (<https://www.citizenscience.gov/#>) and SciStarter.org (<https://scistarter.org/>) are two technology-based repositories for citizen science projects that were accessed for this study. CitizenScience.gov provides a spreadsheet with descriptive and contact data related to 502 US-based citizen science projects (<https://www.citizenscience.gov/catalog/#>). During data collection in early 2023, SciStarter.org listed 1,529 citizen science projects on their site that have a greater global reach than the CitizenScience.gov site. Thus, it was decided to sample from SciStarter.org for this study in order to have access to a greater number of projects from a larger geographic region.

The primary requirement for all citizen science projects contacted for an interview was that they have an online presence to make document analysis possible. Beyond this requirement, projects were selected using a landscape sampling method (Bos et al., 2007) in which a broad yet comprehensive range of projects were sampled regardless of other criteria, which were age of project (i.e., older and newer) and type of project participation,

(i.e., field-based and technology-based). Based on a review of the data on the CitizenScience.gov spreadsheet and my personal experience leading a short-term citizen science project on Zooniverse, projects that were active for five or more years were considered older, more established projects while those launched within 1 – 4 years of data collection were categorized as newer. However, the age of the project was a little more nuanced than what was initially anticipated due to changes in leadership, funding sources, etc., so other factors such as managing organization and volunteer base were used for sampling as well.

With these criteria in place, a collection of 150 citizen science projects varying in age and type of participation were placed in a “List” on my personal SciStarter account and every third project was selected for initial contact. In this manner, 24 citizen science projects, agencies, and programs (referred to now as “projects”) were contacted via email 12 at a time. I received interviews from 18 of those projects (75%), and then interviewed four more citizen science experts, practitioners, and educators through snowball sampling. As mentioned above, I also looked at the number of volunteers and managing organization type of the project to potentially learn more about funding, access to resources, etc. and to increase the likelihood of a broader sample of projects to work with.

Respondents were contacted through email asking them to participate in a semi-structured interview over Zoom (or the web-conferencing service of their choice) that would last 45 minutes to an hour (see Appendix B). I chose to interview everyone that agreed to participate as a measure of reliability and consistency of my findings. However, saturation was met in each primary criteria of age and project type as well.



Project Name	Organization Name	Contact Name	Project Goals	Project Tasks	Project Type	Age of Project	Membership Numbers
Save our Streams	Izaak Walton League of America	Kira Carney (Mid-Atlantic); Heather Wilson (Midwest); interviewed together	Crowdsourcing water quality data across America	Collect images and upload them to iNaturalist; Water monitoring program	Field-based	1969	127 certified members (macro-invertebrates)-MW; 450 active members in Mid-Atlantic
NASA Citizen Science Projects	NASA Science	Marc Kuchner	Participate in online and field-based projects about the Universe, Solar System, Earth, and Space	Varies depending upon the needs of the 33 projects posted on the website	Citizen Science Platform with 33 projects (mix of field-based and tech-based)	2011ish for CitSci	Hundreds of thousands
Cedar Creek Reserve-Woodpecker Cavity Cam	Cedar Creek Ecosystem Science Reserve	Caitlin Potter	Study interactions of red-headed woodpeckers	Identify animals and behavior during field-study and in trail cam videos	Field-based and tech-based (Zooniverse)	Field-based: 2008; Zooniverse: 5/18/21	8,474 registered volunteers (Zooniverse); Field-based project suspended in 2023
Monarch Rx	N/A	Michael Boppre	Understanding gathering of pyrrolizidine alkaloids by monarch butterflies	To record behavior in nature	Field-based with tech-based record keeping (CitSci.org)	2022	107
NASA Globe Cloud Gaze	NASA, GLOBE	Marile Colon Robles	Interpret cloud photos to help scientists better understand our climate	Identify cloud cover, cloud types, and other phenomena in photographs	Field-based with an app; Zooniverse project	Zooniverse: 7/12/21; Globe app: 2016; Globe program 20+ years	12,997 registered volunteers (Zooniverse); hundreds of thousands Globe



Project Name	Organization Name	Contact Name	Project Goals	Project Tasks	Project Type	Age of Project	Membership Numbers
Time to Restore; Nature's Notebook	USA National Phenology Network	Samantha Brewer; Erin Posthumus; Gina Zwicky; Gail Bishop (focus-group participation)	Help pollinators by tracking flowering and seed timing of plants	Track flowering and seed timing of one or more nectar plants where you live	Field-based with apps to record findings (Nature's Notebook and iNaturalist)	Time to Restore: 2021 (3 <sup>rd</sup> year of a 3-year project)	3,000 – 4,000 observations/yr; 148 on stakeholder contact list
Bumble Bee Atlas	Xerces Society	Katie Lamke	Track and conserve bumble bees throughout Nebraska	Attend a training, conduct surveys, photograph bees, submit data	Field-based with an app for record keeping	Xerces Society started in 1971; BBA-PNW 2018, BBA-NEB 2019, BBA-MO 2020, BBA-MN 2021, CA-2022, GP-2022, SE-2023, IA-2023	400 in Midwest Region: ND, SD, NE, MO, KS, IA, MN
UW-Madison Arboretum's Dragonfly Monitoring Project	UW-Madison Arboretum	Julia Whitten	The goal of this project is to monitor the diversity and abundance of dragonflies that live with the UW-Madison Arboretum	Head to an established site and record on our datasheet the species and relative abundance of dragonflies that you see.	Field-based with tech-based record keeping (Anecdata)	Anecdata project: 2022; Project Origin: 2018	10 Membership by admin approval on anecdata; 50 or more volunteers not on the platform. Also, outreach has included families and that was very successful.
K-TESST (Knoxville-Tennessee Environmental Soil and Stream Testing	University of Tennessee-Knoxville	Jill Walton	Educate about soil and water quality	Test soil and/or water quality with are free test kit	Field-based	2022	100 kits given out in total; data return is not great

Project Name	Organization Name	Contact Name	Project Goals	Project Tasks	Project Type	Age of Project	Membership Numbers
SciStarter.org	SciStarter	Darlene Cavalier	Find volunteer opportunities that match topics you're curious or concerned about.	Varies depending upon the needs of the projects registered on the platform. There are also affiliated libraries that have been trained as citizen science outreach facilitators.	SciStarter is a hosting platform and provides educational outreach and citizen scientist training	2011	1,542 projects, 4 CitSci as a service projects, 120 libraries; 70,000 registered users; 160,000 followers on socials
Nebraska Master Naturalist, Nebraska Amphibian Monitoring Program, Nebraska Salamanders	The Nebraska Master Naturalist Program is a public and private partnership supported by the University of Nebraska-Lincoln, Nebraska Environmental Trust, Nebraska Game and Parks Commission and Nebraska Master Naturalist Foundation.	Dennis Ferraro	The Nebraska Master Naturalist Program educates a volunteer network dedicated to promoting the conservation of Nebraska's natural resources.	Our program recruits, trains, manages, and provides resources for our Naturalist members participating in interpretation and outreach, resource management, citizen science, and outdoor skills and recreation in Nebraska.	Varies depending on participation opportunities	August 2010	40 identifiers/22 observers for salamanders; more than 650 NMN members with about 200 actively participating.
Nebraska Butterfly Surveys	Nebraska Game & Parks Commission	Cody Deier	Monitor monarch and regal fritillary butterflies in NE	Record sightings of monarch and regal fritillary butterflies	Field-based	2015; revamped 2020	33 in 2022; 60 all together

Project Name	Organization Name	Contact Name	Project Goals	Project Tasks	Project Type	Age of Project	Membership Numbers
Citizen Scientist Project	UC-Bakersfield & National Geographic	Brittney Beck	To build capacity for citizen science in teacher education programs at Cal State Bakersfield; to include more diverse voices in question-posing, data collection, data analysis and data-informed advocacy through building capacity for global citsci in K-12 and higher education	Varies depending on the project: Teaching Fellows; Summer Camps; My NASA Data; Introductory comp sci supplementary authorization	Field-based and tech-based (Instant Wild; iNaturalist)	2018	3 school districts in central California (summer camps--5 summer 2023, 20 girls per camp) plus graduate teacher education students (35 students/cohort, 100 or so total) at UC-Bakersfield
Microplastics Pollution Monitoring Program	Ocean First Institute	Josh Soll	To raise further awareness about microplastics pollution		Field-based with tech-based record keeping (Anecdata)	Classroom engagement 2021 15 - 20 classes/year 5 - 30 students per class	17 Classrooms 2023
Leave No Trash/Leave No Trace	Leave No Trace Center for Outdoor Ethics	JD Tanner	Pack-in, pack-out training for wilderness areas	Pick up and record trash; maintain natural environment when outdoors	Field-based	1994-Leave No Trace; April 2022 Leave No Trash	More than 70,000-Leave No Trace; 56-Leave No Trash (but one member could be a group of 10 - 20 people)
Community Science with Nebraska Game & Parks	Nebraska Game and Parks Commission	Allie Mayes	Educational outreach and program coordination of sponsored projects	Varies depending on project or program	Field-based and tech-based (iNaturalist, Zooniverse)	Community Science department at NE Game & Parks is about 3 years old.	Zooniverse project (out of data) 1484 volunteers, 263914 classifications, 56138 subjects
Iguanas from Above	University of Leipzig	Amy McLeod	Monitor Galapagos marine iguanas using aerial images	Identify and count marine iguanas from drone images	Tech-based (Zooniverse)	8/04/2020	8692 Registered Volunteers (10302 on 5/04/23)

Project Name	Organization Name	Contact Name	Project Goals	Project Tasks	Project Type	Age of Project	Membership Numbers
Citizen Science Campus, Citizen Science Club, Crowd the Tap	NC State	Caren Cooper	Include citizen science in undergrad curriculum, engage students in citizen science through a sponsored club on campus, lead exposure screening project		Field-based, educational outreach for undergraduate student at NC State, citizen science training for NC State faculty	2019-2020 academic year	20-30 in CitSci Club; all incoming freshmen--Wicked Problems with Tech Solutions; 23000 landing page views on SciStarter. 15 faculty members include citizen science in their curriculum.

To summarize that document, Table 3.3a provides a summary of the respondents based on project participation type. This turned out to be more nuanced than originally planned (i.e., field-based only, and technology-based only), and it was discovered throughout the recruiting process that type of participation also involved having multiple or varied types of participation available for volunteer engagement (4). I was also able to speak with two platform directors, Marc Kuchner from NASA Citizen Science and Darlene Cavalier with SciStarter.org. While every attempt was made to balance participation type in the sampling process, there are considerably more field-based projects than there are technology-based projects. To illustrate, on SciStarter.org there were 1,529 project profiles at the time of my sampling; however, only 106 (or roughly 7 percent) of those projects were noted to be exclusively online participation. Thus, my sample appears to be more reflective of reality than the table would suggest.

Table 3.3a: Interview Respondents by Project Type

Type of Participation	Number of Projects	Project Names
Field-Based Projects	13	Salt Watch, Dolphin Spotter, Save Our Streams, Monarch Rx, Globe Cloud Gaze, USA National Phenology Network (Time to Restore), Bumble Bee Atlas, UW Dragonfly Monitoring, KTESST, NE Butterfly Project, Microplastics Monitoring Project, Leave No Trace, NC State Citizen Science Campus
Technology-Based Projects	3	Iguanas from Above, Cedar Creek Reserve (Woodpecker Cavity Cam), Penguin Nest Check
Multiple Types of Participation	4	NASA Exoplanet Watch, Community Science with NE Game & Parks, Citizen Scientist Project, Nebraska Master Naturalist
Citizen Science Platform	2	NASA Citizen Science and SciStarter.org

Table 3.3b provides the breakdown by age (i.e., younger than 5 years and older than five years), and Table 3.3c provides a breakdown of projects by volunteer population size. Project names are included in each table for clarity.

Table 3.3b: Interview Respondents by Project Age

Age of Project	Number of Projects	Project Names
Younger than 5 Years	14	NASA Exoplanet Watch, Dolphin Spotter, Woodpecker Cavity Cam (Cedar Creek Reserve), Monarch Rx, Time to Restore (USA National Phenology Network), Bumble Bee Atlas, UW-Madison Arboretum's Dragonfly Monitoring, KTESST, NE Butterfly Surveys, Citizen Scientist Project, Microplastics Pollution Monitoring Program, Community Science with NE Game & Parks, Iguanas from Above, NC State-Citizen Science Campus
Older than 5 Years	8	Salt Watch, Penguin Nest Check, Save Our Streams, NASA Citizen Science, Globe Cloud Gaze, SciStarter.org, NE Master Naturalist, Leave No Trace

Table 3.3c: Interview Respondents by Volunteer Population

Volunteer Population Size	Number of Projects	Project Names
1 – 100	6	Citizen Scientist Project, Microplastics Pollution Monitoring Program, NC State-Citizen Science Campus, UW-Madison Arboretum's Dragonfly Monitoring, KTESST, NE Butterfly Surveys
101 – 500	5	Bumble Bee Atlas, Penguin Nest Check, Time to Restore (USA National Phenology Network), Monarch Rx, Dolphin Spotter
501 – 1,000	3	Salt Watch, Save Our Streams, NE Master Naturalist
1,001 – 10,000	4	NASA Exoplanet Watch, Iguanas from Above, Community Science with NE Game & Parks, Woodpecker Cavity Cam (Cedar Creek Reserve)
Population > 10,000	4	NASA Citizen Science, Globe Cloud Gaze, Leave No Trace, SciStarter.org

Looking a little deeper at the sample, cross-sections of the interview respondents was completed comparing age of project with volunteer population in Table 3.3d. Not surprising, most of the younger projects had fewer volunteers than older projects, and that table is a little lop-sided. Table 3.3e is a more balanced where the cross-section of my sample compares type of project participation against project age.

Table 3.3d: Cross-Section of Interview Respondents

Volunteer Population Size	Younger than Five Years	Older than Five Years
1 – 100	6	0
101 – 500	4	1
501 – 1,000	0	3
1,001 – 10,000	4	0
Population > 10,000	0	4

Table 3.3e: Cross-Section of Interview Respondents

Type of Participation	Younger than Five Years	Older than Five Years
Field-Based Projects	9	4
Technology-Based Projects	2	1
Multiple Types of Participation	3	1
Citizen Science Platform	0	2

The section that follows describes the protocol used during my interview with each of the respondents.

### 3.4 Interview Protocol

The research in this dissertation included a semi-structured interview protocol in order to provide the structure needed to keep the study focused on answering the research questions while also allowing for a deeper, more interesting narrative about citizen science to be elicited from the

project leader's perspective. In line with the CML, the scope of the protocol was created to gather insight into how the contexts of the volunteer and the project contribute to the project's approach to learning (Liu & Falk, 2014). Generally, interview questions were framed to guide project leaders to discuss how the personal and sociocultural contexts of the volunteer as well as the sociotechnical and physical contexts of their projects enable and constrain their ability to support volunteer learning goals. Given the prominence of technology use in citizen science, the protocol also contained open-ended questions regarding the project's technology use to support project learning goals.

An Institutional Review Board application was submitted and approved as exempt research in September 2022. In all, there were 21 interviews conducted remotely using Zoom and one interview was conducted in person. All interviews were recorded with respondent permission and transcribed using the transcription tools provided by Zoom.

### **3.5 Document Analysis**

Surprisingly, there is not a lot of academic literature on document analysis as a method of research (Karppinen & Moe, 2012)—that role appears to be largely left for qualitative analysis textbooks and classroom presentations posted on YouTube. Having said that, a few articles were located outlining specific document analysis methods that complimented the data collected through the interviews (Appleton & Cowley, 1997; Bowen, 2009; H. Morgan, 2022). At its simplest form, the document analysis completed in this study involved sorting materials for relevance, identifying their function in the project, and then analyzing those documents according to the CML (H. Morgan, 2022; Sá et al., 2022). The specific steps taken in this analysis were as follows:

The first step in the process was to complete a simple sort of the materials to identify the relevance of the document to this study. This phase was completed as an indicator for manual content extraction and was completed once the interview had been scheduled. The materials examined were both digital and physical artifacts (whenever possible). However, photographic images of physical documents and artifacts were requested when providing that material was prohibitive by cost or project policy. Examples of document forms manually extracted from online sources included website pages, pdfs, slides, and videos. Other documents received either through the US mail or as a photographic image were physical instruction sheets and manuals, field guides, notebooks, and marketing materials.

Next, the function of the materials was determined through analysis of interview data as well as content analysis techniques to catch functions that might not have been noted in the interviews (Neuendorf, 2017). Common functions on project materials noted in this step were communication tools, educational materials, training materials, and record keeping tools or artifacts.

The final step in the document analysis process was to complete thematic analysis of the documents to determine how they were related to the personal, sociocultural, and physical contexts of the CML. This portion of the document analysis process is described in detail in the next section.

### **3.6 Data Analysis**

Although this study takes a descriptive/interpretive approach in line with (Elliott & Timulak, 2015), in order to make meaning of the data presented, there needed to be a focus that was “naturally driven by the specific research questions (Elliott & Timulak, 2015, p. 151).” Looking back at the questions posed in Chapter One, those RQs are intended to test the application of the CML in a novel domain, i.e., volunteer learning in citizen science. This made deductive content



analysis an appropriate method for initiating the coding process. Consequently, a codebook was created reflecting the characteristics of the personal, sociocultural, and physical contexts of the CML (see Appendix D for the deductive codebook). To align this codebook with the research questions, however, it was also necessary to include *learning goals* and *learning opportunities* as described in Section 1.2 at this stage of analysis as well. Thus, the initial codebook included five primary categories with 13 codes as shown in Table 3.6a below:

Table 3.6a: Deductive Content Analysis Categories and Codes

Personal Context	Sociocultural Context	Physical Context	Learning Goals	Learning Opportunities
Motivation & Expectations	Facilitated Mediation	Design	Science Learning	Training & Content Knowledge
Choice & Control	Peer-Group Social Mediation	Orientation	Educational Outreach	Hard-Copy Materials
Prior Knowledge, Interests & Beliefs				Informative Outcomes
				Supplemental Learning Resources

Following the creation of the deductive analysis codebook, coding of the interview data was systematically and iteratively approached according to the method described in (McKibben et al., 2022) in which the deductive method directed data analysis at the start, but novel information was allowed to surface and subsequently and inductively organized into categories outside of the original codebook (see Table 3.6b, Appendix C for definitions). In this manner, as new categories and codes emerged, each interview was revisited to ensure that those codes and categories were included. This process of coding continued until there was thematic saturation of the interview data as it related to the contextual influences of volunteer learning not present in the original interpretation of the CML as shown in the final coding schema in Table 3.6c (Elo & Kyngäs, 2008). This process was made easier by using the qualitative analysis software Atlas.ti23 to help organize codes and visualize themes.

Table 3.6b: Inductive Content Analysis Categories and Codes (new themes and codes in *italics* and highlighted in blue)

Personal Context	Sociocultural Context	Physical Context	Learning Goals	Learning Opportunities	Persona
Motivation & Expectations	Facilitated Mediation	Design	Science Learning	Training & Content Knowledge	<i>Volunteer</i>
Choice & Control	Peer-Group Social Mediation	Orientation	Educational Outreach	Hard-Copy Materials	<i>Project (Organization)</i>
Prior Knowledge, Interests & Beliefs	<i>Technological Mediation</i>	<i>Design Characteristics: Physical, Technological</i>		Informative Outcomes	
<i>Demographics</i>		<i>Influences on Design: Contextual, COVID-19, Funding, Staffing, Staff-Time</i>		Supplemental Learning Resources	
				<i>Presentation Type: Synchronous, Asynchronous</i>	

Table 3.6c: Final Categories and Codes Used For Analysis

Personal Context	Sociocultural Context	Physical Context	Learning Goals	Learning Opportunities	Persona
Motivation & Expectations	Facilitated Mediation	Design	Science Learning	Training & Content Knowledge	Volunteer
Choice & Control	Peer-Group Social Mediation	Orientation	Educational Outreach	Hard-Copy Materials	Project (Organization)
Prior Knowledge, Interests & Beliefs	Sociotechnical Mediation	Design Characteristics: Physical, Technological		Informative Outcomes	
Demographics		Influences on Design: Contextual, COVID-19, Funding, Staffing, Staff-Time		Supplemental Learning Resources	
				Presentation Type: Synchronous, Asynchronous	

Analysis of the physical and digital artifacts took place in much the same manner as the interview data where the thematic analysis was initiated deductively according to the original characteristics and contexts of the CML—albeit with slightly different applications when compared to the interview transcripts given the multimedia characteristics of the data. In other words, the personal, sociocultural and physical contexts of the volunteer and the project were identified through text, graphs, images, and videos. Following the initial deductive pass, project artifacts were iteratively revisited to assess the application of the new codes introduced during the analyses of the interview data.

To transition to the next section on threats to validity, this is the perfect opportunity to reiterate to the readers of this study that I have chosen an interpretive approach to this research that undoubtedly colors the analysis and subsequent results presented here based on my own prior knowledge, interests, and beliefs. While there has been every attempt made to mitigate my personal biases through systematic and iterative examination of the data, it is impossible to eliminate them all. The following section describes these attempts to moderate those risks.

## 4 Findings

As noted in Chapter Three, Section 3.6, data analysis began by using the personal, sociocultural, and physical contexts as defined in the CML in a codebook for deductive content analyses of the digital media and interview transcripts. Through inductive content analysis, additional themes regarding specific learning goals and opportunities, uses of sociotechnical systems for learning, and the unique contexts of the projects themselves that relate to volunteer learning began to surface. In the sections that follow, pertinent findings from this analysis begins with learning goals and opportunities. It then moves through findings related to the personal, sociocultural, and physical contexts of the CML. To end this chapter, findings regarding technology use and project contexts revealed within the data are presented.

### 4.1 Learning Goals and Opportunities

Learning in this study takes on two distinct forms, learning goals and learning opportunities; both are established by the citizen science project as a means to achieve their research or educational outreach goals. Learning goals describe the type of learning a project needs or wants their volunteers to accomplish, while learning opportunities are the resources put in place by the project to achieve those goals. Learning goals in this study fell within the themes of research-focused and outreach-focused. These goals were then found to be supported by either physically- or technologically-mediated learning opportunities.

#### 4.1.1 *Learning Goals*

Learning goals are the intended consequences of a project's efforts to support volunteer learning that can include project-specific content knowledge, data collection strategies, as well as monitoring and observation skills. These skills are the often the primary goals for projects with a

research-driven focus. However, these *research-focused learning goals* are not only the knowledge every project wants their volunteers to develop, they are also the *outreach-focused learning goals* that a project would like to support such as stewardship, the need for conservation, and civic engagement. In this case, these outreach-focused learning goals tend to be more desirable to projects that are more educationally-motivated or outreach-focused.

**4.1.1.1 Research-Focused Learning Goals:** This refers to the type of learning goal that is limited to *process knowledge* and *protocol training*. This was a common theme among all projects—even in those projects with educational outreach as a primary objective—and was evident in statements where there was a training focus to the learning goal. An example of this finding comes from Save Our Streams as they discussed the training and protocol testing steps needed to become a certified stream monitor, “After the field training we will send them (volunteers) a protocol exam, which is basically just asking them to answer some questions about what was talked about during the training—things about safety and site selection.”

Research-focused learning goals were evident in digital resources as well. Zooniverse project tutorials provide a perfect example of this type of learning material where a project provides very specific information regarding the project’s objectives, subject matter, and tasks needed from their volunteers. In the sample images from the Cedar Creek Reserve-Woodpecker Cavity Cam Project tutorial below (see Figure 4.1), volunteers are provided the project objective and subject matter (learning more about the red-headed woodpeckers and their neighbors) and an introduction to the tasks required in the Woodpecker Days and Nights online workflow. The remaining panels (as indicated by the arrows and circles on the bottom of the image) walk the volunteer through the specifics of the classification task on Zooniverse.

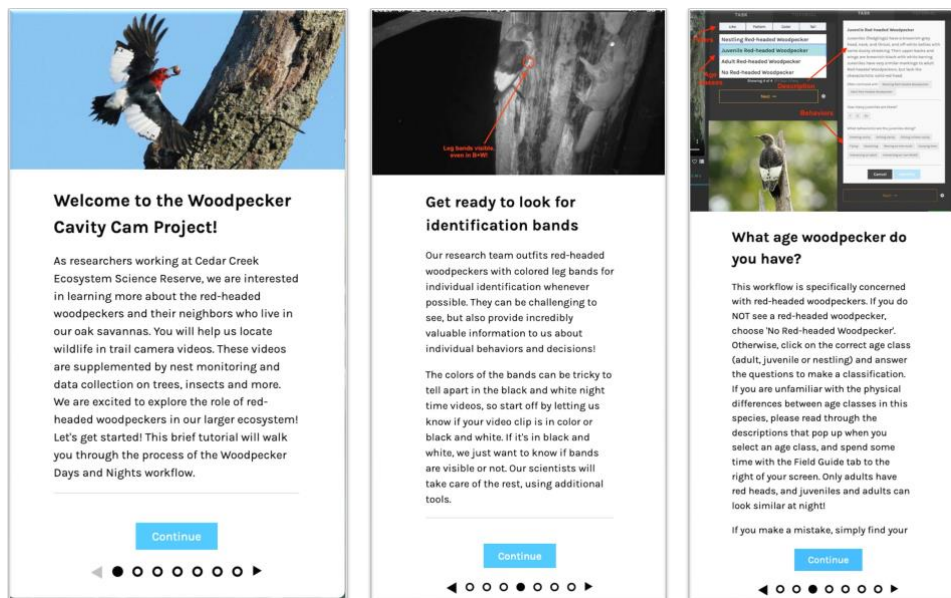


Figure 1: Woodpecker Cavity Cam Tutorial, Zooniverse (<https://www.zooniverse.org/projects/ehwest/woodpecker-cavity-cam>), 2023

In both the document and interview data, one of the research-focused learning goals citizen science projects work to support concerns the process knowledge and protocol training needed for volunteers to complete the tasks asked of them. Besides process knowledge learning goals, the respondents highlighted informative outcomes and supplemental learning materials in connection with educational outreach.

**4.1.1.2 Outreach-Focused Learning Goals:** This learning goal is different than a project's need to train their volunteers to complete a certain task. It speaks to project learning goals more generally, and may include increasing subject matter exposure and knowledge, generating an interest in science and research, and potentially improving community awareness and stewardship. From the Microplastics Pollution Project interview, this comment reflects one of the project's educational outreach goals of fostering interest in science:

*So, my goal is to take students to this project, but also try to foster interest in anything science related...to offer them advice on ways that they can enter the field if they're interested in it, or just how to get into college, how to pursue grad school, if that's what their interest is.*

In the interview data, two additional codes described a project's outreach-focused learning goals: *informative outcomes* and *supplemental learning materials*. Informative outcomes are those specific learning goals of a citizen science project that include community outreach, informing stakeholders, promoting community stewardship efforts, etc. (Phillips et al., 2019). Supplemental learning materials are little more self-explanatory and include learning materials provided by the project to educate participants on a topic that goes beyond what is needed for task completion. Findings from the interview transcripts for these codes show that informative outcomes were mentioned more than twice as often as supplemental learning materials, suggesting more emphasis on increasing subject matter exposure than generating an interest in science and research. An example of supplemental learning resources as a type of an outreach-focused learning goal involves NASA Globe Cloud Gaze. Even though this project was no longer collecting data from their Zooniverse project, it was the project coordinator's decision to keep it running as a supplemental learning resource for K – 12 teachers:

*Cloud Gaze is not actively collecting data, but it's still out there (on Zooniverse) particularly for teachers because teachers found it as a great way for either using it when everybody had to go back home (Covid restrictions) or as a way to practice or train students on how to make the cloud observations before going outside (to use the mobile app).*

Nearly all projects (20/22) published their informative outreach efforts and/or provided access to supplemental learning materials for their volunteers to learn more about the project's subject matter and research objectives. For example, the Zooniverse project, Iguanas from Above,

offers supplemental learning materials to their volunteers in the “About” pages of the project as well as through access to other external project links, i.e., external website, Twitter, Instagram, and Facebook. Information contained within the “About” pages of the project provide volunteers with extra information regarding the project’s subject matter and research objectives. This information is not necessarily required for volunteers to complete the tasks requested of them but is made available to those who are interested in gathering more information on the subject matter. When looking at the project’s external website, Iguanas from Above also publishes results of their educational outreach endeavors with a local German high school as further evidence of the project’s educational outreach goals (see Figure 2).

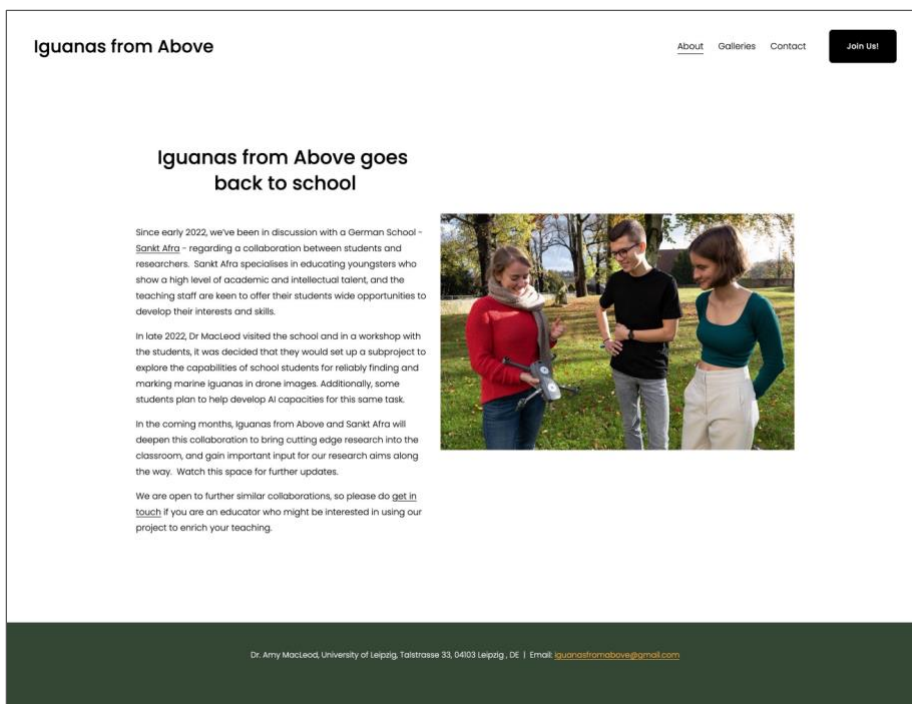


Figure 2: Iguanas from Above, website About page. (<https://www.iguanasfromabove.com/ifa-and-schools>)

In summary, outreach-focused learning goals relate to the generalized goals of subject matter exposure and knowledge sharing. Nearly all projects reported some form of educational



outreach as part of their goals for volunteer learning. The sections that follow discuss how projects are supporting those goals.

#### ***4.1.2 Learning Opportunities***

Learning opportunities are those efforts, i.e., the materials, resources, activities, and events that a project offers to support their learning goals. In this study, these opportunities can be described as predominantly physically- or technologically-mediated offerings. However, there were several projects that combined their physical and digital resources to provide unique learning opportunities to meet their volunteer learning goals. A third category, hybridized learning opportunities, accounts for these configurations. Each of these categories is discussed in further detail below. The variety of learning opportunities employed by the projects in this study are depicted in Table 4.1.2.

***4.1.2.1 Physically-Mediated Learning Opportunities:*** Learning opportunities situated in the physical world include in-person training events as well as any of the printed materials and artifacts projects used to support their volunteer learning goals. Several project leaders mentioned providing their volunteers with hard-copy learning resources in keeping with the physical characteristics of both project training protocols and project-facilitated learning opportunities. For example, the Salt Watch project offers multiple physically-mediated volunteer learning opportunities, including offering brochures and tri-folds during in-person training sessions, bio-blitzes, farmers markets and other eco-friendly events within the Chesapeake Bay area of Maryland. They also provide printed and hard-copy learning materials in their waterway testing kits mailed via USPS to anyone that asks (including me). The Salt Watch project coordinator discussed the physicality of the

training kit and its contents and what participants were intended to learn from the physical objects, i.e., that ice salt is being overused and damaging our water sources (see Figure 3):



Figure 3: Salt Watch testing kit, brochures, stickers, and marketing artifacts, received via USPS 2/03/2023

Physically-mediated learning opportunities are those artifacts and events that are accessed and attended in the physical world. As shown in the examples from Salt Watch, these learning opportunities can be used to support both science training and educational outreach learning goals of the project. When volunteer learning opportunities move online or other digital formats, the learning becomes technologically-mediated.

**4.1.2.2 Technologically-Mediated Learning Opportunities:** As the name of this theme implies, technologically-mediated learning opportunities are those that are offered in some sort of digital format. Table 4.1.2 demonstrates that these materials can be presented synchronously in the form of webinars, live feeds, online workshops, etc. or they can be asynchronously presented through written and graphic material on websites, downloadable pdfs and slides, discussion boards and forums, as well as videos and images offered on social media. The majority of projects reported engaging in some sort of facilitated training opportunity with their volunteers using online resources such as Zoom, Skype, or other webinar-type interfaces as

noted by the program director from SciStarter, “We (SciStarter) also do live events. They're online events where we'll walk somebody through... the projects that align with the criteria that their community has set.”

Asynchronous learning opportunities were numerous and spanned a variety of online and mobile platforms. Self-guided learning and training opportunities were by far the most prevalent form of technologically-mediated material reported by project representatives. In fact, every project noted some sort of online training or educational outreach resource available to their volunteers to access or use on their own. Examples from the interview data include this quote from Dolphin Spotter discussing the availability of a tutorial video and instruction manual on their website:

*I've made a tutorial video on how to set up the trail camera settings (to host a spotting station), and also the installation of it physically, and then also an instruction manual on how to buy the supplies.*

And this quote from Microplastics Pollution Project discusses their use of the online citizen science platform Aneccdata for administration of their project:

*I have essentially created some data sheets and educational sheets on the Aneccdata website where people can go through the steps themselves and try to learn about microplastics themselves.*

In each case, the materials these projects described in the interviews were easily located on their websites.

Some projects also provided technologically-mediated supports for social learning. For example, projects hosted on Zooniverse, Aneccdata, and CitSci.org can create discussion forums that not only support asynchronous project-facilitated communication and learning but also support social learning opportunities as volunteers interact and learn from each other. Still other

projects rely on other forms of online communication, such as Facebook, Twitter, or even Slack to encourage social learning. After reviewing projects' discussion boards, however, most did not appear to be very popular outside of a few known exceptions. Projects from this research with active discussion boards include the three Zooniverse projects (i.e., Woodpecker Cavity Cam, Iguanas from Above, and NASA Globe Cloud Gaze) and NASA's Exoplanet Watch, which has a very active Slack channel.

Technologically-mediated learning opportunities can take on a number of forms and be accessed synchronously or at a time more convenient for the volunteer. However, opportunities for social learning experiences are not always utilized by a project's volunteers. What was shown to be more widely-accepted by projects and volunteers are when physically- and technologically-mediated learning opportunities are blended for a hybridized model of learning.

**4.1.2.3 Hybridized Learning Opportunities:** Hybridized learning occurs when field-based projects blend technology-mediated learning opportunities to achieve volunteer learning goals. As Table 4.1.2 depicts, many of the field-based projects used a hybridized model for volunteer training where a portion of their training was available online. Roughly half of those projects required volunteers and program participants to complete initial process knowledge and training modules prior to engaging in field-based training activities while the others offered online training as an option. Additionally, many of the projects offered synchronous online training events a couple times a year for volunteers to attend using Zoom, although one project, Nebraska Butterfly Survey, decided to discontinue live online trainings this year (2023) in favor of concentrating their efforts on in-person trainings in order to work on streamlining the training protocol. In all of these projects, the live trainings have been recorded for volunteers to view asynchronously as needed.

When asked how the projects offering hybridized training monitored completion rates, responses ranged from “the honor system” to relying on third parties (SciStarter and National Geographic) that provide and monitor volunteer training progress.

*Table 4.1.2: Training Format Options in Citizen Science Projects*

<b>Project Name</b>	<b>Synchronous Training</b>	<b>Asynchronous Training</b>	<b>Hybridized Training</b>
Bumble Bee Atlas	Field-based-Optional Tech-based-Required	Required if cannot attend synchronous training	Required to attend field-based training
Dolphin Spotter	Field-based-Optional	Required	Optional
NASA Exoplanet Watch	Tech-based-Optional	Required	N/A
Iguanas from Above	Not Offered	Optional	N/A
KTESST	Field-based-Optional	Optional	Optional
Leave No Trace	Field-based-Required Tech-based-Optional	Optional	Optional
Microplastics Pollution Monitoring Program	Field-based-Required	Optional	Not Offered
Monarch RX	Not Offered	Optional	Not Offered
NASA Citizen Science Portal	Not Offered for Portal	Optional for Portal	Not Offered for Portal
Globe Cloud Gaze	Tech-based-Optional	Required on mobile app	Optional
NE Butterfly Surveys	Field-based-Required Tech-based-Not Offered	Required if cannot attend field-based training	Not Offered
Community Science with NE Game & Parks	Field-based-Optional Tech-based-Optional	Optional-availability depends on project	Optional-availability depends on project
NE Master Naturalist	Field-based-Required	Required if cannot attend all field-based trainings	Required if unable to attend all field-based trainings
Penguin Nest Check	Not Offered	Required	Not Offered
Salt Watch	Field-based-Optional Tech-based-Optional	Optional	Not Offered
Save Our Streams	Field-based-Required Tech-based-Optional	Required	Required for certification
SciStarter.org Citizen Scientist Training	Tech-based-Optional	Required	Optional
The Citizen Scientist Project	Field-based-Required Tech-based-Optional	Required for Teacher Education Program	Required for all programs
Time to Restore (USA National Phenology NW)	Field-based-Optional Tech-based-Optional	Optional	Required to complete either type of training
UW Dragonfly Monitoring Project	Field-based-Required Tech-based-Optional	Optional	Optional
Cedar Creek Reserve (Woodpecker Cavity Cam)	Field-based-Required Tech-based-Optional	Optional	Optional for CCR N/A for WCC
NC State-Citizen Science Campus	Field-based-Optional Tech-based-Required	Required	Required

Bumble Bee Atlas provides an example of how citizen science projects offer hybridized volunteer training programs. The following quote and images (Figures 6, 7, and 8) discuss their volunteer training protocol and how that training is offered in a hybridized format:

*Anybody that attends a field training, we ask them to watch the online training...If they attended that (training) they can go to the in-person training. If they want to go to the in-person training and they missed the online webinar, we have recordings. So, they're always available for people.*



Figure 6: Bumble Bee Atlas Virtual Training Announcement on Facebook, <https://www.facebook.com/groups/171717265280499>, accessed 5/12/2023



Figure 7: Bumble Bee Atlas Field Training Announcement on Facebook, <https://www.facebook.com/groups/171717265280499>, accessed 5/12/2023

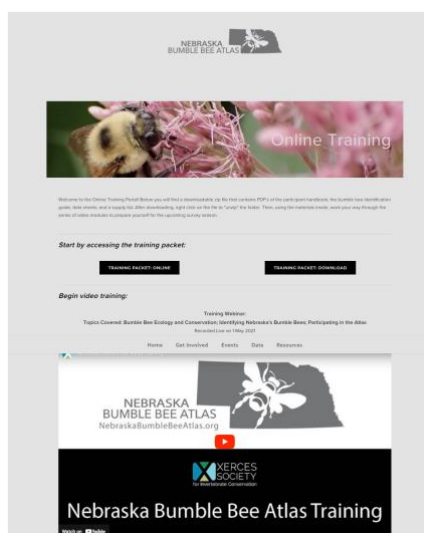


Figure 8: Bumble Bee Atlas Virtual Training Recording and Materials, <https://www.nebraskabumblebeecall.org>, accessed 5/12/2023

Field-based citizen science projects have always embraced physically-mediated learning opportunities whether it be through in-person training or offering handouts at farmers markets. Many of these projects have also adopted technology to support volunteer training opportunities. While many of the field-based projects in this study require the completion of initial online training prior to moving on to in-person training, others are leaving this format as an option for volunteers. In either case, findings show that technology is a prominent influence in supporting learning.

## **4.2 Technology as a Support for Learning**

It makes sense that citizen science projects will take advantage of as many resources as they can to support the learning goals they have for their volunteers. Using technology as a support of learning is no exception. Many projects reported that they rely on technologies like online platforms and mobile apps for data collection and analysis—tools which may or may not require additional training for volunteers to use effectively. Examples of the platforms and applications reported by project representatives and confirmed through document analysis include: SciStarter, Zooniverse, Anecdata, CitSci.org, iNaturalist, Nature’s Notebook as well as a few project-specific online tools and mobile applications. Additionally, the use of social media, like Facebook, Twitter and Instagram, and other sociotechnical systems, like YouTube and Zoom, were also shown to be used as a support for volunteer learning. Technology uses that impact volunteer learning falls into two additional themes: technological mediation of project tasks and sociotechnical-mediated learning opportunities. Technology-mediated project tasks were functional and research-focused, while sociotechnically-mediated learning opportunities served as enrichment.

### ***4.2.1 Technological Mediation of Project Tasks***

Technological mediation of project tasks refers to a project’s use of ancillary services, platforms, and/or mobile applications for data collection and analysis. While all 22 projects and programs had an online presence of some sort, 12 of the 22 (55%) projects used a third-party service or app to mediate project tasks, i.e., Zooniverse, iNaturalist, Anecdata, CitSci.org, or Nature’s Notebook. The remaining projects reported use of technology to mediate volunteer activity, but these projects relied upon proprietary or project-specific websites and mobile apps for

such activities. Either way, additional training was necessary for volunteers to complete tasks using the Zooniverse, iNaturalist, Nature's Notebook projects as well as for the 3 projects using proprietary or project-specific applications.

Additionally, several of these projects incorporated multiple third-party or proprietary platforms for project task mediation based on the type of participation or observation being completed by the volunteer. For example, USA National Phenology Network volunteers can choose between Nature's Notebook or iNaturalist to upload their observations based on the type of observation data they are collecting. Nature's Notebook "is great for repeated observations of the same plants over time," while iNaturalist "is great for species identification assistance and one-time observations in a place you don't plan to return to."

On the iNaturalist platform, supplemental training is provided to explain what an observation is and how to post them onto the platform using the volunteer's technology of choice (see Figure 9).

**Getting Started**

Hi and welcome to iNat! This guide will walk you through some of the main features of the site.

Help

Getting Started

Video Tutorials

Community Guidelines

Contributor Guide

Managing Projects

Botanist Guide

Teacher's Guide

Help Us Translate

Posting Observations | Exploring Observations | Organisms | Identifying Observations | Places

**Posting Observations**

This article describes:

- What are observations?
- How to make an observation with your iPhone
- How to make an observation with your Android
- How to make an observation from the web
- How to import observations from Flickr

**What Are Observations?**

An observation records an encounter with an individual organism at a particular time and location. This includes encounters with signs of organisms like tracks, nests, or things that just died. When you make an observation, you'll record:

- Who you are**  
You'll need to make an iNaturalist account and please only post your own personal observations.
- Where you saw it**  
Record both the coordinates of the encounter as well as their accuracy. You can obscure the location from the public.
- What you saw**  
Choose a group of organisms like butterflies or better yet a specific organism like the Monarch butterfly. If you provide evidence you can leave this blank and the community can help.
- When you saw it**  
Record the date of your encounter, not the date you post it to iNaturalist.
- Evidence of what you saw**  
By including evidence like a photo or sound, the community can help add, improve, or confirm the identification of the organism you encountered. Help the community by taking clear well framed photos, by including multiple photos from different angles.

Your observations don't need to include all of these parts, but they do in order to become research quality observations for science. Remember, you should make separate observations for each separate organism you encounter.

Figure 9: iNaturalist Getting Started: Posting Observations




Additionally, Nature's Notebook has an extensive training program available for volunteers to learn how to use their own software. The image below (see Figure 10) from the Nature's Notebook website provides an outline of the training materials available with each item represents a link for more training.

Nature's Notebook Home | USA-NPN Home | Help  SEARCH

**nature's notebook** MY OBSERVATION DECK

OBSERVE - EDUCATE - FOR GROUPS - MORE WAYS TO CONNECT -

Home » Observe » Learn How to Observe

 Once you pick a site and species, and register them online, you're ready to observe. Download and print your datasheets and head outside!  
Image credit: California Phenology Project

## Learn How to Observe

Follow the steps below to learn how to observe in your back yard.  
To view these instructions in Spanish:  
[Versión en español](#) (con una [introducción a la Red Fenológica](#))  
View our [printable instructions](#) for getting your sites set up outside.  
Or, learn how to observe if you are part of a [group](#).

- › 1. JOIN NATURE'S NOTEBOOK
- › 2. SET UP YOUR ACCOUNT
  - › Choose a Site
  - › Choose Plant and Animal Species
  - › Set Up Your Sites and Species Online
- › 3. START OBSERVING!
  - › Get Organized To Go Outside
  - › Record Plant Observations
  - › Record Animal Observations
  - › Submit Observations Online

**Observe**

Why Observe?

Become an Observer

My Observation Deck


**Learn How to Observe**

The Plants and Animals

Join a Campaign



**NATURE'S NOTEBOOK RESOURCES**


Use the [resources](#) we have created to help you become a better observer!

 **Repetition isn't redundant... Yes! Yes! No!**

When making *Nature's Notebook* observations for your species, each of the phenophase observation questions should be treated individually. Your answer to each phenophase question, even though the observation may seem similar to another observation question, may help to discern behavior patterns for the species at a future time. Each observation recorded helps analysts to tease out those specific species' behaviors. So, it is important to record no or yes to seemingly similar questions.

[See all Nature's Notebook Nuggets »](#)

FOLLOW US  

 **Nature's Notebook mobile apps for Android and iPhone.**

[About Us](#) | [FAQs](#) | [Glossary](#) | [Accessibility](#) | [Terms of Use](#)

Nature's Notebook is a project of the USA National Phenology Network.



 

Figure 10: Nature's Notebook-Learn How to Observe, <https://www.usanpn.org/nn/guidelines>, accessed 5/13/2023.

Bumble Bee Atlas uses the Bumble Bee Watch data collection infrastructure provided by the Xerces Society, the organization that sponsors Bumble Bee Atlas. Bumble Bee Watch has both an online interface as well as a mobile app dedicated to collecting data from volunteer observations. Volunteer training from Bumble Bee Watch includes how to use each system plus additional training on how to make and submit quality observations. The YouTube video tutorial below is just one example of the training options available for volunteers to engage with:

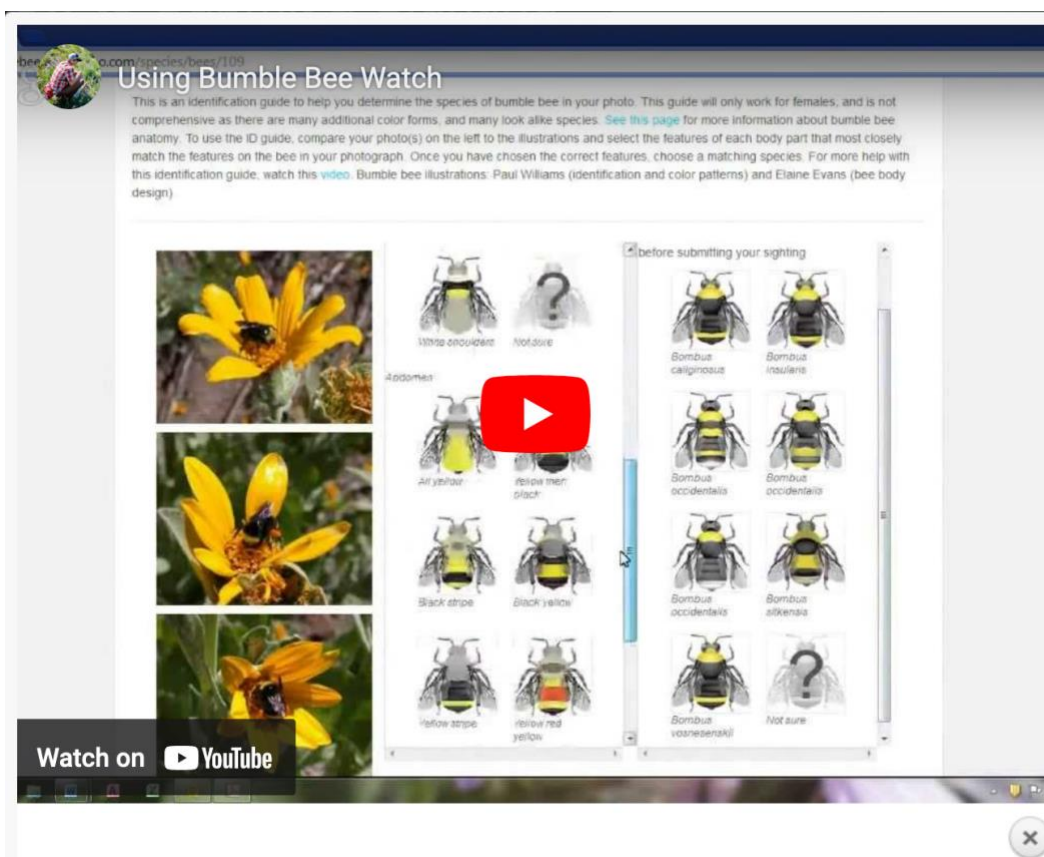


Figure 11: Video Tutorial for Bumble Bee Watch Website and Mobile App from the Xerces Society (<https://youtu.be/p7Kp3Awf2MQ>), accessed 5/13/2023.

#### ***4.2.2 Sociotechnical Media as a Support for Learning***

The sociotechnical media reported by the 22 projects interviewed in this study goes beyond what is normally thought of as social media. It includes email, Facebook, Instagram, Twitter, YouTube, and virtual meeting platforms, i.e., Zoom, Skype, etc. Moreover, there were a few projects that reported use of other sociotechnical media such as blogs and newsletters, Slack, or even Tik Tok to support volunteer learning. Project use of these platforms has already been discussed in the Learning Opportunities section of this chapter (section 4.1.2), but the extent to which they are used by citizen science projects warrants a deeper investigation.

Sociotechnical media were a significant support to volunteer learning for all 22 projects as it gave those projects means to broadcast information about project outcomes and educational outreach opportunities to their volunteers. 20 of the 22 projects reported using social media of one kind or another to communicate with their volunteers and document analysis found that the two projects that did not mention social media use during the interviews were actually engaging the public (and their volunteers) on a number of social media platforms. An example of what social media use looks like comes from Nebraska Master Naturalist on Instagram. Here, the post below is providing notice of openings in an upcoming in-person training, thus communicating educational outreach and volunteer training opportunities to other users on Instagram (see Figure 12):



Figure 12: Nebraska Master Naturalist on Instagram, accessed 5/13/2023.

It should be pointed out there were two project leaders, one from NASA Globe Cloud Gaze and one from Penguin Nest Check, that do not do or at least severely limit their personal engagement in social media communication due to the age range of their participants, i.e., school-aged children in grades K – 12. As noted by the program director of NASA Globe Cloud Gaze, this decision to not engage is most likely due to agency policy, which may be influenced by federal laws like COPPA (Children’s Online Privacy Protection Act, 1998).

*If you go to the (NASA) Globe program, you won't see a chat. That's because we want to protect children...The benefit of partnering with (NASA) Globe or Globe Cloud is that we use the (NASA) Globe program social media team, and then we go under the guidance of NASA policy. So, there is a social media presence, there's just rules that we need to follow, like how do we respond back to messages or interact (with participants). But social media is hands down the best way to communicate about something.*

Technology is an important tool for citizen science—especially as a support for volunteer learning. It provides access to resources and training that volunteers can reach at will, it helps

projects instruct how volunteers complete their tasks, and it provides an avenue for them to communicate with others in a public-facing and more engaging way. In that regard, sociotechnical media gives citizen science projects a variety of methods to support their research and outreach objectives. The sections that follow reveal the unique organizational, sociocultural, and physical contexts of citizen science projects that reflect the ways that they support volunteer learning.

### **4.3 The Multiple Contexts of the Project**

The document analysis revealed that the projects themselves had their own unique contexts that can affect what, how, and to what degree they support volunteer learning. For instance, in the six online projects, it was evident that the physical context of being a technology-mediated project influenced how the project could facilitate and support volunteer learning. This observation was mirrored in the review of artifacts from field-based projects as well—how a project approaches and supports volunteer learning is a product of that project’s unique organizational, sociocultural, and physical contexts.

The interviews provided greater insight into the contexts of volunteer learning goals, including the impact of project and volunteer contexts along with other influences such as social distancing and COVID restrictions, funding and money and staffing. These contexts naturally impacted the opportunities they could provide to support their education and research goals. This section looks at the organizational, sociocultural, and physical contexts of the 22 citizen science projects that influenced project volunteer learning goals and the strategies put in place to support those goals.

### **4.3.1 Organizational Context**

Similar to the original interpretation of the CML, there are “personal” characteristics of the project that have an impact on volunteer learning goals and opportunities. These characteristics from the original model include choice and control; motivation and expectations; and prior knowledge, interests and beliefs.

**4.3.1.1 Choice and Control:** In the CML this traditionally refers to the power a person has to choose when, where, and what they learn (J. H. Falk, 2002). In this research, organizational choice and control refers more to the decision-making processes a project goes through as they develop their research-focused and outreach-focused learning goals and look at how to support those educational outreach and volunteer learning goals. An example from Microplastics Pollution Monitoring Program regarding their volunteer recruitment criteria and processes describes the educational outreach strategy they implemented:

*Mostly I am getting volunteers and teachers and students who are interested in the project by reaching out to them directly... What I do is we'll essentially just reach out to every principal or teacher I can find in every school in each county and see who responds.*

**4.3.1.2 Motivation and Expectations:** Although motivation and expectations are combined into one characteristic in the CML, given the application of those characteristics to citizen science, these are conceptually distinct at the organizational level. Project expectations related to the assumptions projects had regarding the abilities or skills their volunteers possess or are capable of acquiring over time with training. For example, Monarch Rx voiced their concern regarding the complexity of the project task being asked of their volunteers:

*I have the impression we might overburden some of the volunteers with the complexity of our question, because the background is, you*

*know, it's unexpected to see butterflies gathering toxins from dry organic materials.*

On the other hand, project motivation relates to the purpose of a project—motivation supports the answer to the project’s “why”. For example, NASA’s Exoplanet Watch describes one of their overarching project motivations, “My goal from day one to make this project is that Exoplanet Watch is for anyone and everyone, so not only astronomers, but anyone that has an interest in exoplanets and science and NASA and space.” This motivation related to inclusion had a meaningful influence on their volunteer learning goals by prioritizing how they present training materials for all skill levels.

**4.3.1.3 Prior Knowledge, Interests and Beliefs:** The final characteristic in the project’s organizational context is prior knowledge, interests, and beliefs. In three projects, it was the project leader’s *personal* individual prior knowledge, interests, and beliefs that most directly influenced project learning goals. One such comment came from the Citizen Scientist Project, describing the project leader’s prior experience as an educator, “I think that as a teacher, educator, learning is always at the center of whatever we do, whether it's teaching teachers, or you know, teaching students directly.” This quote clearly indicated how the personal experiences of the project leader shaped the project goals related to learning.

However, there were a couple of projects with recent staff changes, where the *project’s* collective prior knowledge, interests and beliefs influenced current learning goals and training efforts. An example comes from Save Our Streams where a recently hired regional coordinator discusses the project’s pre-existing network helped them understand the project’s learning goals and how they were supported:

*I (Atlantic Region Project Coordinator) think, in addition to everything, (Midwest Region Project Coordinator) said, the pre-existing network, that at least, we've both come into—neither of us really had to start from scratch. And so, definitely for me, there's already such a strong network of people that I just kinda ride the wave with the promotion that they do.*

Like the personal context in the CML, findings showed similar characteristics at the organizational level in citizen science projects—albeit with some distinct differences in how these attributes are defined. However, as with the original model, each one of the characteristics within the organizational context of the project had a role to play in the project's volunteer learning goals and how they are supported. The next section looks to find project which characteristics within the sociocultural context of the CML can also have an impact on learning.

### **4.3.2 Sociocultural Context**

Findings regarding the sociotechnical support of project interaction and volunteer learning were reported in Sections 4.1.2 and 4.2 of this chapter. This section, however, focuses on the sociocultural contexts, i.e., facilitated mediation and peer-group social mediation of the project. How these contexts influence a project's learning goals will be discussed a little later in the chapter.

**4.3.2.1 Facilitated Mediation:** At the project level, facilitated mediation refers to the ability of the project to engage with volunteers during learning opportunities. As mentioned earlier, these opportunities can be in person or virtual, synchronous or not, or in any combination of these formats. In all but one project, projects engaged with their volunteers in project-facilitated learning situations in some form or another, but primarily through volunteer training sessions and



interaction with volunteers on social media and/or in discussion boards. About half of the mentions of project-facilitated mediation co-occurred with a project's informative outcomes and educational outreach goals. This quote from Cedar Creek Reserve-Woodpecker Cavity Cam demonstrates the relationship between informative outcomes and project-facilitated mediation as she discusses taking volunteers on tours to restricted areas to learn more about the other research projects going on at the reserve:

*I have been trying to put together some kind of volunteer appreciation events—take them to other places on the property (they're not accustomed to going), take them on a research tour or a driving tour, or give them an opportunity to walk and see how it all fits together.*

Generally speaking, facilitated mediation of volunteer learning comes with the territory for citizen science projects. This type of engagement is expected and a natural course of action as projects work to train and engage with their volunteers. Another natural influence on citizen science projects were the partnerships that define a project's peer-group as part of their organizational environment.

**4.3.2.2 Peer-Group Social Mediation:** 15 of the 22 project interview transcripts demonstrated peer-group social mediation at the project level. Respondents often reported having partnerships with other organizations, collaborations with stakeholders, or working with sponsors and steering committees to achieve project outreach-focused and research-focused goals. An example of organizational peer-group social mediation comes from the Nebraska Game and Parks Community Science Program Director:

*Trying to do this cross-level guidance or teaching facilitation, it takes a lot of collaboration (with other Nebraska Game and Parks divisions) in order to be able to build trust and in order to be able to have those relationships. It's essential for my job to make sure that we're doing community science really well. But I don't have direct control over facilitating [teaching].*

This project-level peer-group social mediation was also evident in many of the online documents. For example, the Nebraska Master Naturalist program lists their program partners on their website, a common practice among citizen science projects. The image below gives just a sample of the partnerships and sponsors affiliated with the project. In reality, Nebraska Master Naturalists reports more than forty partners and sponsors, and has relationships with many more.

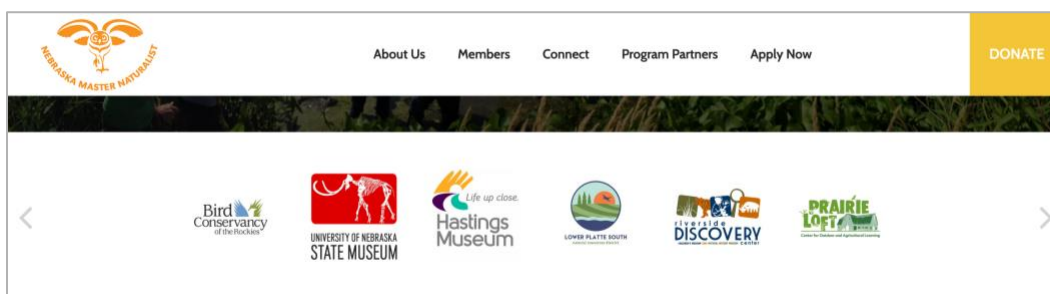


Figure 13: Nebraska Master Naturalist, Program Partners, <https://www.nemasternaturalist.org/program-partners/about-the-program.html>, accessed 5/05/2023.


USA National Phenology Network also has a large partnership and collaboration circle, as the title of “network” suggests, although their description of those relationships is less specific and represents more collaborative arrangements than sponsorship relationships as shown in Figure 4.14. In all of these examples, peer-group social mediation and knowledge sharing played a role in the contextual make up of citizen science projects.

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It is through our partnerships with governmental agencies, NGOs, academic institutions, and more that we are able to carry out our mission to collect, store, and share phenology-related information.


Image credit: California Phenology Project

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- Educators
- Citizen Scientists

**OUR PARTNERS**

Partnerships are critical to the USA National Phenology Network and are supported by a National Coordinating Office. Together, we work to advance the mission of the USA-NPN.



Search all active Local Phenology Programs or view all LPPs with Impact Statements.

We recognize other Phenology Networks around the world:

[Global Phenology Networks](#) - Over the last several years, representatives from the International Society of Biometeorology Phenology Commission (ISB-PC) and the World Meteorological Organization Commission for Agricultural Meteorology (WMO-CAGM) have been discussing the concept of a "Global Alliance of Phenological Observation Networks" (GAPON). [This webpage](#), constructed by the USA National Phenology Network, with assistance from ISB and WMO-CAGM, is an initial attempt to move forward in this area.

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<ul style="list-style-type: none"> <li>About Us</li> <li>Our Partners</li> <li>Why Phenology?</li> <li>A National Indicator</li> <li>Staff</li> </ul>	<ul style="list-style-type: none"> <li>Partner with Us!</li> <li>Researchers</li> <li>Natural Resource Managers</li> <li>Educators</li> <li>Citizen Scientists</li> </ul>	<ul style="list-style-type: none"> <li>Explore Data</li> <li>Observational Data</li> <li>Models and Maps</li> <li>Visualization Tool</li> <li>Data Quality</li> </ul>	<ul style="list-style-type: none"> <li>Peer-reviewed Results</li> <li>Our Reports</li> <li>Our Newsletters</li> </ul>	<ul style="list-style-type: none"> <li>Status of Spring</li> <li>Pheno Forecasts</li> <li>News</li> <li>Events</li> </ul>

Figure 14: USA National Phenology Network, Our Partnerships, <https://www.usanpn.org/partner/current>, accessed 5/05/2023.

### 4.3.3 *Physical Context*

The physical context describes project design strategies as well as the cues provided to others that describe the what, why and how of the project (i.e., a project's orientation). Given that this research focuses on the project perspective (rather than the volunteer), concepts in the CML were extended to include organizational characteristics and factors that may have an impact on a project's priorities concerning their approach to volunteer learning, discussed further in Chapter 5. These factors (as defined in Appendix C) included COVID restrictions as well as factors within the project's organizational space such as funding/money, staffing, and time. Section 4.1.2 has already reported findings on project design goals and characteristics, and Section 4.1.1 has reported findings that speak to a project's goals and objectives, so this section focuses more on the influences reported to impact a project's strategy for achieving their learning goals.

**4.3.3.1 *Project Design and Orientation:*** As discussed in Chapter Three, Section 3.6, the physical context includes the project's design strategies (i.e., form or structure of the project) as well as the project's overarching purpose and function (i.e., orientation). These themes were relevant across all interviews. However, while most of the data regarding the influence of format on project success was overwhelmingly positive, North Carolina State-Citizen Science Campus provides a different perspective on how some technological mediation can actually be a negative influence that prevents volunteers from engaging in learning opportunities:

*It's (SciStarter) not a perfect system technology-wise for us. It's just this difficulty with there being so many projects with their own logins. And then, trying to aggregate those observations together; and that requires another login. It just puts it over the top for a lot of people.*

What a project wants to accomplish with volunteer participation also influences their learning goals and the opportunities that are offered to support them. These goals and objectives can be related back to the project's function and purpose (i.e., its orientation). When looking at the ways in which a project's goals and objectives can influence how and to what extent a project supports volunteer learning, a quote from Leave No Trace provides an example how the organizational values of the project can influence how they prioritize volunteer learning goals:

*Volunteerism and stewardship, they've always been things that have been important to us. But it's really just over the last couple of years that we've really written those things into our strategic planning.*

Across the interviews, a project's physical characteristics as well as their orientation were factors that influence the learning goals and opportunities a project can strategically support.

**4.3.3.2 COVID and Influences of the Project's Organizational Space:** COVID, money, staffing, and time were the largest factors respondents reported impacting their educational outreach and volunteer learning objectives. COVID restrictions were noted by 15 of the 22 contacted projects (68%) as a substantial influence on how they engaged with and trained their volunteers. Several of those projects directly attributed their current hybridization of training and volunteer learning to the limitations imposed on public gatherings during the pandemic, i.e., "with COVID we transitioned part of that (training) to be online, and we've kept it in this hybrid format since then" (Save Our Streams.)

Additionally, there were many projects reporting increased interest in their projects during COVID. For example, Salt Watch noted increased public attention to the project during this time frame:

*They (people) wanted to get out, they wanted to do a citizen science project or community science project that they didn't need in-person or online training for, but they wanted to get out and explore the outdoors. So, I think that was something that also led to a bunch of volunteer attention (during COVID restrictions).*

However, COVID also took its toll on many projects, and they have yet to recover to pre-COVID participation levels as noted by the educational outreach director for Penguin Nest Check, “I know that I’m down because of COVID. I lost a lot of traction with two years not being able to do it.” So, while COVID changed how many projects engaged with their volunteers, and some reported that it was a positive outcome, it wasn’t necessarily a positive for everyone.

Obviously, funding and money are always going to influence what a project can and can’t do with educational outreach and volunteer learning opportunities. In fact, only 4 of the 22 projects (18%) did *not* mention funding as a contributing factor. However, looking at the projects that *did* report funding as a factor, this quote from Nebraska Master Naturalist offers some insight in how grant funding can “giveth” and how lack of that funding can “taketh away”:

*The goal was to have Master Naturalists in the schools. That got funded by the Claire M. Hubbard Foundation, and that started going really good. We teamed up with the NRDs (Natural Resource Districts) to get that in the schools... It’s on hold right now until we get another grant.*

Staffing capacity was another factor that was reported by 16 of the 22 projects (72%) to have an influence on a project’s outreach and learning goals. While lack of staffing is often a negative factor—and was the primary response from interview respondents—there were a couple of projects and programs that reported staffing as a more positive influence on volunteer learning. An example of this finding comes from a quote by NASA’s Citizen Science Director, “The Science

Activation Projects (sponsored by NASA),...they all have a mandate to their funding to help people learn things...They have a lot more resources and experts on the team to help.”

Not surprisingly, time is not necessarily on a project’s side, and is often related to the level of staffing at project. For 8 of the 22 projects (36%), time was a factor that interview respondents reported as influential in how they are able to approach educational outreach and volunteer learning goals. For example, the education coordinator from Leave No Trace reported how staff time impacts their outreach and training decisions, “We have to really look at everything that comes in and prioritize and decide what we're able to actually work on and conquer for the year. So, it really comes down to (staff) time.” On the other hand, it was interesting for Bumble Bee Atlas’ project coordinator to note that having just one region to have as her priority provided her with the time to engage in educational outreach activities and build stronger relationships with the volunteers in her region:

*We're not trying to do 6 projects at once, but rather we put all of our effort into making these projects really good, creating relationships with our volunteers, doing some analysis, sharing that information out so that it's more...It's well rounded.*

Regardless of the amount of time a project has to use, available staff time influences the degree to which projects can pursue their educational outreach and volunteer learning goals.

In summary, the findings show that citizen science projects have their own unique organizational, sociocultural, and physical contexts that shape their volunteer learning goals and the resources they provide to support those objectives. Moreover, COVID and other influences tied to a project’s organizational space (i.e., funding, staffing levels, and staff time) have been shown to affect their volunteer learning goals as well. In the final section of this chapter, the focus

moves back to the individual, and findings regarding the volunteer's personal and sociocultural contexts are presented.

## **4.4 The Multiple Contexts of the Volunteer**

The CML states that what and how well a person learns is largely dependent upon the personal, sociocultural, and physical contexts of that person (J. H. Falk & Dierking, 2018). While it is possible to gather some insight into volunteer characteristics through the analysis of online artifacts (mostly through review of social media sites, discussion boards, and project statistics), this study describes projects' understanding of their volunteer base as reported in interviews. Combining these data, it was possible to identify relevant aspects of the volunteers' personal, sociocultural, and physical contexts and how that impacts the strategies used by projects to support intended volunteer learning.

### **4.4.1 Personal Context**

As a reminder, the personal context of the CML includes the characteristics of choice and control, expectations and motivation, volunteer demographics, and prior knowledge, interests, and beliefs, all of which were represented in the data. The following sections review how these concepts apply to citizen science.

**4.4.1.1 Choice and Control:** Offering volunteers with options in how and when they learn was a significant strategy projects used to enhance volunteer engagement with the project's training and other learning opportunities. In fact, 20 of the 22 projects mentioned volunteer choice and control during the interview. Options varied from project to project but generally fell within a couple of themes: training options and use of technology for collecting and submitting data.



Examples of training options and learning opportunities offered to volunteers have been discussed a number of times throughout this chapter. However, giving volunteers some control over how they collect and submit their data (which relates to multiple learning goals) was also discussed in connection with multiple goals. An example of this finding comes from UW Arboretum Dragonfly Monitoring Project where the director discusses accommodating volunteers who choose not to submit their data electronically:

*Another option that we provide is—if they are really passionate about volunteering and collecting the data, but they absolutely hate, and will not use the platform....Just send me your data sheets. Just drop them off one day, and I'll upload them for you. So, I think, not wanting that to be a barrier is important.*

**4.4.1.2 Motivation and Expectations:** Motivation is the willingness for individuals to engage in an activity (Jennett et al., 2016), and expectations are an individual's perception regarding the experiences that occur during that activity (Skarlatidou et al., 2019). According to the CML, learning is bolstered when it is personally rewarding and the expectations regarding the experience are satisfactorily met (Liu & Falk, 2014). Projects were able to speak to their volunteers' motivation much more confidently than they could to volunteer expectations. This is not at all surprising, however, given that volunteer motivation is one of the most studied aspects of participation in citizen science. On the other hand, volunteer expectations were mentioned infrequently, likely due to lack of direct questioning, but possibly also demonstrating limited project understanding of the concept. As result, findings from this study speak predominantly to projects' appeals to both intrinsic and extrinsic motivators to encourage volunteer engagement and project participation.

For example, this quote from KTESST speaks to the intrinsic motivators they have observed in their volunteers:

*They're (volunteers) interested in... testing their well water. We had someone who was interested because they bought property with a pond, so that's what they tested. And so, I think it really depends on what takes their interest.*

Additionally, providing supplemental learning materials for volunteers to grow their content knowledge – which was done by all 22 projects – is a response to another intrinsic motivator, i.e., appeal to curiosity. NASA's Exoplanet Watch has a creative delivery of this supplemental material by calling their repository for this content the “Exoplanet Travel Bureau” (see Figure 15):



Figure 15: NASA Exoplanet Watch, supplemental learning resources, <https://exoplanets.nasa.gov/alien-worlds/exoplanet-travel-bureau/> accessed 5/05/2023.

Many projects also reported extrinsic motivators associated with volunteer participation such as recognition opportunities on social media, awards for service, and even initiation of contests and leaderboards. Most projects discussed extrinsic motivation more for retention than for learning. An example of this result comes from Nebraska Master Naturalist as the director talked about the awards banquet and social event held every year:

*Every year we try to have a social event, at least one social where we give accolades for years of service, for hours of service... We'll get 50 to 100 people at those things; and that ... recharges them and keeps them (volunteers) going.*

While intrinsic motivation is more closely related to learning, and these results are consistent in that projects appeal to volunteers' extrinsic motivators in hopes of keeping their trained volunteers engaged in their projects.

**4.4.1.3 Demographics:** Volunteer demographics have been a point of interest in citizen science for quite some time (Pateman et al., 2021) in part due to the tremendous influence some characteristics have on the way projects designed learning goals and supports. As a result, interviewees were directly asked about this issue and their responses focused on the following three themes: age groups, education level, and ethnicity.

Age-related categories included identifiers such as adult, child, all ages, and retirees and were reported by 16 of the 22 projects (73%). In line with the literature, 13 of the 16 projects (81%) reported older adults and retirees as their primary volunteer base (Spiers et al., 2018). Adult volunteers were reported by 7 projects, and children (outside of students) were reported by 2 projects. The final category, all-ages, was reported by 7 projects that noted volunteers from a wide range of ages participating in project tasks.

Three projects reported actively engaging with elementary school children (i.e., K-6). These projects are Penguin Nest Check, NASA Globe Cloud Gaze, and Cedar Creek Reserve-Woodpecker Cavity Cam. Additionally, the NASA Citizen Science program also provides educational resources for elementary school children. The table below provides educators with access to age-appropriate project resources as well as guidance on how to use NASA projects for education for particular age groups.

<b>NASA Citizen Science Project</b>	<b>K - 5</b>	<b>6-8</b>	<b>9-12</b>	<b>13-16</b>	<b>Standards Connections</b>
1. <a href="#">GLOBE Clouds - GLOBE Observer app.</a>	ESS	ESS	ESS		NA
2. <a href="#">GLOBE Trees - GLOBE Observer app.</a>	ESS	ESS	ESS		NA
3. <a href="#">GLOBE Land Cover - GLOBE Observer app.</a>	ESS	ESS	ESS		NA
4. <a href="#">GLOBE Mosquito Habitat Mapper - GLOBE Observer app.</a>	ESS	ESS	ESS	ESS	NA
5. <a href="#">Goldstone Apple Valley Radio Telescope (GAVRT)</a>	ESS	ESS	PS		NGSS
6. <a href="#">Growing Beyond Earth</a>		LS	LS		Florida State Stds
7. <a href="#">Planet Hunters TESS</a>		ESS		ESS	NGSS, CC ELA / Math
8. <a href="#">The International Astronomical Search Collaboration (IASC)</a>			ESS	ESS	NA
9. <a href="#">Radio JOVE</a>			PS	PS	NSES (1996)
10. <a href="#">Floating Forests</a>	ESS			ESS	NA

Primary NGSS DCI Domains: **LS** = Life Science   **PS** = Physical Science   **ESS** = Earth Space Science  
Abbreviations: NGSS = Next Generation Science Standards, CC = Common Core, ELA = English Language Arts, NSES = National Science Education Standards, NA = Not Applicable

Figure 16: NASA Citizen Science Educational Resource Guide, <https://bit.ly/LearnNASAcitsci>, accessed 5/12/2023.

Finally, there were only a couple projects that mentioned the educational attainment of their adult volunteers. In both cases, interview data noted volunteers being primarily people with professional, college, or graduate degrees, which is also consistent with the literature (Blake et al., 2018).

When asked about the demographic makeup of their volunteer base, 13 out of 22 (59%) projects commented on race and ethnicity. In 8 of those projects (61%), volunteers were reported to be predominantly white. The remaining projects either reported an international volunteer base or they are specifically and actively recruiting volunteers and participants from marginalized or under-represented sectors of their community.

**4.4.1.4 Prior Knowledge, Interests, and Beliefs:** Although volunteers' prior knowledge, interests, and beliefs were not emphasized, it is worth pointing out that these characteristics were

mentioned by half of the projects interviewed. One such example that speaks to the public's accumulated knowledge regarding the effects of water pollution comes from Save Our Streams:

*I would also say just the climate that we're in right now with environmental issues has kind of primed the pump for people to be receptive to this program, to community science in general. We're not starting out at the dawn of people being worried about clean water, we're about 70-80 years into that movement.*

Additionally, some projects were more keenly aware of the advantages of having interested volunteers, as demonstrated by this quote from KTESST, “by more directly targeting those who already have invested interest, we're hoping to increase our data recovery.” Thus, findings show there is some project understanding of the prior knowledge, interests and beliefs of the individuals they are engaging with, which can have an impact upon the learning goals and opportunities those projects choose to prioritize.

#### **4.4.2 Sociocultural Context**

For the most part, the CML points the focus of the sociocultural context of learning squarely on in-person learning that occurs with others, i.e., facilitated and peer-group socially mediated learning opportunities. However, learning in citizen science is often self-guided and/or technologically mediated. As a result, this study analyzed project leaders' understanding of the key social contexts in which their volunteers are learning.

**4.4.2.1 Facilitated Mediation:** In a surprising number of projects (15), facilitated mediation of learning was reported at the volunteer level—meaning that volunteers were positioned as the knowledge authorities in a learning situation with others. However, results from this study did not necessarily fit the literature where the transition from peer-group member to volunteer facilitator happens organically (Jackson et al., 2020). In this case, two other themes were evident: educators

bringing projects to the classroom and volunteers involved in train-the-trainer scenarios. In each of these cases, the projects themselves are the foundation for a learning opportunity within another curriculum. This moves outside the scope of this study, indicating a topic for further research.

**4.4.2.2 Social Mediation:** The social structures of volunteer participation were a little more complex than initially expected. Although there were 14 projects (64%) that spoke about the group dynamics of their volunteers, 8 of those respondents (57%) alluded to participation in multiple distinct roles, some of which invoke additional contextual factors (e.g., leading a program or teaching a class using the project as an experiential learning activity.) USA National Phenology Network offers insight into their experience:

*We do have backyard observers, which might be individuals who are looking at the phenology of the plants in their yards or somewhere local. And then we have those larger local phenology programs where usually you have a leader... So, the volunteers themselves may go in alone or in pairs, or they might have a group during training, but usually then they'll have a schedule where they're making regular observations on those plants, and they kind of do it on their own.*

There were a few projects (i.e., Nebraska Master Naturalist, North Carolina State-Citizen Science Campus, and USA National Phenology Network) that noted the very intentional creation of volunteer groups under their organizational umbrella. Nebraska Master Naturalist describes this finding:

*The majority of people love to be in groups and be social. So, that's why we have Chapters. We have a River City Chapter, and we have the Salt Creek Chapter here in Lincoln, and we have the Greater Omaha Chapter out of Kearney. They have their own little meetings, and they get together. And so, lots of times, when we have a Bio-Blitz, we very seldom get one master naturalist. We usually get 4 or 5, and they come together.*

Volunteers participate in projects on their own, with friends and family, or with other social groups organized within the project itself. The results here show that these social contexts of participation are dynamic and can vary due to location, organizational structures, as well as the nature of the participation tasks.

#### **4.4.3 Physical Context**

The physical context in this research is slightly different than the original definition provided by Falk & Dierking, which places the physical context of the CML in the material and to some extent digital spaces of the broadly-defined museum. In citizen science, however, the physical context of the volunteer is interpreted to include the method by which learning opportunities are provided and supported by the project. Overall, these findings were very similar to those for project strategies for educational outreach and volunteer learning (Section 4.1.2). However, there are couple of relationships worth pointing out.

Much like findings from physical contexts of the project, the interview data also show relationships between project characteristics and volunteer personal and sociocultural contexts, indicating a meaningful influence volunteer and organizational contexts have on citizen science projects. UW Arboretum Dragonfly Monitoring Project provides an example of the relationship between volunteer sociocultural contexts and project physical characteristics, where a project activity was created to provide a social context that volunteers wanted to experience:

*There were some people that only wanted to attend the dragonfly walks, and I think they enjoyed the social component of it...And then, with the introduction of the dragonfly walk, it's been a really nice way to make it a more social endeavor. So, we do have some of our volunteers that will come on those walks.*

This relationship between the volunteer and the project is also evident in the Facebook page from Bumble Bee Atlas (Nebraska, Missouri, Great Plains) demonstrating peer-group social mediation using sociotechnical communication that is managed by the project (see Figures 17a and 17b):

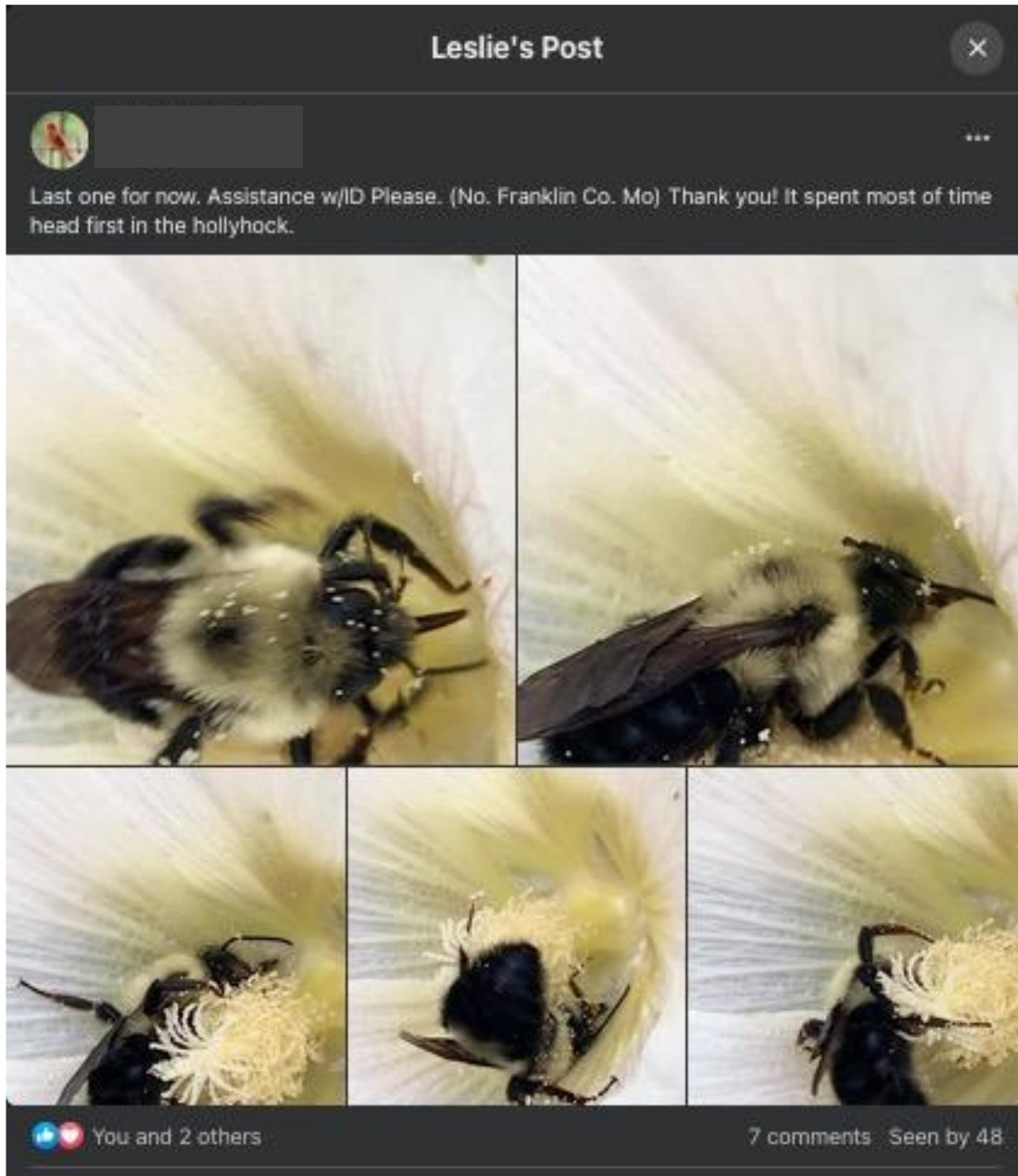


Figure 17a: Bumble Bee Atlas on Facebook, <https://www.facebook.com/groups/1717171265280499>, accessed 6/14/2023



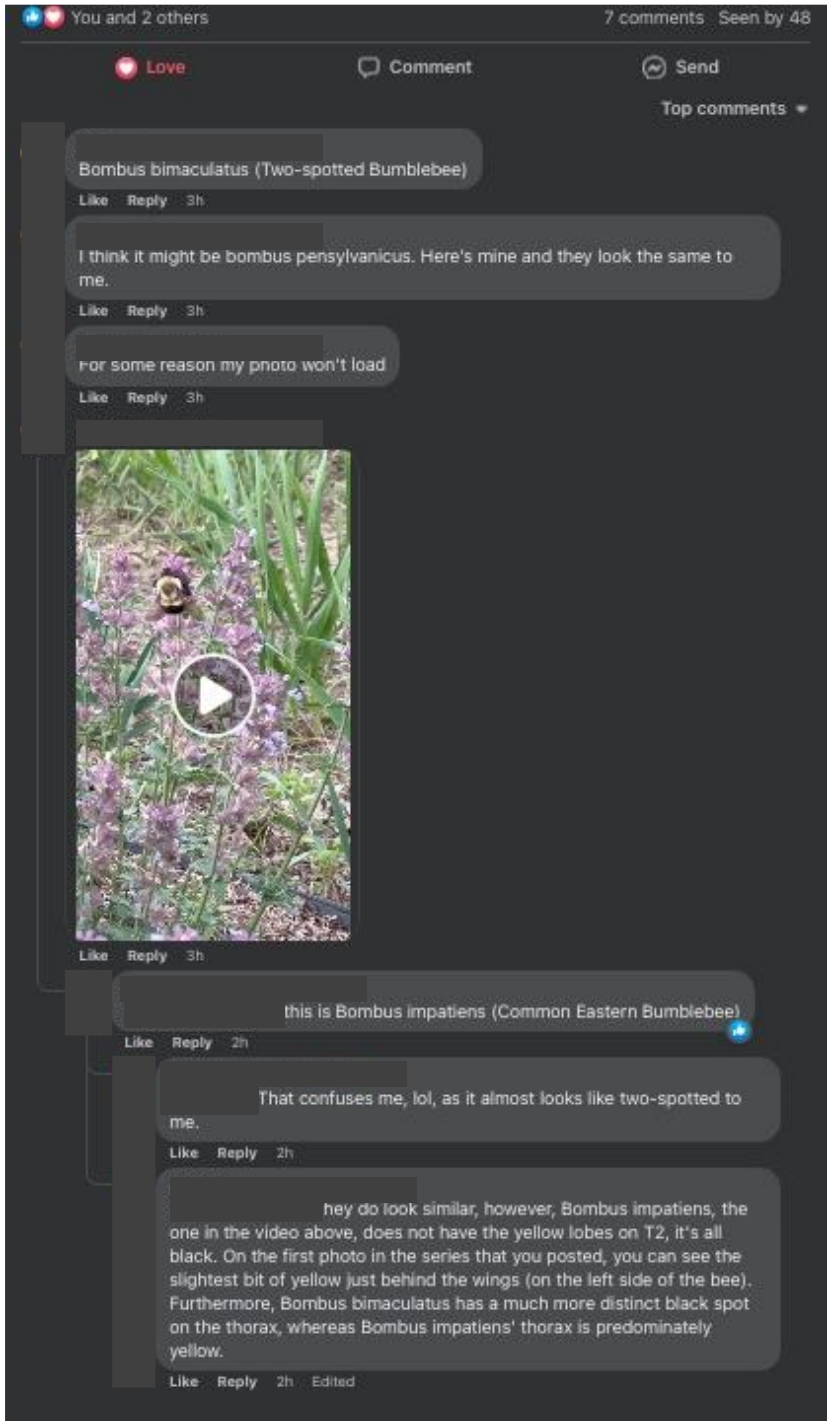


Figure 17b: Bumble Bee Atlas on Facebook, <https://www.facebook.com/groups/1717171265280499> , accessed 6/14/2023

Project leaders reported a fairly decent understanding of who their volunteers are and the social structures surrounding their participation in the project. Although citizen science projects are well-versed in what motivates their volunteers, findings discussed in this section also reflect that volunteer expectations regarding the project are not as well understood. Moving forward, this concept of volunteer expectations as well as volunteer-facilitated mediation of learning are topics for further research.

## **4.5 Threats to Validity**

For many critics, qualitative research “is anecdotal, illustrative, descriptive, lacks rigor, is unsystematic, biased, impossible to replicate, and not generalizable” (Edwards & Holland, 2013, p. 91). It is not real science. This section looks more specifically at the threats to validity contained in this study and explains how these critiques validity issues common to qualitative research can be mitigated, i.e., through careful planning, thoughtful instrument design, and thorough systematic and iterative analyses of the data. It ends with a discussion of the specific limitations imposed on this work given the pressures of time, money, and experience.

### ***4.5.1 Internal Validity***

Internal validity is defined as the extent to which the findings presented in research reflect the truth of the matter being studied (Norris, 1997). In this dissertation, internal validity was attained in a few ways: by asking the right questions in the interview, by using the appropriate codes during analysis, and by speaking with multiple parties involved in the same project. In the first instance, questions contained in the interview protocol were inspired by the CML while also being informed by my personal knowledge and academic experience in citizen science research. This protocol was then peer-reviewed, and a pilot interview was conducted where feedback was

provided regarding effectiveness of the questions asked to provide the responses needed for this study. Revisions were made to the protocol to better match this feedback prior to moving forward with interview partners.

In the second instance, deductive content analysis operationalizing the personal, sociocultural, and physical characteristics of the CML worked to ensure validity of the interview transcripts and project artifacts. Inductive coding of new themes in the data maintained internal validity by upholding naming conventions and definitions common to the citizen science literature as well as the CML where appropriate. Having said that, some terms were problematic within the CML, such as within-group social mediation, that required diversion away from those terms, though the definition of the characteristic remained the same.

The final way in which internal validity was accomplished involved speaking with multiple people within or involved with the same project in four separate instances (i.e., Save Our Streams, USA National Phenology Network, Penguin Nest Check, and SciStarter). Regarding Save Our Streams and USA National Phenology Network, interviews involved multiple members of the same organization at the same time. This helped interview partners in these two projects confirm answers to interview questions in real time and often provided me with deeper takes to these questions as well.

In the case of Penguin Nest Check, it was by chance that a 2<sup>nd</sup> grade class at a local school district had adopted one of the nests for the 2022-2023 season. I was able to speak with this educator regarding her experiences with the project and therefore could confirm my analysis of the data received in the interview with the coordinator from the project and the document analysis of the online materials. In another example outside of the two group interviews, North Carolina

State University-Citizen Science Campus uses SciStarter.org as a platform for their student engagement program. Through my interview with the coordinator of this program, I was able to check my analyses of the interview data and online artifacts. In each of these cases, speaking with others with different forms of involvement in the same project worked as member checking that helped validate the methods and analysis of this study.

#### **4.5.2 Reliability**

Reliability refers to the repeatability of a measurement or a result, i.e., when an instrument measures the same thing, it gives similar results with each test (Fitzner, 2007). It also refers to the trustworthiness of the research, “particularly in relation to the appropriate methods chosen, and the ways in which those methods are applied and implemented in a qualitative research study (Rose & Johnson, 2020).” When reliability is a concern, this inconsistency undermines the usefulness and value of the results. Ensuring reliability began with the iterative nature of the data analysis where, as new codes were discovered or older codes were updated, I would return to earlier interviews to incorporate those data into the analysis as well. To further ensure that the results were as reliable as they could be for a study involving the points of view of others--beyond consistency in protocol delivery and document analysis techniques—it was decided to maintain the interview schedule even when saturation had been reached after the 15<sup>th</sup> interview. Moreover, the final interview completed during data collection occurred more than a month after the next to last interview and while I was deep into the coding process. As such, I was able to verify the effectiveness of my interview protocol to give similar responses over time and with different respondents.

### **4.5.3 External Validity**

External validity refers to the relative generalizability of findings to other domains, scenarios, or groups (Noble & Smith, 2015). The study presented here is in fact a test of generalizability since one of its intents is to test whether or not the CML works in another closely-related domain outside of the broadly-defined museum. (Rodon & Sese, Feliciano, 2008) notes this is an appropriate test given the common features, characteristics, and in some cases, settings between museums and citizen science projects. However, whether or not results from one domain can transfer to the other largely depends on how closely related those features, characteristics and settings are to one another (Rodon & Sese, Feliciano, 2008). This is the basic test of transferability in qualitative research. So, while I test for theoretical transferability of the CML to another domain (i.e., citizen science), the wide net thrown for sampling in this study should ensure that these findings are equally applicable to citizen science more generally.

### **4.5.4 Limitations**

As with any research, this dissertation comes with a number of limitations. First, this research is limited in scope to volunteer learning in citizen science. There are venues of informal science learning that could have been selected, such as youth camps, DIY science clubs, or libraries, that would have provided equally rich insight as is the case with learning in citizen science. Secondly, even though citizen science is a global practice, and there are a number of projects examined in this study with a global geographic scope, the work itself is limited to projects with English speaking leadership for ease of communication during the interview process. Finally, this study did not include interviews with project volunteers—and the insight into volunteer learning for these specific projects is inherently one-sided as a result.

As with any study that requests participation of a known population, there is a sampling bias related to self-selection. In other words, the respondents who chose to participate in the study are not the same as those that have declined the offer. Conversely, the projects that agreed to the interviews come from a wide range of scientific disciplines and backgrounds and were able to provide insights regarding volunteer learning beyond their current experiences. This diversity provided unexpected insights from a varied group of project leaders, education directors, and program directors all interested in volunteer learning goals and the opportunities that support them.

## 4.6 Summary

Citizen science has two overarching goals, to do science and to educate and train those members of the general public who want to learn to do the science, both of which are reflected in their learning goals. The learning opportunities that support those goals can be physical, technology-mediated, or a combination of the two. During COVID restrictions, citizen science projects had to pivot to create online and hybrid learning opportunities, and worked to ensure that these learning opportunities could be presented live over Zoom or recorded to be watched later. As of 2023, volunteer learning can still happen at any time and in a lot of different ways due to citizen science projects embracing the technology tools available to them.

Technology use for volunteer learning comes in a number of formats—websites, online science platforms, social media and mobile applications—that might need additional training for volunteers to use. While some of these tech tools allow volunteers to complete tasks and record data to online databases, others provide sociotechnical mediation of learning opportunities. Platforms such as Facebook, Instagram, YouTube, Zoom, and even TikTok have been used by projects to communicate with volunteers *and* to allow volunteers to communicate and learn from

each other. However, the ways in which citizen science projects use technology to approach and support volunteer learning often depends on their unique organizational, sociocultural, and physical contexts.

Similar to the original version of the CML, citizen science projects have their own contexts that are related to volunteer learning. These contexts include the organizational contexts of choice and control, motivation, expectations, and prior knowledge, interests, and beliefs, and the physical contexts of project format and purpose. However, unique to the project are factors related to their organizational space such as partnerships, funding and money, staffing levels, and staff time that establish the contexts in which they set their volunteer learning goals and provide the resources that support those goals. While these contexts can create a unique approach to volunteer learning for a citizen science project, the personal, sociocultural, and physical contexts of the volunteer are taken into consideration by projects.

Volunteer participation in citizen science is dynamic, and can be self-guided, done in pairs, or as part of larger social groups. Some citizen science projects have specific goals and objectives related to their target volunteers that may limit who can participate, while others are open to everyone. However, volunteer demographics can also affect the level of communication projects are able to provide their volunteers, which impacts facilitated and social learning opportunities. Consequently, understanding who their volunteers are and how they are participating in the project can have an effect on project learning goals and how those goals are supported. Moreover, citizen science projects are keenly aware of volunteer motivation, and are always looking at ways they can appeal to both intrinsic and extrinsic motivations of their volunteers. What this all points to is

a nuanced understanding, on the part of projects, of the personal, sociocultural and physical contexts of citizen science volunteers.

The next chapter takes a deeper look at these findings, discusses how they apply to the research questions posed in Chapter One, and introduces a new Contextual Model of Citizen Science Learning.



## 5 Discussion

Within the study of citizen science, there has been a lot written about its volunteers. Although the literature available is more generally tied to volunteer motivation and participation research (Skarlatidou et al., 2019), there is quite a bit of literature available regarding volunteer learning (Jackson et al., 2020; Mugar et al., 2015; Roche et al., 2020) as well as the potential learning outcomes derived from those experiences (Fu et al., 2019; T. Phillips et al., 2018). There are even academic articles (Celino et al., 2018; Cunha et al., 2017; Law et al., 2017) and frameworks available (Pocock et al., 2014; Shirk et al., 2012) to help researchers determine whether or not citizen science would be the right fit for their project. Yet, within those publications, there isn't a lot of discussion regarding why projects choose particular volunteer learning goals or why they opt for the learning opportunities they provide to support them.

Additionally, based on the current study, what is generally known about volunteers in citizen science (Pateman et al., 2021; Spiers et al., 2018), might not always match a project's actual, intended or desired volunteer base as discussed later in Section 5.3.1. Thus, the power of the CML to help explain the how and the why of what people choose to learn in informal settings may help projects develop learning opportunities that better match their goals and volunteer needs (J. H. Falk & Dierking, 2018). Despite its potential to improve learning outcomes in these situations, however, the CML has yet to travel outside of the broadly defined museum into venues such as citizen science. Through the exploration of hundreds of pages of online materials and the analyses of nearly 30 hours of interview data, this chapter discusses my interpretation of those findings, explores whether or not this idea of contextual influences on learning can translate to citizen science. As the chapter progresses, the first three sections answer the research questions

posed in Chapter One. The chapter concludes by presenting an adaptation of the CML for citizen science, the Contextual Model of Citizen Science Learning (CMCSL).

## **5.1 Project Contexts and Volunteer Learning Goals**

As mentioned in Chapter Four, volunteer learning goals appear to come in two primary flavors: research-focused and outreach-focused. Findings also revealed that to some extent most of the projects in this study offered learning opportunities to accomplish both of these learning goals. However, a more nuanced analysis of the data shows that prioritizing one type of learning goal over the other is often determined by the unique organizational, sociocultural, and physical contexts of the project itself (Wiggins & Crowston, 2012). To answer RQ1, we must consider the organizational context, leadership, and partnerships at the project level and how those contexts impact volunteer learning.

### ***5.1.1 Project Priorities and Their Influence on Volunteer Learning***

In line with the literature, the findings from this study reflect some of the more common goals of citizen science, i.e., volunteer knowledge gain, specific skills training for volunteers, and scientific knowledge generation (Hecker et al., 2018; Turrini et al., 2018). However, it is important to note that studies like (Turrini et al., 2018) and frameworks like (T. Phillips et al., 2018) or (Pocock et al., 2014) provide little insight into how and why projects adopt and support specific goals. In response to this gap in the literature, this dissertation looks to uncover some of those details.

Since volunteer learning is such a large component of this study, one of the questions of the interview protocol specifically asked respondents whether or not volunteer learning was a

specific goal or priority of their project. Most of the responses to this question were as expected, e.g., during the interview with the Bumble Bee Atlas project coordinator, the conversation often returned to the project's conservation and educational outreach efforts even when that type of answer may not have been directly related to what was asked. Consequently, it wasn't at all surprising when her response reflected the project's educational outreach and conservation goals:

*Yeah, it (volunteer learning) is (a goal) in the sense that providing people with knowledge... (so that) the masses can do something to further our mission of protecting pollinators.*

On the other hand, a few responses were a little unexpected. For example, Cedar Creek Reserve-Woodpecker Cavity Cam provides an enormous amount of educational outreach to their regional community just outside of Minneapolis, MN (i.e., 3,000 – 4,000 students per year). So, it was noteworthy that the director's response to the learning goal question was, "I would say no (it's not a priority). It's a nice add on," given the level of educational outreach she reported earlier in the interview. However, the reserve's physical context, i.e., it is an ecological research facility funded through the University of Minnesota, makes her response to my question much more understandable.

Why a project prioritizes specific volunteer learning goals were reported to be influenced by that project's organizational motivation to engage in citizen science as well as its primary purpose or focus (i.e., orientation). Basically, if a project's overarching purpose is to involve the public in the conservation effort they hold dear (like Bumble Bee Atlas), their goals for volunteer learning appear to be much different than a project that's primarily relying on volunteer participation for data collection (like Woodpecker Cavity Cam for Cedar Creek Reserve). In the first instance--where educational outreach is a key motivator and focus of the project--a common

volunteer learning goal often repeated by project respondents with similar orientations is “to educate the public and get them engaged”(from Dolphin Spotter). Conversely, when the project motivation and focus is more research-focused, so too are the learning goals, i.e., “to gather accurate observations so (the project) can be pushed forward”(from Monarch Rx). In each of these cases, a project’s motivation to use citizen science as well as its underlying orientation may help in understanding why some volunteer learning goals are prioritized over others. Yet, project motivation and orientation are not the only contexts that impact volunteer learning goals—project leadership, and the personal contexts associated with him or her, can also influence what the volunteer learning goals are and how they’re supported.

### ***5.1.2 Project Leadership Can Influence Volunteer Learning Goals***

The decisions a project makes regarding volunteer learning are not made in a vacuum—there are a bevy of project dynamics at play that can sway a project as they choose their volunteer learning goals. One finding that stood out was the impact that the personal contexts of project leadership had on the volunteer learning goals their projects intended to support. More specifically, in analysis of the interview data, the background of project leadership—namely their prior experiences, knowledge, interests, and beliefs—was a key factor leading to prioritization of volunteer learning goals in their project.

In some respects, these contextual influences of project leadership on volunteer learning resembles the concept of prior experiences in managerial decision-making, where a manager’s prior experiences have an impact on future decisions they make for the organization (Dietrich, 2010; Obioma Ejimabo, 2015). However, the influences on project leadership decision-making were decidedly different to managerial decision-making research in a couple of ways. First of all,

the decision-making literature places considerable weight on management's prior experience in making decisions for the organization, not necessarily their prior experiences in general (Bowman, 1963; Obioma Ejimabo, 2015). Secondly, although leaders' beliefs (primarily in the form of cognitive biases) *are* an important concept in managerial decision-making, prior knowledge and interests appear to be secondary considerations despite their strong relationship to earlier decision-making activities (Dietrich, 2010; Obioma Ejimabo, 2015). The prior knowledge, interests and beliefs of project leadership as an influence on the decisions they make for their project (like prioritizing some volunteer learning goals over others—or not having any identifiable learning goals at all) are therefore of potential interest in the citizen science context as well.

As described in CML research, prior experiences, as well as prior knowledge, interests, and beliefs have all been shown to support what individuals choose to learn in informal settings (J. H. Falk, 2011; Vainikainen et al., 2015). As such, it is reasonable to expect that those same characteristics in project leadership could have an influence on the decisions made regarding volunteer learning goals. This theme was in fact observed throughout many of the interviews, for both research-focused and outreach-focused projects, e.g., the director of NASA's Exoplanet Watch is an astronomer with NASA's Jet Propulsion Lab, with a lot of night sky to cover and a tool that could be made easier to learn for amateurs; or the founder of SciStarter's interest in teaching others how to be a citizen scientist. Basically, the background of who is managing volunteer learning indicates a lot about the type of learning goals a project has and how they'll go about supporting them.

For a more detailed example, Penguin Science's education outreach director has a background of more than 20 years classroom educator experience before joining the project and

launching her outreach program, Penguin Nest Check. Penguin Science is a National Science Foundation grant funded project doing “strictly science data collection” on Adelie penguin habitat changes in Antarctica. On the other hand, Penguin Nest Check is all about outreach and was created “(for students) to be engaged in something that is not a textbook.” Its mission is to create and provide learning opportunities for educators to bring Penguin Nest Check into the elementary classroom through age-appropriate curriculum development. As such, learning is not a specific goal of the program in the traditional sense where there are measurable outcomes reported back to the funding authority. The director stated in the interview that targeting measurable learning outcomes would have been too disruptive to a classroom, so specific learning goals were removed from the grant. However, the resources are there for learning in the classroom to happen, and as the director points out “if the teachers didn’t think the kids were learning something, they wouldn’t do it.”

Educational outreach for Penguin Science could have taken so many different directions other than engagement with elementary school children. Had there been any other person on the science team in charge of developing the program instead of a former schoolteacher who wanted to get “these kids to think about what’s happening in the world,” it’s likely Penguin Nest Check would have been completely different project than what it is today. There wouldn’t be the opportunity for children to make flags and see them fly at the camp in Antarctica or for them to learn first-hand from an educator during a Skype call from the field that the entire continent is actually a desert and is almost 10,000 miles away from where they are in the US. The opportunity for 4<sup>th</sup>, 5<sup>th</sup>, and 6<sup>th</sup> graders to learn about ecological monitoring would most likely be replaced with a crowdsourced project in a high school or college biology class or on a platform like Zooniverse

where more nests could be monitored, and the data collected from these sources would be more reliable. Whatever the alternatives could have been, the reality is that a former schoolteacher with more than 20 years of classroom experience did create Penguin Nest Check, based on prior experiences, knowledge, interests, and beliefs that guided development of a program designed to support learning.

### ***5.1.3 The Socio-Organizational Context and Its Role in Volunteer Learning***

The socio-organizational context of a citizen science project not only includes the relationships they build with steering committees, stakeholders, program partners, and the like, it also includes resources that are often associated with those relationships, i.e., findings from this study related to funding and money, staffing levels, and staff time. This was evident in several projects where relationships with sponsors affected project decisions on volunteer learning goals and subsequent opportunities that support them. For example, in the interview with the NASA Citizen Science Director, he reported that while most of the projects funded by NASA are science funded and do not have volunteer learning as a specific goal, “When a (science-funded) project launches, we look at the website and make suggestions to the team as to how they can help train their volunteers.” Moreover, when volunteer learning is a goal of a NASA sponsored project, not only are additional funding and resources made available to the project, but “external reviewers look at the project and checks to make sure learners are learning,” so there’s also an additional level of oversight involved. In either case, it is evident that a project’s relationship with NASA directly influences how they approach and are able to support volunteer learning.

Partnerships and their potential influence on volunteer learning in citizen science can be tied back to the literature on organizational development and strategy (Meinhardt et al., 2018), as

well as to the literature on organizational networks (Kenis & Knoke, 2002). More specifically, the relationships built with others outside of the organization to obtain resources will influence the decisions that are made by the organization as a consequence of those affiliations (Frishammar, 2006; Gulati et al., 2017). This definition fits better than the peer-group (within-group) social mediation from the original sociocultural context of the CML. It recognizes that not all partnerships fostered within a citizen science project are among peers—there are hierarchies in many of these relationships that influence decision making and project strategies that need to be recognized.

Obviously, there are also relationships among peers in citizen science project space—especially for knowledge sharing and collaboration—that do fit the CML description of peer-group social mediation of learning. Although this type of relationship was rarely talked about in the interviews, potentially because it was not directly elicited, it did show up in one interview with a focus group with USA National Phenology Network. The interview itself was scheduled with one member of the program but based on the peer-group relationships of the original respondent with other projects, there were four respondents (all education coordinators) that attended the session. While it was unconventional for a respondent to invite their peers to an interview, it was also a great way to gather more insight into volunteer learning strategies across projects at the same time.

In short, the relationships projects have with other organizations can and do have an impact on how they approach volunteer learning. While some of those relationships are predicated on funding partnerships, others are more collaborative in nature. In answer to RQ1, the above sections demonstrate that citizen science projects have organizational and socio-organizational contexts



that influence the learning goals they set. The approaches they take to meet those goals answers RQ2, discussed below.

## **5.2 Project Contexts and Learning Opportunities**

Identifying contextual characteristics that influence why citizen science projects choose the volunteer learning goals they do is really only one piece of the volunteer learning puzzle. Again, RQ2 inquired into the nature of volunteer learning opportunities and resources a project provides to support those goals. In the CML, project design and orientation, i.e., the two primary factors within the physical context of informal learning, are wholly within the project's control (J. H. Falk & Dierking, 2018; Schwan et al., 2014). For the most part, this held true when looking at the model through the lens of citizen science, e.g., project orientation and design are key factors in how projects approach and support volunteer learning. However, there are a couple of key differences in how orientation and design are defined and applied in this research to better fit citizen science. The sections below discuss those differences and how these contexts are applied to the opportunities and resources volunteers are provided to support volunteer learning.

### ***5.2.1 Format and Purpose of Volunteer Learning***

As mentioned in Chapters Three and Four, this study interprets the physical contexts of orientation and design a bit differently than the CML. In the original framework, design is the physical construction, architecture, colors, shapes, and sounds of the museum space (J. Falk & Storksdieck, 2005; Lin, 2011) while orientation refers to the cues and organizers a museum uses to lead the public through those spaces (J. H. Falk & Dierking, 2018; Schwan et al., 2014). Within this study, however, *design* in citizen science maps instead to the methods projects use to achieve

their research and/or outreach objectives as well as to describe their modes of engagement with their volunteers, i.e., field-based, technology-based or hybridized. Likewise, the definition of *orientation* differs for citizen science projects as it refers to the different ways that projects to describe what the project is about, why the project's objectives are important, and why the project needs citizen science participation to achieve their research or conservation goals. Combined, citizen science design and orientation describe a project's format and overall purpose in a way that more closely resembles prior literature (Wiggins & Crowston, 2011b, 2012). Accordingly, *format* describes the modes in which project tasks are performed or their learning opportunities are offered (i.e., field-based, technology-based, hybridized); and *purpose* describes what the project is about (i.e., research-focused, outreach-focused). This *format and purpose*, rather than *design and orientation*, have a profound effect on how projects approach and support volunteer learning.

The format of a project often affects how a project offers volunteer learning opportunities, e.g., online projects rely on technology to mediate volunteer learning objectives while field-based projects generally achieve these goals through engagement in the physical world. However, the current study found that even field-based projects rely heavily on technology to facilitate volunteer communication, task completion, and learning opportunities. While project use of technology will be discussed in greater detail in the following section, it is important to note in this instance that there has been a hybridization of field-based citizen science projects that means more activities are technology-mediated—especially since the onset of the pandemic in 2020—that has impacted how projects provide volunteer learning opportunities (Bowser et al., 2020; Dwivedi, 2021). In fact, several respondents from field-based projects reported some hybridization of project format as they transitioned from in-person training to web-based training during that time. Many of these

pandemic-related adjustments to volunteer learning opportunities became permanent features in field-based projects because “the demand (for online training) was there (during COVID restrictions), and it was so popular that we’ve decided to keep it going (from Leave No Trace).” Basically, the current study found that how volunteer learning opportunities were provided had to evolve as field-based projects were compelled to change so they could continue providing opportunities to support their volunteer learning goals when continuing their prior practices became impossible due to pandemic social distancing and group size restrictions.

The hybridized format displayed by many field-based projects in this study should not be confused with a change in their overall *purpose*. That purpose has remained the same as has their commitment to pursue their research or outreach objectives, and I was able to investigate the types and amounts of learning materials made available to volunteers as they engaged in either research-focused or outreach-focused projects. Not entirely surprising, the form and function of learning materials were largely congruent with the primary project objectives.

For example, research-focused projects tended to use platforms that contained some kind of data collection or processing element to it such as Anecdata, CitSci.org, iNaturalist, and Zooniverse. These platforms need very little training to use and provide projects with additional space to publish task requirements and research protocols. Additionally, learning opportunities provided on these platforms tended to be task specific and protocol-oriented with few supplemental learning resources offered for additional learning opportunities. These projects typically supplied enough learning materials needed for volunteers to complete the tasks requested of them but not much else.

On the other hand, outreach-focused projects provide a great deal of information related to the conservation effort or phenomena of interest, often through project-managed websites and social media accounts. These sites are very purpose-oriented and provide volunteers with opportunities to learn more about the project itself, its primary goals and objectives, as well as ways for the public to get involved. What was surprising was that the outreach part of the project was primarily hosted on a resource-heavy site, but the participatory part was hosted on a third-party platform like Anecdata, iNaturalist or Zooniverse. While hosting participatory engagement on these sites is perfectly fine for project management and data collection, using third party sites impacts the learning opportunities a volunteer was initially exposed to. Moreover, when the citizen science project was hosted on one of those platforms, it was often left to its own devices with little program management and “kind of allowed to run itself (from Leave No Trace).”

Leave No Trace and their support of volunteer learning offers an excellent example of this dichotomy of learning opportunity where the home website ([www.lnt.org](http://www.lnt.org)) is quite robust and provides viewers with access to in-depth project information, supplemental learning resources, and age-appropriate learning material for K-12 educators. Yet, the program’s offshoot citizen science project, Leave No Trash, is hosted on [CitSci.org](http://CitSci.org) and provides direct access to very few learning opportunities for volunteers outside of the snippets of background found on its homepage. This observation was made despite there being a Resources tab available for the inclusion of additional learning materials onto the platform. While there is a link to the main Leave No Trace website available on Leave No Trash, this indirect access to supplemental learning materials may be overlooked by some volunteers and still others may get lost in the sheer vastness of the information contained on primary website.

It was stated in the beginning of this section that projects have both a format and a purpose that affects how they support their volunteer learning goals. The findings point to the malleability of a project's format allowing for accommodation for training, learning and participation while their purpose remains steadfast offering a little bit of predictability. As projects had to pivot their focus during the pandemic and alter how they trained their volunteers, their purpose aligned with types of learning opportunities they provide both then and now. The section that follows discusses how technology has been used by nearly every project in this study as a gateway to volunteer learning.

### ***5.2.2 Technology's Impact on Volunteer Learning has Evolved***

Regardless of a project's format, having an online presence of some sort was a sampling requirement of this research. Not only did this provide triangulation of data, it also provided an opportunity to investigate the current state of technology-mediated learning opportunities more generally; it also means that projects without an online presence may operate quite differently than the findings reported here. Along with technology-based projects, more and more field-based projects were including technology-mediated participation options into their research goals (e.g., use of mobile apps to complete monitoring or data collection tasks) as well as in their strategies to meet volunteer learning goals. Although format hybridization was discussed in section 5.2.1, it only described why field-based projects moved to technology for learning, it did not necessarily go into the specifics of their use of technology and how it has evolved over time. In this section, I discuss the types of technology being used and how those different technologies have been applied to support volunteer learning in citizen science.

Technology use in citizen science can mean a lot of things depending on who is discussing it. It can describe the use of scientific equipment and tools as was the case in projects such as NASA's Exoplanet Watch or Microplastics Pollution Monitoring Program; or it might mean the use of mobile applications like those described in data from Bumble Bee Atlas and NASA Globe Cloud Gaze. It might also mean a project's use of the internet and the online tools that go with it, as was the case for nearly all of the projects examined in this research—even if they didn't specifically mention their online presence during the interview, like KTESST or Nebraska Master Naturalist. While the unique ways projects defined and used technology is certainly interesting (and a topic for future research), examining how the majority of projects in this study are defining and using technology provides a better idea of the state of technology use in citizen science more generally. As such, the rest of this section looks at how the projects examined in this research are using the internet to engage with their volunteers and to support their volunteer learning goals.

When asked how their project uses technology in the interview, it was honestly a little surprising to me that the majority of the projects (13) reported using email as a primary source of communication with their volunteers rather than public facing social media accounts given the assumed age of project leaders being younger (i.e., 30s – 40s). It was also interesting that some of these projects were using this tool as a source of learning as well. After a review of the distance learning literature, however, email has actually been used as a tool for education practically since its inception (Hassini, 2006; Huett, 2004), so it is a more routine function of email than what was initially assumed.

In this study, many of the respondents did regard email as “good for communication reminders (from UW Arboretum Dragonfly Monitoring),” but others were sending more training

specific messages like “survey tips or things to be on the lookout for” (from Bumble Bee Atlas) or were providing their volunteers with informative outreach and project updates explaining “what the data are showing from what they’re collecting” (from USA Phenology Network). When projects used email in this manner, it was largely due to projects “serving really large geographic areas” (from Save Our Streams) or wanting to isolate specific sectors of their volunteer base like “all these people in New Jersey” (from SciStarter), i.e., in scenarios reminiscent of those found in distance learning (Huett, 2004).

The other online tools projects have incorporated into volunteer learning opportunities included social media as a tool for learning, which has been observed in other domains. For instance, in higher education, social media has been introduced as a support for self-regulated learning for undergraduate students (Dabbagh & Kitsantas, 2012); and in healthcare, social media engagement has been shown to foster collaboration and feedback loops among medical professionals that parallels engagement in processes of lifelong learning in older adults (Kind & Evans, 2015). When looking at social media as a support of learning in citizen science, findings from this study demonstrate similar characteristics where volunteer engagement among themselves as well as with project leadership provide opportunities for social interaction and collaboration in support of volunteer learning.

One such example of this learning opportunity comes from the Facebook page of Bumble Bee Atlas where I had posted what I thought was a bumble bee feeding off a salvia plant in my garden (see Figure 18). A conversation ensued with another volunteer (i.e., peer-group social mediation) trying to figure out the type of bumble that was captured in the image. We both got it wrong, and a moderator of the page stepped in and provided the correct identification (i.e.,

facilitated social mediation) thus providing a learning opportunity for me and the other volunteer as well as for others who may read the post later. As of June 7, 2023, the post has 12 comments and has been viewed by 114 other members of the Bumble Bee Atlas-Nebraska Facebook group demonstrating that the post was a learning opportunity other members of the group engaged with:



Figure 18: Bumble Bee Atlas Facebook post made by Hollie K. Rosser, 5/16/2023.

Throughout this dissertation, the importance of technology to mediate volunteer learning in citizen science projects has not gone unnoticed. In answering RQ2, this research found that technology is not only instrumental in defining a project's format, it also influences how projects achieve their volunteer learning goals. Additionally, use of tools like email and social media have been shown to play a role in the mediation of learning within the sociocultural contexts of both the project and the volunteer. This indicates that the sociotechnical context is also important to



understanding learning in citizen science, which is not addressed in the CML. The section that follows discusses the relationship between the personal and sociocultural contexts of the volunteer and the project's supports to volunteer learning to answer RQ3.

### **5.3 The Project's Alignment with Volunteer Contexts**

According to the CML, people learn better when their personal and sociocultural contexts align with the physical contexts of the museum (J. Falk & Storksdieck, 2005). Similarly, RQ3 asks how citizen science projects are aligning their learning goals and opportunities with the personal and sociocultural contexts of their volunteers. To look for an answer to this question, findings from Section 4.4.1.3 report the current demographic of their volunteer base (i.e., predominantly older, well-educated white men and women), and findings from Section 4.4.1.1. show projects are affording their volunteers with more choice and control over how they access and complete project training and research objectives. However, findings from this research also found that, in an effort to expand the scope of who participates in the project, citizen science projects are looking for ways to make their projects more inclusive and appealing to a wider range of people. Therefore, in answer to RQ3, the sections that follow discuss how citizen science projects are trying to align their learning opportunities with the personal and sociocultural contexts of their volunteers through inclusive design and practices, and by supporting volunteer choice and control.

#### ***5.3.1 Increasing Focus on Inclusion***

Findings from this study show that volunteers in citizen science projects are varied largely across age groups, education level, and ethnicity, but this variety in demographics is often dependent upon project learning or outreach objectives that are purposefully intended for certain groups of people (i.e., students and/or other members of our community underrepresented in

STEM). In those situations, the participation and learning opportunities provided reflect those demographics. For example, SciStarter is in partnership with Girl Scouts and has created a launching page and curated a list of citizen science projects appropriate for school-aged girls in the US (see Figure 19). When participation is not targeted, however, learning opportunities and training resources were written with educated adults in mind as shown in the homepage of Monarch Rx on CitSci.org (see Figure 20). In each of these cases, participation and learning opportunities were created to match the age group and education demographics of their volunteer.

The screenshot shows the SciStarter website interface. At the top, the SciStarter logo is on the left, and navigation links for #CitSciMonth, Libraries, Trainings, @Girl Scouts, Dashboard, Projects, Events, and Partner Gateways are on the right. A search bar is also present. The main content area features a large photograph of two girls with green backpacks walking through a forest. Below the photo, the text reads: "Welcome to SciStarter! You are on your way to becoming a citizen scientist by doing REAL science in need of YOUR help! Girl Scouts has teamed up with SciStarter to curate projects for girls, volunteers, and others to deepen their engagement in citizen science and explore outdoor STEM. Watch the SciStarter LIVE: Citizen Science for Girl Scouts webinar. Check out the options below and click each button for recommended projects." On the right side, there is a sidebar with a graphic that says "girl scouts scistarter THINK LIKE A CITIZEN SCIENTIST". Below this, it lists "Girl Scouts and SciStarter", "Girl Scouts SciStarter Project on iNaturalist", "Goal: Explore nature and biodiversity", "Task: Share the biodiversity that you and your troops", and "Where: Global, anywhere on the planet".

Figure 19: Girl Scouts on SciStarter; <https://scistarter.org/girlscouts-info>, accessed 6/15/2023.

The screenshot shows the Monarch Rx project page on the CitSci.org platform. The header includes the CitSci logo and navigation links. The main banner features a monarch butterfly on a leaf with the project title 'Monarch Rx'. Below the banner, a statistics bar shows 108 members, 25 observations, 19 locations, and 90 measurements. The main content area is titled 'Welcome to Monarch Rx' and contains several sections: 'About' (describing monarch butterflies and their feeding habits), 'Goals' (understanding the gathering of pyrrolizidine alkaloids), 'Tasks' (recording behavior in nature), and 'Get Started' (instructions for data collection). The 'Project Owner' section identifies Michael Boppré as the Contact Manager. A 'Project Dataset' section has a 'Download' button. At the bottom, there is a 'Find Us On SciStarter' logo.

Figure 20: Monarch Rx homepage on CitSci.org, <https://www.citsci.org/projects/monarch-rx>, accessed 6/15/2023.

Issues of diversity and inclusion have been a hot topic of conversation in citizen science for the last 10 – 15 years. Countless papers have been written asserting the need for citizen science projects to strengthen their efforts in recruiting a more diverse volunteer base as a way of enhancing their engagement with local communities and for improving the quality of their research (Nelms et al., 2022; Pateman et al., 2021). Moreover, project leaders also want to expand participation due to organizational values related to inclusion as well as funding that heavily emphasizes broadening participation (*Advancing Informal STEM Learning (AISL)*, 2022), as was found in the Citizen Scientist Project, “We intentionally choose girls who are underrepresented in STEM (for our summer camps)—students of color or who are experiencing poverty (based on free/reduced cost school lunch status).”

Citizen science is not alone in having this conversation either—research shows that museums have been trying to improve the diversity and inclusion of attendance in their institutions

for quite some time as well (Jennings & Jones-Rizzi, 2017; Mihelj et al., 2019). This dialogue is implicated (to some degree) within the sociocultural context of the CML (J. H. Falk & Dierking, 2018). In fact, *Learning from Museums* spends a considerable amount of space “unpacking culture: i.e., behavior, norms, social relations, assumptions and roles” (J. H. Falk & Dierking, 2018, p. 34). However, these cultural influences on learning have been blended into the larger theme of within-group social mediation. As a result of citizen science’s interest and the CML’s attenuation of diversity and inclusion issues in the arts and sciences, analysis specifically looked at how the projects in this research are approaching inclusivity.

Nearly all of the projects interviewed understood the social and scientific benefits of diversity and were actively looking at ways in which their project could be more inclusive. Moreover, there were three primary areas of concern respondents specifically mentioned when talking about diversifying their volunteer base: age, racial and ethnic communities, and accessibility. In line with literature in citizen science participation (Pateman et al., 2021; Spiers et al., 2018), project volunteers examined in this study were reported to be “mostly older white dudes (from NASA’s Exoplanet Watch),” and “retired folks with a college or graduate degree (from USA National Phenology Network).” Several projects like Penguin Nest Check, the Citizen Scientist Project, and Microplastics Pollution Monitoring Program also reported active engagement with younger volunteers through project-facilitated mediation or through the fostering of relationships with educators, schools and scouting groups. Still other projects, like Bumble Bee Atlas, NASA Globe Cloud Gaze, and Leave No Trace looked to specific social media platforms like TikTok and Instagram to “post everything that’s cooler and hip” (from Leave No Trace) or to “give some

pictures of pretty things” (from Bumble Bee Atlas) with the goal to engage new (and younger) volunteers.

Targeted social media campaigns were used to engage with under-represented racial and ethnic communities both in the US as well as abroad. For example, when NASA Globe Cloud Gaze wants to engage with the Hispanic community in the US and South America, “Facebook is the most preferred platform (for that community).” Additionally, projects such as Salt Watch and Iguanas From Above are incorporating online learning materials as well as pamphlets, kit instructions, etc. in Spanish in an effort to accommodate members of their volunteer community who are primarily Spanish speakers. Only one off-shoot project, Crowd the Tap from North Carolina State-Citizen Science Campus, noted community engagement with “Black and African American households on par with national demographics” which was important for both scientific rigor and environmental justice goals (Mahmoudi et al., 2022). Findings from this study show there is a great deal of effort by citizen science to expand participation by previously excluded populations in their projects, but deeper discussion of this topic is not the focus of this work.

The final area of concern voiced by interview respondents was the engagement and active inclusion measures several projects had in place to accommodate disabled and neurodivergent members of their communities. Naturally, and fitting the available research (Hecker et al., 2018; Hein, 2009), one of the benefits inherent to online citizen science is that “anyone anywhere can participate” (from NASA Citizen Science) and can accommodate “volunteers who have chronic illnesses who have not been able to contribute before” (from Iguanas from Above).

Field-based projects, however, might not be able to accommodate individuals with disabilities quite as easily, as noted by the coordinator from Save Our Streams, “The training is

somewhat physically demanding, and you have to be able to navigate walking through a stream.” Conversely, Leave No Trace, which operates its outreach primarily out of the back country of the Rocky Mountains, is now offering some of their training courses totally online or “in the front country where it’s more accessible (and potentially ADA compliant)” to provide more opportunities for individuals with reduced or atypical mobility to participate in the program. Even when it’s difficult for field-based projects to accommodate individuals with mobility restrictions, projects like UW Arboretum Dragonfly Monitoring Project are providing spaces that are “neurodivergent and dementia friendly” (e.g., areas with quiet spaces, clear signage and other landmarks, natural lighting, and plain flooring); and staff at NASA Globe Cloud Gaze make a point of engaging through “emails from neurodiverse adults (telling the project) how much they like making the observations.” It all points to a growing awareness by citizen science leadership that diversity matters and the inclusion of volunteers from all walks of life and ability are an asset that can bring new ideas and innovations to the project.

### ***5.3.2 Volunteer Choice and Control***

Having options in how, when, and where learning happens has been shown to improve learning—especially when that learning is informal and freely chosen (Bamberger & Tal, 2007). Moreover, when the learner has the freedom to select the option that best fits their needs, the learning that happens is more likely to be sustained (Hein, 2009). This is the crux of the concept of choice and control within the personal context of the CML (J. H. Falk & Dierking, 2018), and has been observed in this study as project attempts to align their learning opportunities to the personal needs and preferences of their volunteers.

Unlike the CML however, citizen science projects rely on volunteers to complete tasks that often require some level of training, much like the training a new hire undertakes in a work setting. In this regard, personal choice and control looks a little bit more like the constructs of autonomy and agency found in job design literature (Wu et al., 2015). Yet, given the voluntary nature of the work performed, the freedom to choose how and when to complete training more closely mirrors the characteristics of choice and control within the CML (Bamberger & Tal, 2007). Thus, how citizen science projects attempt to align their learning goals and opportunities to the volunteer is truly a blend of both constructs.

In job design, autonomy has been defined as the “substantial freedom, independence, and discretion” a person has been given by the employer to complete their work (Hackman & Oldham, 1976); and has been shown to improve motivation, productivity, and commitment to the employer (Gagné & Bhave, 2011). Additionally, autonomy in task completion can enhance a person’s sense of agency, empowerment, and self-efficacy (Wu et al., 2015), which has also been documented in citizen science (Bowser et al., 2014; Tiago et al., 2017). Given the potential benefits to the project, it makes sense that citizen science projects want to incorporate volunteer autonomy into their participation objectives and might even prefer to let their volunteers “go out anywhere and collect data for us (from Leave No Trace).” Although that level of autonomy is not always possible (or even desirable), several projects did offer some flexibility in what their volunteer participation looked like. Projects like Nebraska Master Naturalist, UW Arboretum Dragonfly Monitoring Project, and Save Our Streams reported that they encourage members to engage with other projects and partnerships for deeper training and participation experiences; while others like NASA’s

Exoplanet Watch, Cedar Creek Reserve-Woodpecker Cavity Cam, and Nebraska Game and Parks offer online options to their field-based research.

However, due to the rigor required of their research, even this level of freedom does not always work for projects. Therefore, it is understandable when volunteer autonomy is restricted to factors that are essentially outside of project control anyway, such as when and how often a volunteer participates in project activities. Nebraska Butterfly Survey provides a good example of this conundrum. Volunteers are given the autonomy to choose when, how often, and with whom they complete their monitoring assignments, but the project coordinator prefers to select where his volunteers are completing the task for research reasons, i.e., “(volunteers) are allowed to pick (their) own points, but those are much less statistically rigorous (and) useful (to the project).” But sometimes, as is the case with Cedar Creek Reserve-Woodpecker Cavity Cam’s field-based projects, who you participate with might also be under the project’s control as well, “because we have concerns specific to volunteers about research, integrity, and impact on other research (at the reserve).” However, project leadership for the reserve does try to make up for their lack of volunteer autonomy in their field-based projects by offering a variety of workflows in the online version of the project on Zooniverse, “so there’s something for everybody... and “Joe off the street” can contribute to this project.” Therefore, while giving volunteers autonomy can provide projects with a motivated and engaged volunteer base, it appears that the ability to offer it has its limits in citizen science.

Where volunteers were found to be afforded more autonomy and agency is in the methods in which they receive project training—something that the projects in this study appear to be willing to offer their volunteers. This area of autonomous participation is in almost direct



opposition to the literature in job design (Khoshnaw & Alavi, 2020), and is more closely aligned with personal choice and control's effect on learning as described in the CML (Basten et al., 2014). While volunteer learning opportunities offered by citizen science have been shown in this study to include much more than just training materials, volunteer training has the potential to directly affect a project's research outcomes. Consequently, investigating how projects are aligning these specific learning opportunities to their volunteers is worthwhile and necessary.

As mentioned in Section 5.2.1, much of the choice and control afforded volunteers in completing their project training stems from the social distancing requirements of the pandemic—where many projects switched to an online platform (like Zoom or YouTube) to reach their volunteers and conduct trainings. What has been discovered since then is that volunteers really like having options in how they complete training and continuing to provide those options has benefitted many of the projects examined in this research. For example, projects like Bumble Bee Atlas, Salt Watch and several others have reported considerable growth in participation since adding online and asynchronous training options to their project, i.e., “being able to reach our audience remotely...is a big reason for our program to have expanded so much (from Salt Watch).” However, what is left to be seen is what the effect of a volunteer's choice and control to select their method of training has on their task performance and the quality of their data. But that is a topic for another study and is for now outside the scope of this research.

RQ3 asks how a project's learning opportunities align with the personal and sociocultural contexts of their volunteers. What was found in this study was that citizen science projects are actively trying to open the doors of science to members of our community that have previously been denied access. In doing so, not only are they altering learning opportunities to meet those

needs, they are changing their projects in ways that make them more inclusive and accommodating for volunteers with limited mobility and neurocognitive differences as well. Moreover, the COVID pivot to online training observed in many field-based projects continues to provide volunteers with options that preserve their choice and control over how and when they learn even when their autonomy may be hindered when they are actively performing tasks for the project. As a result, this research shows that citizen science projects are taking the personal and sociocultural contexts of their volunteers into consideration as they strive to support their volunteer learning goals.

While there have been several opportunities throughout this dissertation to explore other theoretical explanations for citizen science's approach to volunteer learning, the CML has provided a framework that examines these strategies in a systematic and cohesive manner. However, there are enough differences within that framework that allow for consideration of new interpretation specifically for citizen science. In the final section of this chapter, the foundations of the contextual model of citizen science learning are presented.

#### **5.4 The Contextual Model of Citizen Science Learning**

This section of Chapter Five is the culmination of my research and offers the Contextual Model of Citizen Science Learning as my contribution to the theory and the practice of citizen science. By moving the CML outside of the museum, the CMCSL provides new insight into the four contexts affecting learning in citizen science that projects can use to help define their learning goals and provide appropriate supports for those goals. The table below provides an outline of those contexts (see Table 5.4: The Contextual Model of Citizen Science Learning). As with the original model, those contexts have characteristics that describe and define their influences on learning, described in the following sections.

Table 5.4: The Contextual Model of Citizen Science Learning

<i>CONTEXTS OF THE CMCSL</i>	<i>CHARACTERISTICS</i>	<i>DEFINITIONS &amp; COMPARISONS</i>
<b>Volunteer Context</b>	Motivation & Expectations	motives that drive participation; updated-CS lit assumptions regarding skills needed; same-CML
	Prior Knowledge, Interests & Beliefs	learning is framed within & limited by past pursuits & values; same-CS/CML
	Volunteer Choice & Control	autonomy & agency in participation; updated-job design lit choice & control in learning; same-CML
	Volunteer Demographics	age, education level, & ability impact learning; new def-CS lit
<b>Social Context</b>	Facilitated Mediation	learning is led by people thought to be skilled; same-CS/CML
	Sociocultural Mediation	range of social structures that work together for meaning making; updated-CS/CML
	Sociotechnical Mediation	tech as a mediator of participation & learning; new def-CS lit
<b>Physical Context</b>	Format	field-based, technology-based, hybrid; new def-CS lit
	Purpose	primary objectives of project; new def-CS lit
<b>Organizational Context</b>	Organizational Background	prior experiences, knowledge, interests & beliefs of the project or its leadership-new def-CML
	Organizational Expectations	perceptions regarding volunteer skills & abilities-new def-CS lit
	Socio-Organizational Relationships	partnerships & peer-group connections-new def-org lit

#### 5.4.1 The Volunteer Context

The personal contexts of the volunteer do not stray very far from that of the CML and include the factors of motivation and expectations; prior knowledge, interests, and beliefs; and choice and control as a result. However, as was discussed in section 5.3.1, volunteer demographics play an important role in how citizen science projects approach learning. The CMCSL includes this characteristic as a core concept for defining the volunteer context. Additionally, the application of motivation and expectations as well as choice and control differ enough from the CML to warrant new definitions to accurately describe the volunteer context of the CMCSL.

**5.4.1.1 Volunteer Motivation and Expectations:** *Volunteer motivation* is well-described in the citizen science literature (as discussed in Section 2.3), and has been defined as the intrinsic and extrinsic motives that drive volunteers to participate in a citizen science project (Kragh, 2016).

Applying the same definitions in a model describing volunteer learning in citizen science will make it easier for practitioners and researchers of citizen science to understand.

*Volunteer expectations* are not as well-defined in the literature (in citizen science or volunteerism), which also reflects the findings from this study. Thus, the definition from the CML was used to create a definition of volunteer expectations: the volunteer's assumptions regarding the skills and resources needed to participate in the project or their perception of what participating in citizen science project activities entails. This definition is similar to that of the CML, which defines expectations as the individual's "self-related agenda (regarding) the realities of the museum (J. H. Falk & Dierking, 2018, p. 151)," albeit with modifications to reflect participation in project activities rather than the experience of being a visitor at a museum.

**5.4.1.2 Prior Knowledge, Interests, and Beliefs of the Volunteer:** Findings from this study regarding the *prior knowledge, interests and beliefs* of the volunteer did not differ from the definitions provided in the CML (i.e., Section 2.4.1). In each model, these concepts describe how learning is framed within, and potentially limited by, a person's prior knowledge, interests and beliefs (J. H. Falk & Storksdieck, 2005).

**5.4.1.3 Volunteer Choice and Control:** Section 5.3.2 described how choice and control in citizen science differ depending on how the volunteer is engaging with the project at a given point in time. When volunteers are performing tasks and actively engaged in the collection or analysis of data on behalf of the project, volunteer choice and control more closely resembles *autonomy* and *agency* as described in the job design literature (Wu et al., 2015). Volunteers are typically given some leeway and freedoms to choose what they do for a project, when they do it, and who

they do it with, but this level of *choice* and *control* can be limited by project needs and objectives, usually to support the science.

However, when volunteers are engaged in training or exploring other learning opportunities offered by the project, *choice and control* more closely resembles the definitions provided by the CML (Bamberger & Tal, 2007), where volunteers are afforded the ability to actively select the type of learning opportunities they engage with. This level of choice affords volunteers a feeling of control over their own learning—a cornerstone of informal learning (Sacco et al., 2014). In the CMCSL, choice and control refers to both the feeling of control over learning and the autonomy and agency experienced in the participation process.

**5.4.1.4 Volunteer Demographics:** Some citizen science projects deliberately seek out volunteers from certain demographic groups based on a number of factors such as leadership preferences to work with a particular group of people (i.e., students), funding requirements (*Advancing Informal STEM Learning (AISL)*, 2022), or specific project research and outreach objectives related to volunteer demographics (e.g., addressing environmental justice concerns that impact communities of color.) While the CML correctly points out that a person’s cultural identity influences learning (J. H. Falk, 2011), the role of other demographics such as age, education level, and ability, which impact opportunities that support learning, was not prioritized in the model. These characteristics were shown in Section 5.3.1 to be important factors within citizen science to not only gauge a project’s approach to volunteer learning but to address issues of inclusivity in STEM more generally (Hein, 2009). As such, *volunteer demographics* was added to the CMCSL to reflect its defining impact on learning in citizen science.

#### **5.4.2 The Social Context**

The sociocultural context of the original CML includes the characteristics of *facilitated* and *within-group social mediation*. However, results of this research show that technology plays an outsized and evolving role in how learning is mediated in citizen science. Thus, the model presented here includes sociotechnical mediation along with facilitated and within-group social mediation.

Additionally, some of the terms used in the CMCSL to describe the modes in which citizen science projects approach their volunteer learning goals have been changed for a couple of reasons. First, there is sufficient overlap in each of the three types of mediation (where facilitated and within-group social mediation often occur simultaneously with sociotechnical mediation) that relabeling this context to be more general and treating it as a category containing multiple types of mediation, is appropriate in this case. Secondly, the term “within-group” is confusing given its more common association with experimental design. Although the conceptualization of the term is useful when referring to the social groups common to situations of informal learning (Kisiel & Anderson, 2010), it does not necessarily speak to the cultures, norms, beliefs and values often associated with the social groups that participate in citizen science together (e.g., families, friend-groups, work-groups, etc.). Thus, the sociocultural context of the CML is represented as the *social context* of learning in the CMCSL, to account for the broader scope of mediation in this context; and within-group social mediation has been renamed *sociocultural mediation* to better describe the social groups and the influence that culture has on those groups that are common in informal learning settings (Hein, 2009). The specific definitions of *facilitated*, *sociocultural*, and *sociotechnical mediation* within the *social context* of learning are described below.

**5.4.2.1 Facilitated Mediation of Learning:** In the CML, *facilitated mediation* of learning occurs when learning opportunities are led by individuals that are thought to be skilled and knowledgeable by the learner, such as museum guides or docents (Basten et al., 2014). This type of mediation also closely resembles the role project leaders and coordinators play in volunteer training and outreach activities in citizen science. Thus, the definition of *facilitated mediation* in both models are aligned and the CML definition is retained.

**5.4.2.2 Sociocultural Mediation of Learning:** Section 4.4.2 described the social structures of volunteer participation that can have an impact on learning, e.g., on their own, with friends and family, or with social groups created by the project or by others. Each of these social groups can be influenced by the cultural norms, values, and beliefs of its members, which in turn influence the learning that takes place within those groups (Bodrova, 1997). This description of the social structures found in citizen science essentially match the intent of within-group social mediation as defined in the CML (Shaby et al., 2019), i.e., social groups will work with each other to “decipher information, reinforce shared beliefs, and for meaning making (J. H. Falk & Dierking, 2018, p. 151).” However, due to their distinct impact on volunteer experiences and range of relevant social structures observed in practice, as well as terminological clarity for an interdisciplinary field, *sociocultural mediation* is a better fit for the CMCSL than the original terminology.

**5.4.2.3 Sociotechnical Mediation of Learning:** The CML does not address technology as an influence on learning. However, the findings from this study (specifically Section 5.2.2) showed that technology is an important mediator of volunteer learning—so much so, that it would be hard to adequately describe learning in citizen science without including it somewhere. This mediation

can take place on websites, with online tools, or on social media platforms. Additionally, the number of projects that are entirely technology-based (i.e., do not involve field-based participation) is substantial enough to require that technology be addressed in a model of learning in citizen science. As a result, since the uses of technology are inherently inter-related within this context, *sociotechnical mediation* is the more appropriate term to be included within the *social context* of the CMCSL.

### **5.4.3 The Physical Context**

As discussed in Section 5.2.1, the *design* and *orientation* of the museum do not necessarily fit the physical context of a citizen science project very well, as most projects are not centered on an intentionally designed environment. According to the CML, *design* refers to the physical structures and spaces of the museum and *orientation* refers to the cues that lead people through those spaces (J. H. Falk & Storksdieck, 2005)—neither of which clearly aligns with the methods by which citizen science projects engage with their volunteers, nor describes the research or outreach goals that influence how a project approaches volunteer learning. Instead, findings from this study show that the *format* and *purpose* of the project are a better fit, defined as follows.

**5.4.3.1 Format:** The *format* of citizen science refers to two characteristics of the project: the methods projects use to achieve their research and outreach goals, and the modes of engagement projects use to communicate with and train their volunteers. Findings from this study show that projects can be described as field-based, technology-based, or hybridized in each of these characteristics. While field-based and technology-based projects are fairly self-explanatory, hybridized projects can take on a couple of different forms, i.e., field-based projects that rely on



technology for training purposes or those field-based projects that rely on mobile and/or online tools for data collection and analysis support. Moreover, this definition of format is closely aligned with the literature in citizen science regarding the citizen science project design space (Davies et al., 2016; Wiggins & Crowston, 2014). Thus, the definition and use of *format* to describe aspects of the physical context in the CMCSL aligns well with the citizen science literature.

**5.4.3.2 Purpose:** Basically, *purpose* refers to the primary objectives of a citizen science project, i.e., whether it is research-focused or outreach-focused. These objectives guide what the project does, what they consider important and can even hint at why volunteer participation is needed for the project—all of which influence a project’s volunteer learning goals. As with format, this definition for *purpose* aligns with the literature in citizen science (Wiggins & Crowston, 2011b) and more closely fits with the intent of describing the physical context of the CMCSL than that of the CML by referring to the impact of project goals on the learning environment.

#### **5.4.4 The Organizational Context**

The largest difference between the CML and the model presented in this dissertation is the acknowledgment that there is an *organizational context* of citizen science projects that has a tremendous impact on the learning goals that the project adopts and the resources that are offered to support those goals, which is notably present in prior work on citizen science, e.g. (Wiggins & Crowston, 2011b). While most of these factors are derived from the CML (J. H. Falk, 2011), they are modified to better match the organization. These differences include some combining and redefining of *prior experiences, knowledge, interests, and beliefs*; separating and redefining *motivation and expectations* into their own unique concepts; and introducing *socio-organizational*

*influences* (i.e., relationships with partners and other projects) as a new characteristic of the organizational context that have a direct impact on volunteer learning. The sections that follow discuss these characteristics of the *organizational context* of the CMCSL.

**5.4.3.3 Organizational Background:** In the original model, *prior knowledge, interests, and beliefs* are separate characteristics from *prior experiences* (J. H. Falk & Dierking, 2018). However, in citizen science, Section 5.1.2 shows that these characteristics are more or less indistinguishable within the organization—all impact volunteer learning in similar ways by influencing the decisions projects make regarding volunteer learning. As such, the *organizational background* of the project is defined in the CMCSL as the influence on project objectives and learning goals resulting from the project's and/or the project leaders' past intellectual pursuits and values.

**5.4.3.4 Organizational Expectations:** From the citizen science literature, *organizational expectations* are defined as the perceptions citizen science projects have regarding the skills and abilities their volunteers possess or are capable of acquiring through training (Becker-Klein et al., 2016). They are the mirror image of volunteer expectations, i.e., volunteers' assumptions regarding the skills needed to participate in a citizen science project's activities. These expectations of citizen science projects are directly related to the learning goals and opportunities provided to achieve those goals, which are important to include in the CMCSL.

**5.4.3.5 Socio-Organizational Relationships:** In section 5.1.3 *socio-organizational relationships* were defined as the affiliations and associations citizen science projects have with other parties that impact how that project approaches volunteer learning. These relationships can come in a couple of different forms: *partnerships* and *peer-group connections*, each of which

influences learning in unique ways. Partnerships are formal affiliations between citizen science projects and sponsors, steering committees, stakeholders, etc. which often impact project goals, funding, and staffing levels (i.e., the means by which a project can support volunteer learning goals) and closely resemble relationships found in the organizational networks literature (Gulati et al., 2017). On the other hand, peer-group connections are those informal relationships citizen science projects have with others that tend to involve knowledge sharing and collaboration, which can impact the direction of the project, and more closely aligns with within-group social mediation of learning from the CML (Schwan et al., 2014). *Socio-organizational relationships* have an impact on volunteer learning goals and the strategies citizen projects enact to meet those goals and are therefore a meaningful component of the CMCSL.

In many respects, citizen science is a close cousin to research and outreach programs housed within the broadly-defined museum. Accordingly, it seemed appropriate to examine the CML's effectiveness in identifying how the personal and sociocultural contexts of the volunteer influence a project's approach and support of volunteer learning. However, this current work clearly shows that the unique contexts of the citizen science project—beyond what is described within the physical context of the original framework—are also influential in volunteer learning. Applying the CML as a model of learning in citizen science by including those contexts stretches the model beyond its useful limits. Therefore, this work contributes an adaptation of the CML, the Contextual Model of Citizen Science Learning (CMCSL), which incorporates four key contexts to citizen science learning: the personal contexts of the volunteer, and the social, physical, and organizational contexts of the project. The chapter concludes with a brief summary and review the CMCSL and how the answers to the RQs in Chapter One contributed to that model.

## 5.5 *Summary*

This chapter looked to accomplish two things: to answer the three research questions posited in Chapter One and to discuss this work's contribution to theory. This summary provides a brief review of the answers to those RQs and then revisits the new model introduced in Section 5.4, the Contextual Model of Citizen Science Learning. It concludes by detailing how the answers to the RQs pointed me toward the development of a new model of volunteer learning in citizen science.

RQ 1 asked about the citizen science project contexts that influence volunteer learning goals. In Section 5.1, these influences were shown to be project priorities, the personal contexts of leadership, and the relationships projects have with others. Looking at these factors through the theoretical lens of the CML, findings from this study show that project priorities are their motivation and purpose (i.e., orientation), with purpose describing project objectives and motivation describing the need for citizen science participation to accomplish those objectives. Another influence on these objectives are the prior experiences, knowledge, interests and beliefs of project leaders, which frame their decisions on volunteer learning goals and how to support them. The final influence was the impact project relationships have on volunteer learning goals and the opportunities they can provide to support those goals. Here, partnerships are defined as those formal relationships with funding agencies, stakeholders, etc. as well as other informal peer-group connections with other projects and organizations where knowledge-sharing and collaboration were more common. Thus, RQ1 was answered in this research by identifying the contextual factors of project priorities, prior experiences of project leadership, and relationships with other projects and entities as important influences on volunteer learning goals in citizen science projects.

Section 5.2 focused on the second RQ, which asked how contexts of the project impact the learning opportunities they provide their volunteers. This question was answered by looking at the project's format and purpose, which are parallel to but different from the concepts of design and orientation from the CML. In the study presented here, the project's format is defined as the modes of engagement and methods by which citizen science projects use to achieve their research and outreach objectives, i.e., field-based, technology-based, and hybridized format. Project purpose is defined as the primary objectives a citizen science project prioritizes that describes what the project does (i.e., research-focused, outreach-focused), why that activity is important, and why they need citizen science participation to achieve those goals. Both factors, format and purpose, were shown to not only impact the learning goals a project focuses on; they also impact how and to what degree those learning goals are supported.

The final RQ asked how the project's learning goals and opportunities aligned with the personal and sociocultural contexts of their volunteers. Answers to this RQ were offered in section 5.3 and revealed that citizen science projects are currently creating learning content specific to their known volunteer base, whether that is based on age group or some other demographic. However, findings from this study also show that many citizen science projects are looking at ways to be more inclusive, which can change the volunteer learning goals and opportunities offered by the project.

Additionally, there has been an increase in the choice and control projects are providing their volunteers in completing their training and participation activities, especially since the onset of social distancing restrictions from the COVID-19 pandemic. Even after restrictions were lifted, many of these options were retained to preserve volunteers' power to determine how and when

they learn. As a result, and in answer to RQ3, citizen science projects are trying to align their learning opportunities to the contexts of their volunteers by recognizing the importance of volunteer demographics and by maintaining resources that afford their volunteers with the power to choose how and when learning takes place.

When looking at the full picture of how the personal, sociocultural and physical contexts of learning applied to citizen science, modest adjustments were attempted to get the CML to apply to a space outside of the museum. However, this study found that organizational contexts beyond those described in the CML's physical context characteristics of format and purpose (design and orientation) also had a substantial influence on a project's learning goals and the strategies they elect to meet those goals. This work therefore presents an adaptation of the CML, the Contextual Model of Citizen Science Learning (CMCSL), which includes these organizational contexts and changes others to align with the volunteer learning goals and opportunities described in this study. As shown in section 5.4, these contexts are the volunteer context, the social context, the physical context, and the organizational context.

Within the contexts of the CMCSL there are 12 characteristics and factors of both the volunteer *and* the project that were shown to influence learning in citizen science. While many of these characteristics are similar to those found in the CML, a closer examination of learning in citizen science shows that there are several factors that either did not fit within the confines of the theory or needed significant changes to their definitions. This was evident with the need to add organizational characteristics of the project to the model as well as making significant changes to definitions regarding project format and purpose (i.e., design and orientation in the CML) and characteristics within the sociocultural context. More importantly, technology use is portrayed as

a secondary feature of the museum experience in the CML whereas this study found that technology has a more significant role in citizen science and its approach to learning. In sum, the evidence presented here substantiates the need to develop a new model of learning for citizen science, the CMCSL.

In the next and final chapter, I discuss the contributions of this work to theory and practice and look forward to future work.

## 6 Conclusion

This chapter provides an overview of the work done, how this work contributes to theory and practice, and looks towards future work. The chapter concludes with a brief review of the answers to the research questions posed in Chapter One.

### 6.1 Overview

The purpose of this study was to explore both volunteer learning from the perspective of the citizen science project and the effectiveness of using the personal, sociocultural, and physical contexts as described in the CML to identify the key factors that influence how projects approach volunteer learning. The study involved semi-structured interviews with 27 project leaders, education coordinators, and outreach directors from 22 citizen science projects, programs, and agencies. Document analyses of the associated project websites, digital and physical learning materials, and marketing resources (approximately 450 documents) to triangulate the interview data as well as to provide additional insight into the projects and how they are approaching volunteer learning.

As seen in Chapters Four and Five, project leaders spoke to many of the personal, sociocultural and physical contexts of their projects. However, those same findings showed that while the CML can be an effective framework to examine volunteer learning, it required substantial retooling to adequately support understanding informal science learning in a citizen science project. Thus, the Contextual Model of Citizen Science Learning was developed to address that theoretical gap. The CMCSL offers citizen science projects and researchers a framework of four contexts with 12 elements of the project and the volunteer that can affect learning.



## 6.2 Contributions

The research presented in this dissertation contributes to citizen science theory and practice through the introduction of a new framework, the Contextual Model of Citizen Science Learning (CMCSL).

### 6.2.1 Contributions to Theory

This study sought evidence supporting the generalizability of the CML to other closely-related domains outside the broadly-defined museum—and mostly accomplished that goal. However, it was too heavy of a lift for the framework to withstand without significant changes to the model, which led to the development of the CMCSL, the primary contribution of this study. Based upon the knowledge and experience of project leaders—something rarely, if ever, accomplished in the literature—this framework moves the idea of contextual influences on learning out of the museum to create a new model of informal STEM learning centered on citizen science participation. As such, it expands our perspective on how informal learning is shaped and differentiates the contexts of citizen science from other institutions.

At its core, findings from this study show that, like the CML, the CMCSL describes the *who, where, why, and what* of learning in citizen science that ultimately influences *how well* volunteers learn what projects want them to. In other words, the CMCSL brings a new dimension to the discussion on learning in citizen science that gives weight to the contextual influences of both the project and the volunteer. Beyond citizen science, contextualizing the organizational factors that influence the learning of others is a novel approach—whether that learning is back at the museum, in scouting or an after school program, or in other institutions that place value on informal learning—and could prove to be equally applicable to those situations.

### ***6.2.2 Contributions to Practice: Learning from the Project's Perspective***

From a practical standpoint, findings from this study show that volunteer learning goals and the strategies citizen science projects take to support them largely depend on the dynamic and synergistic contexts of both the project and the volunteer. While this might sound obvious, these influences were not clearly and systematically identified in the prior literature yet have profound implications for decision-making surrounding project design in citizen science. Although it might be easy for projects to think of a few of these factors on their own as they develop their approach to volunteer learning, others might not be as readily apparent or easily understood. The CMCSL offers citizen science project leaders with a new framework that describes current practices and priorities which can help identify those project-related and volunteer-related characteristics they may otherwise overlook but which are important to consider.

Moreover, this research shows that a project's approach to volunteer learning is not created in a vacuum and can evolve based on changes in organizational priorities, values, or relationships. By demonstrating how the changing use of technology supports volunteer learning, this work also suggests opportunities for continuing professional development of citizen science project leadership. The CMCSL can therefore bring clarity to citizen science projects in those situations that helps them make informed decisions regarding their volunteer learning goals and the opportunities they provide to support them, to the benefit of both the project and volunteers.

## **6.3 Future Work**

One of the goals of this study was to understand the perspective of the project leaders on how citizen science projects develop and support their volunteer learning goals. The findings point to the different ways in which projects are offering learning opportunities to support those goals. Yet, because volunteers were not included in this research, there is no easy way of knowing *how* or even *if* volunteers are using those learning materials provided by the projects in this study. Thus, future work should take a deeper look at volunteers' use of project learning opportunities to see which resources and opportunities they value, and the alignment of these priorities between volunteers and projects.

Another path for future work involves a deeper investigation of hybridized projects, specifically those field-based projects that turned to online formats for volunteer training during COVID-19 restrictions. This pivot provides an excellent opportunity to investigate volunteer learning and skills development pre- and post-pandemic to see if there are any differences across training formats. Participation and retention could also be examined in as a signal of alignment between volunteer contexts and project goals. Both of these directions for future work would involve incorporating the perspectives of volunteers. In research on citizen science, it is relatively rare to examine both project and volunteer perspectives for a variety of reasons, but the CMCSL provides a framework that could help ease those challenges.

Taking the research back into the focus of the project, future work can also look at those citizen science projects that do not have an online presence to verify whether their approach to volunteer learning matches the findings discussed in this dissertation. This work can be used to strengthen the CMCSL and ensure that this framework is a reliable resource for citizen science projects and researchers to use in investigations of the contextual influences on learning in citizen science. A

tool or practical guide could also be developed to walk researchers and developing citizen science projects through the volunteer and project contexts that influence volunteer learning goals as part of the project design process.

## **6.4 Summary**

This dissertation looked to answer three questions: How project contexts impact their volunteer learning goals; how those contexts impact the support of those volunteer learning goals; and how those learning opportunities are aligned with the contexts of their volunteers. Evidence from document analysis and interview data provided the details on how those questions were answered.

The first question was answered by identifying how a project's purpose, their relationships, and the prior experiences of project leadership can influence the learning goals projects choose to prioritize. These influences included whether the project was research-focused or outreach-focused, the amount of impact sponsors, stakeholders, or steering committees have on project learning goals, and the influence of a project leader's earlier experiences and decisions related to learning goals. In each of these situations, characteristics within the organizational context of CMCSL were influential in how volunteer learning goals of the project were developed and prioritized.

In the second question, the focus of the research moved to the learning opportunities provided by citizen science projects to support their learning goals. This question was answered by looking at the physical contexts of the project. In this case, the format in which projects were mediated and the methods through which learning resources were offered (field-based, technology-based, or hybridized formats) played a significant role in how volunteer learning

opportunities were provided. Additionally, project purpose often determined the amount and types of learning opportunities offered—with research-focused projects offering just enough training for volunteers to complete the tasks asked of them while outreach-focused projects offered access to much more. Regardless of format or purpose, however, technology was a large component in how citizen science projects supported volunteer learning.

The final question asked how learning opportunities are intended to meet the needs of volunteers. Findings here pointed to characteristics within the personal context of the volunteer, namely personal demographics and volunteer choice and control, being the most influential factors citizen science projects considered when providing learning opportunities for their volunteers. The research showed that projects recognized the current general demographics of their volunteer base and worked to design their learning materials accordingly. However, project leaders also acknowledged the importance of inclusion, in support of several broader goals, and were actively seeking ways to align their projects with the needs and interests of a wider range of people as a result. Findings also pointed to an increased awareness of volunteer choice and control that led many projects to offer multiple modes of the same learning opportunity in order to provide their volunteers with the power to choose *how* and *when* they engaged in learning, a notable shift in practice prompted by pandemic adaptations to project participation.

Finally, this work points to the contexts of the project and the volunteers being more intertwined and fluid than originally imagined or documented in the literature. These contextual influences, as documented in the Contextual Model of Citizen Science Learning, come together through complex arrangements to create the volunteer learning goals and the opportunities citizen

science projects provide to support meaningful informal science learning experiences through engagement in authentic scientific research.

FIN

## 7 References

*Automatic citation updates are disabled. To see the bibliography, click Refresh in the Zotero tab.*

## **8 Appendixes**

### **8.1 Appendix A – Email Interview Request**

Hello, my name is Holly Rosser and I'm completing my dissertation research on how citizen science projects support volunteer learning. This work has been reviewed and approved under IRB # 0640-22-EX. As part of this work, I am interested in speaking with project leaders, such as yourself, to explore the ways in which citizen science projects are using their resources to provide learning opportunities for their volunteers. Would you be willing to sit down and discuss this topic with me for about an hour over Zoom? While I am located in the US Central Time Zone, I am more than willing to accommodate your availability to the best of my ability.

If you are able help me with this research, I would appreciate it if you could respond to this e-mail with three dates (and times) you are available to chat. I will do my absolute best to work within this schedule.

I look forward to hearing from you soon,

Sincerely,

Holly K Rosser



## 8.2 Appendix B – Semi-Structured Interview Protocol (Summarized)

### PARTICIPANT IN CONTEXT

1. What is your role in the project?
  - a. Does your role involve supporting volunteer learning? If so, how?

### VOLUNTEER DEMOGRAPHICS

2. Let's start off with some background on your project. How many volunteers do you have in your project?
  - a. Do you have any insight into the demographic make-up of your volunteer base?

### VOLUNTEER TASKS

3. What are the primary tasks do you have volunteers complete for your project?
  - a. Are volunteers required to have any specific skills to be qualified for participation?
4. What are the social arrangements around volunteer participation? For example, is it primarily a solo effort, done in groups, or something else?
  - a. Are there other common ways that people participate in the project?

### VOLUNTEER TRAINING

4. What kind of training is expected for volunteers?
  - a. Are there any supporting materials for volunteer training? If so, what kinds of materials do you provide and what formats are they in?

- b. Are there any specific reasons why you chose those formats over others?
5. Some of the ways that projects use technologies to support training include communicating with volunteers, sharing files, providing additional resources, and coordinating trainings. Can you describe how technologies support your project in the area of training volunteers?
- a. Can you describe why that decision was made?
- b. I'm examining training materials as part of my research. Are there any training materials for your project that I wouldn't be able to find online that you could share with me?

#### VOLUNTEER LEARNING GOALS

6. Is volunteer learning a specific goal or priority for your project?
- a. Can you describe why that decision was made?
7. From a project management perspective, what factors do you think have had the most influence on how your project supports volunteer learning?
8. Are there any other things that you think are important that I forgot to ask about related to the themes that we discussed?

## 8.3 Appendix C – Codebooks

### 8.3.1 Deductive Analysis Codebook

<b>Context</b>	<b>Characteristics</b>	<b>Definition</b>
Personal Context	Motivation & Expectations	Learning is mostly intrinsically motivated, meaning that it is self-motivated, emotionally satisfying, and personally rewarding. Learning is also enhanced when a person's "self-related agenda" matches with reality of the experience.
	Choice & Control	Learning is enhanced when there are choices and control over what and when a person learns.
	Prior Knowledge, Interests & Beliefs	Learners actively self-select the programs and projects to participate in. Meaning is framed within (and constrained by) a person's prior knowledge, interests, and beliefs.
Sociocultural Context	Facilitated Mediation	Socially-mediated learning can occur with individuals we perceive to be skilled and knowledgeable (i.e., teachers, project leaders/coordinators, etc.)
	Peer-Group Mediation	Social groups utilize each other to help in deciphering information, for reinforcing shared beliefs, and for meaning making. These groups can student groups, families, friend groups, etc.
Physical Context	Design	The physical structures and spaces of the museum
	Orientation	The cues that lead people through the physical spaces or the museum
Learning Goals	Research-focused	Project learning goals that center around training volunteers to complete tasks that meet the scientific priorities of the research team.
	Outreach-focused	Project learning goals directly related to educating participants and the general public on the phenomenon of interest.
Learning Opportunities	Training & Process Knowledge	This is the project specific information provided to participants so they can complete tasks and activities asked of them.
	Hard-Copy Materials	Physical resources available to participants that provide training, task instruction, and access to supplemental learning materials.
	Informative Outcomes	Specific education goals of a project related to project objectives. This can include community outreach, informing stakeholders, community stewardship efforts, etc.
	Supplemental Learning Resources	Learning materials created or provided by the project to educate participants on a topic that goes beyond what is needed for task/protocol completion.

### 8.3.2 Inductive Analysis Codebook

<b>Context</b>	<b>Characteristics</b>	<b>Definition</b>
Personal Context	Demographics <i>Age</i> <i>Education</i> <i>Ethnicity</i> <i>Ability</i>	Data related to the volunteers' age, education level, ethnicity, physical and neurocognitive abilities
Sociocultural Context	Technological Mediation <i>Sociotechnical Media</i>	Efforts made by a project to incorporate mostly online technologies into their volunteer training programs. This includes the use of social media tools and platforms for learning (YouTube, Zoom, Socials, etc.).
Physical Context	Design (Format) <i>Physical</i> <i>Technological</i>	Features of the project attributed to the type of activity, training and learning materials provided to volunteers. These are generally technological or physical design characteristics of the project.
	Orientation (Purpose)	Orientation in citizen science is what the project is about, why it's important and why the project needs citizen science participation.
	Influences on Design <i>Contextual</i> <i>COVID-19</i> <i>Funding</i> <i>Staffing &amp; Staff-Time</i>	Factors that may or may not be within the project's control that influences how they are able to support volunteer learning.
Persona	Volunteer	Characteristics or data related to volunteers, participants, or program members
	Project (Organization)	Characteristics or data related to the project, i.e., organization
Learning Opportunities	Presentation Type <i>Synchronous</i> <i>Asynchronous</i>	Participation in citizen science activities can be either synchronous or asynchronously completed, i.e., live or recorded