Teaching With Citizen Science: An Exploratory Study of Teachers' Motivations & Perceptions

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Abstract

With the continued emphasis in the United States on science teaching reform as a way to increase science learning and the scientific literacy of all, the integration of informal science learning activities like citizen science is emerging as a possible way to enhance formal science teaching and learning. There is a limited but growing number of studies indicating that the general public is learning science content and process from participating in citizen science, but research in this area is just beginning and the use of citizen science projects by teachers in formal classroom settings has barely been examined at all. This qualitative study examined three research questions: 1) What motivates experienced middle school science teachers to use citizen science programs in their classrooms? 2) What do experienced middle school science teachers perceive to be the impact on their students as a result of using citizen science in their classrooms? and 3) What do experienced middle school science teachers perceive as the challenges in using citizen science in their classrooms? Twenty-two middle school teachers from across the United States were interviewed about their motivations and expectations regarding their use of citizen science projects in their classrooms. Using a basic thematic analysis, responses from these semi-structured interviews were coded and themes were developed. Findings indicated that teachers use citizen science to engage their students in authentic science experiences that make a contribution to science and society. Also, teachers perceive that citizen science activities broaden students' perspectives and build their agency to make a difference in their environment. Teachers perceived two main challenges with citizen science: making the task meaningful and ensuring that students experience the whole scientific process. This study makes a start at understanding why teachers use citizen science and how they perceive it to impact their students.

To my husband, Joe, for his love and support every step of the way

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Chapter 1: Introduction

The low level of science understanding and scientific literacy of K-16 students and the general public in the United States is causing major concern (National Research Council [NRC], 2011; 2013; National Science Board, 2010; President's Council of Advisors on Science & Technology, 2010). A scientifically literate society with a foundational understanding of science, technology, engineering, and mathematics (STEM) is essential to success in everyday life and in the workplace (NRC, 1996). One way to address this concern is to improve STEM teaching at all levels in schools across the country. The development and release of the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) is one attempt to reform the teaching of STEM and thereby increase student understanding of science. The NGSS require a shift in teachers' concepts of science teaching, focusing on the practices of science as well as content. This change is intended to bring more authentic science experiences into the classroom (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014).

Interestingly, several studies indicate that much science learning happens outside of school, in more informal environments (Falk & Needham, 2013; Falk, Storksdeick, & Dierking, 2007; Rennie, 2014). Experiences in informal learning environments such as museums, science centers, after-school programs, and camps have been shown to impact public awareness of, attitude towards, interest in, and learning of science (NRC, 2009; 2015). As a result, there is increasing interest in how informal programs, or at least critical aspects of them, might augment STEM teaching and learning in the formal environment. Bringing informal science experiences into the formal education setting could increase the meaningfulness and relevance of science instruction and may hold some promise for schools looking to boost student achievement and interest in STEM.

One type of informal science activity, citizen science, is becoming increasingly popular with the public (Bonney et al., 2015); and although people may not always recognize the term “citizen science,” many are familiar with the idea under a different name such as “crowd-sourced science” or “community-based monitoring” (Lewandowski, Caldwell, Elmquist, & Oberhauser, 2017). Citizen science involves volunteers of all ages participating in a variety of science activities from counting bird species to monitoring the water quality of streams to marking surface features of the Moon. The data collected and/or analyzed by the volunteers are used by professional scientists (i.e., scientists associated with a university or other research institution who are conducting the research study) in their research, so the citizen scientists are making real contributions to science. For example, one popular project—the Great Backyard Bird Count—involves volunteer birdwatchers across the United States counting the number and types of birds that they see. They send their data to scientists at the Cornell Lab of Ornithology who are studying the distribution and movements of bird species. The volunteers are not trained as professional ornithologists, but they can still collect needed data and contribute to the research.

These projects have many characteristics of informal science programs (NRC, 2009) as they are voluntary, non-assessed or assessed in a non-traditional way, often learner-directed, and non-curriculum based (Hofstein & Rosenfield, 1996). For example, backyard birdwatchers send thousands of bird observations to scientists in projects like eBird and Project Feederwatch (Sullivan et al., 2009), weather observers gather data from home weather stations (National Oceanic & Atmospheric Association [NOAA], 2006), and amateur astronomers use their own telescopes to observe variable stars (American Association of Variable Star Observers [AAVSO]), n.d.).

Rationale of the Study

Although most citizen science happens outside of school, some teachers are now using these types of activities in their classrooms, and many citizen science projects provide some type of educational resources to assist teachers in classroom implementation. A few programs even offer professional development-type classes and workshops. For example, Project Budburst has a website offering a whole range of educational support, from lesson materials to online professional development (National Ecological Observatory Network, 2015). On the Journey North website (Journey North, 2015), teachers can find similar resources plus reading and assessment strategies.

Although some teachers may be seeing the potential benefits of integrating an informal activity like citizen science into the formal educational environment, such a mixing of educational environments is bound to have challenges. Additionally, the adoption of innovation by teachers, whether the innovation is a new curriculum or a new type of technology or a new grading system, takes time. Successful change requires careful consideration and respect of a teacher’s values and beliefs since these values and beliefs play a large role in what gets taught and how (Ertmer, 2005; Hong & Vargas, 2016). Therefore, if integration of citizen science into the formal classroom is to be successful, it is essential to understand teachers’ values and beliefs regarding teaching with citizen science.

Significance of the Study

With the continued emphasis in the United States on science teaching reform as a way to increase science learning and the scientific literacy of all, the integration of informal science learning activities like citizen science is emerging as a possible way to enhance formal science teaching and learning. There is some anecdotal evidence and a limited but growing number of studies indicating that the general public is learning science content and process from participating in citizen science, but research in this area is just beginning.

Furthermore, although participation in citizen science by the general public is beginning to be studied, the use of citizen science projects by teachers in formal classroom settings has barely been examined at all. As of this writing, I have only been able to find a few studies that study citizen science as used in a formal education setting. Hiller and Kitsantas (2014) studied middle school students participating in a horseshoe crab citizen science project. Ballard, Dixon, and Harris (2017) studied youth-focused community and citizen science (CCS) by examining two programs occurring at multiple sites, some of which were formal education settings. Ruiz-Mallén, Riboli-Sasco, Ribrault, Heras, Laguna, and Perié, (2016) examined the learning outcomes of secondary students in Spain who were involved in a citizen science project. Finally, Wallace and Bodzin (2017) studied the impact of participation in citizen science on ninth graders' identity development as citizen scientists. Beyond these empirical studies, there are stories of citizen science being brought into the formal classroom environment at all levels, some essays discussing and debating potential educational benefits of participation in citizen science, but no formal studies of how this intersection of informal and formal education looks from a teacher's perspective; in other words, how citizen science is being used by teachers, teachers' reasons for using citizen science, how a citizen science activity fits into existing curricula, how much time students spend engaging in citizen science, and what types of citizen science projects are being used. Also, it is not known what the impact of participation is on students and teachers (e.g., changes in attitudes, learning, science identities, understanding of the nature of science, etc.), and whether or not there are significant challenges to implementation and participation. This study helps fill a gap in the research literature and provides a first look at the use of citizen science in formal education through the eyes of teachers. It makes a start at understanding why teachers use these activities and their values and beliefs regarding citizen science and its impact on their students.

Also, the findings of this study may be of use to designers of citizen science projects who are interested in developing projects that support teachers and classroom use implementation. Administrators and professional development providers may be interested in the findings when they consider how best to support teachers in integrating citizen science into an existing science curriculum. This, in turn, could facilitate the wider use of citizen science by teachers.

Finally, this study uses a qualitative methodology, allowing the teachers themselves to describe their expectations and perceptions of citizen science. Concepts and themes that arise in this study may form a useful framework for future studies into teachers' use of citizen science.

Overview of the Dissertation

In Chapter 2, I provide a review of relevant literature in the following areas: 1) science teaching reform, 2) scientific literacy and science practices, 3) the intersection of formal and informal science learning, 4) citizen science and science learning, and 5) citizen science and participant motivation. I also give an overview and some definitions of citizen science. Finally, I state the purpose of the study and discuss its research questions.

In Chapter 3, I outline the methodology used to address the research questions, including the data collection instruments and data collection process, and the analysis procedures. Finally, I discuss credibility, consistency, researcher positionality, and ethics as they relate to this study.

In Chapter 4, I present the findings of the study, including a description of the participants' teaching experience and their use of citizen science both personally and in the classroom. I also describe the themes and subthemes that I found in analyzing participant interviews, and I illustrate these themes with extracts from the interview transcripts.

In Chapter 5, I discuss the findings, exploring several concepts in greater depth and making connections to relevant literature. Finally, I discuss limitations of the study and give some suggestions for future areas of research.

Chapter 2: Review of the Literature

In this chapter, I explore the literature in five main areas: 1) science teaching reform, 2) scientific literacy and science practices, 3) the intersection of formal and informal science learning, 4) citizen science and informal science learning, and 5) citizen science and participant motivation.

Science Teaching Reform

Although many scholars would cite the launch of Sputnik in 1957 as the beginning of science teaching reform in the United States, I will focus on more recent events, specifically the development of national science education standards. These national standards serve as a consensus of experts, describing not only what should be taught but also how it should be taught.

In 1989, the American Association for the Advancement of Science's (AAAS) published *Science for All Americans,* followed in 1993 by *Benchmarks for Science Literacy*. *Science for All Americans* outlined what adults should know about science by the time they graduate from high school. *Benchmarks* described goals for what students should understand and do in science, math, and technology at the end of certain grade levels. These volumes did not recommend any particular type of instruction (although *Science for All Americans* includes a chapter on effective teaching and learning), but focused on the elements of science literacy and the essential big ideas that are important for all people to know (American Association for the Advancement of Science [AAAS], 1989; 1993). Three years later, in 1996, the National Research Council's *National Science Educations Standards* (NSES) called urgently for change in science teaching and a focus on science as inquiry. The NSES stated that learning science is an active process, but hands-on activities are not enough. Activities must also be “minds-on,” and students must understand and learn how to conduct scientific inquiry (NRC, 1996).

Implementing NSES with a focus on inquiry can be problematic. The NSES do not provide a specific definition of inquiry, nor a specific set of instructions for carrying it out in the classroom. Examples of activities and suggestions for teaching are provided, but it is left to the teacher to interpret these ideas and transfer them to a particular classroom setting. This lack of specific instruction may be viewed as empowering for teachers, giving them the flexibility to create activities that fit their own style of teaching and their own classroom environment (Keys & Bryan, 2001), but it may also create a certain amount of confusion, uncertainty, and discomfort for teachers. In fact, many teachers have a poor understanding of inquiry (e.g., equating inquiry with “cook book” labs) and have trouble implementing inquiry-based teaching, citing factors such as insufficient time, poor student behavior, and a lack of materials (Hong & Vargas, 2016).

Sixteen years after the publication of the NSES, the National Research Council (2012) published *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* to inform the subsequent publication of the Next Generation Science Standards (NGSS) in 2013. Both publications reaffirmed the importance of inquiry-based instruction but also included shifts in how teachers needed to view science teaching. Instead of focusing on facts, teachers should help students to develop explanations of phenomena. Instead of separating inquiry from content, inquiry or science practices should be infused into all science learning (Reiser, 2013). Furthermore, ideas that are common to all domains of science—crosscutting concepts like energy, scale, and systems—should be a part of science learning. The three dimensions of the

NGSS—disciplinary core ideas, science and engineering practices, and crosscutting concepts—should be woven together like strands on a rope to strengthen science learning (Krajcik et al., 2014).

Scientific Literacy and Science Practices

Scientific literacy has been defined in many ways. *Science for All Americans* (AAAS, 1989) presents a multi-faceted definition that includes

> being familiar with the natural world and respecting its unity; being aware of some of the important ways in which mathematics, technology, and the sciences depend upon one another; understanding some of the key concepts and principles of science; having a capacity for scientific ways of thinking; knowing that science, mathematics, and technology are human enterprises, and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal and social purposes. (Introduction, The Recommendations Reflect a Broad Definition of Science Literacy)

The National Science Educations Standards (NSES) described scientific literacy as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity (NRC, 1996, p. 22). The more recent Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) continue that idea, focusing on disciplinary core ideas, scientific practices, and then adding crosscutting concepts. Also, a group of researchers based at the University of Michigan created a framework for scientific literacy for South Korea that included five dimensions: content knowledge, habits of mind, character and values, science as a human endeavor, metacognition, and self-direction (Choi, Lee, Shin, Kim, &

Krajcik, 2011). It is clear that to be scientifically literate, one must know more than just science content. The emphasis on both science concepts and processes is seen as a critical component in science education, as students need to understand not only science content but also how science works.

In his overview of the history of scientific literacy, George DeBoer (2000) describes the development of scientific literacy as a lifelong process that is facilitated by diverse educational environments. He concludes that there are many ways to define scientific literacy and many routes to achieving it, saying "the important thing is that students learn something that they will find interesting so that they will continue to study science both formally and informally in the future" (p. 597). The Center for Advancement of Informal Science Education (CAISE) report, *Making Science Matter* (Bevan et al., 2007), builds on this idea. It describes scientific literacy as a complex, emerging vision and states that "no single institution, such as schools, afterschool or youth organizations, or science-rich cultural institutions, can achieve this vision acting alone" (p. 12). Fostering scientific literacy involves a diversity of organizations, personnel, and settings.

According to the National Research Council (NRC), in order to develop scientific literacy, including an understanding of the nature of science, one must engage in the practices of science. The NRC goes on to state that not only should students learn and perform science practices, but that the practices should "reflect those of professional scientists and engineers" (NRC, 2012, p. 41). In other words, the practices should be authentic. Engaging in authentic scientific practices helps students learn how scientific knowledge develops, how scientists work, and that there is more than one scientific method (NRC, 2012).

Intersection of Formal and Informal Science Learning

Informal learning takes place outside of school and is typically learner and interest-driven. Furthermore, it is a powerful life-long phenomenon since people spend most of their lives outside of a traditional school setting, visiting parks and museums, taking walks through a forest, watching television at home, etc. These types of settings provide many opportunities for informal science education (NRC, 2009). The Center for the Advancement of Informal Science Education (CAISE) describes informal science education as "grounded in a view of the human as naturally curious, social, and actively engaged in learning" and "characteristically pleasurable, open-ended, equitable, and accessible" (CAISE, website2015).

Besides being a valuable experience in its own right, informal science education is seen as having much to offer the world of formal science education. As an engaging and pervasive experience, informal science can go beyond what the schools can do to help increase scientific literacy and achieve "lifelong, life-deep, and life-wide" science learning (NRC, 2009, p. 28). For example, experiencing science education across a variety of settings may positively impact the development of student science identity and agency, especially in groups underrepresented in science fields (Carlone & Johnson, 2007, 2014; Stromholt & Bell, 2017), since identity is developed through social interaction in and across different environments (Aikenhead, 2001; Banks et al., 2005; Gee, 1999, 2000). Holstein and Vargus (1996) consider informal science learning and formal science learning as complementary and discuss ways that informal experiences could be brought into the formal learning environment. They separate learning context from learning methods and put both constructs on a continuum from compulsory/formal to free-choice/informal. They conclude that context and methods can be mixed, and that this blending will provide a wide variety of learning experiences for diverse learners, thereby "meeting the challenge of 'science for all'" (p. 107).

Another group of researchers (Stocklmayer, Rennie, & Gilbert, 2010) also maintained that informal and formal learning are complementary and valuable; however, bringing the two contexts together is not a simple task. They discuss challenges to blending the two types of learning (e.g., the difficulty that schools have in visiting informal sites) and recommend a model whereby "the formal sector integrates the capabilities of the informal sector into its everyday working, thus creating a 'third space' for science education" (p. 29). It seems clear that while a blended or hybrid model of informal and formal science learning would be beneficial, there are still challenges to overcome in implementing such an idea.

Overview and Definitions of Citizen Science

Citizen science in one form or another has existed for hundreds of years. In 1776, Thomas Jefferson began asking volunteers in Virginia to collect weather data (NOAA, 2006), and in the 1800s, bird-counting programs were initiated that involved lighthouse bird-strikes, migration patterns, and species counts (Droege, 2007). Yet, since the mid 1990s, citizen science has grown substantially (Bonney, 2015; Wiggins & Crowston, 2015) in part because the Internet now provides opportunities for projects, participation, and communication that were not possible before. In online projects like Galaxy Zoo (galaxyzoo.org), Moon Mappers (cosmoquest.org), and Stardust@Home (stardustathome.ssl.berkeley.edu), the public uses a home computer and an Internet connection to analyze the large amounts of data coming in from various NASA and ESA (European Space Agency) missions. In projects such as eBird (ebird.org), Squirrel Watch (projectsquirrel.org), and Journey North (learner.org/jnorth), volunteers collect data in "the real world" and then upload it to scientists via the Internet. Furthermore, many projects offer volunteers opportunities to talk with other participants in online forums, access additional content and keep track of their progress on project websites, and learn of project updates and new discoveries through social media. Largely due to the Internet, interest and participation in citizen science continues to grow.

With the growth of citizen science came the need to more tightly define it. The term "citizen science," as it is typically used today, refers to volunteers assisting scientists in their research and was first introduced by the Cornell Lab of Ornithology in 1994 to describe their many bird watching programs (Bonney et al., 2015). In 2009, a Center for Advancement of Informal Science Education (CAISE) inquiry group examined different types of public involvement with professional science, what they termed "Public Participation in Scientific Research" (PPSR), and divided these activities into three categories: contributory, collaborative, or co-created. Contributory projects are designed and managed by scientists, with participants supporting the research through data collection. Collaborative projects often involve participants in the project design and/or refinement as well as the analysis of data and the communication of results. Finally, co-created projects are those that are truly collaborations of professional scientists and the public. Participants are involved in all aspects of the scientific process including the development of the project itself. The CAISE group stated that citizen science activities most often fell in the “contributory” category, as they usually involve volunteers simply contributing data to the project, not working with scientists as collaborators or in creation of a project (Bonney et al., 2009).

Other groups have put forth broader definitions of citizen science. Cornell’s Citizen Science Central offers this definition for its citizen science projects: “projects in which volunteers partner with scientists to answer real-world questions” (Cornell University, 2015). The newly launched web publication *Citizen Science Today* calls citizen science “the involvement of non-professionals in the scientific process” (Citizen Science Today, 2015), and *SciStarter*, a popular online repository of citizen science projects, defines citizen science as “the public involvement in inquiry and discovery of new scientific knowledge” and adds that ‘amateur science,’ ‘volunteer monitoring,’ ‘crowdsourced science,’ and ‘public participation in scientific research’ are all “aliases” for citizen science (SciStarter, 2015).

Recently, the term *citizen science* was added to the Oxford English Dictionary (OED) (Bonney et al., 2015). The OED’s definition, “scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions,” has been adopted as “a starting point for discussion” by the Citizen Science Association (Citizen Science Association, 2015). At this point, there is not an official or even widely accepted definition of citizen science. In fact the term is under considerable review and discussion by researchers and educators who are actively involved with these programs (Eitzel et al., 2017). However, I will use the OED definition in this study, as it contains the core idea present in all definitions—

the general public doing science along with professional scientists--and is comprehensive enough to include all types and levels of volunteer involvement.

Citizen Science and Science Learning

A number of studies have looked at the educational aspects of citizen science projects in the informal environment. For example, Evans et al. (2005) reported several educational outcomes for volunteers in the Neighborhood Nestwatch program. Participants reported that they learned about new bird species in the local environment, birds' predators, and the development of young birds. The researchers also found instances of scientific thinking on the part of the volunteers such as concerns about quantity and quality of data collected, the effect that birdfeeders might have on the results, and various questions about the methodology of the study. Evans et al. (2005) looked at what they termed a participant's "sense of place," that is, an awareness of and relationship to the local environment. The study indicated that most participants experienced an increase in awareness of and attention to the different types of birds in their yards, as well as the different habitats. Many participants felt more connected to their environment, and 56% changed their behavior as a result--building more birdhouses, creating habitats, and not cutting down trees. This could be seen as developing agency, the act of influencing one’s environment (Bandura, 2006). Brossard, Lewenstein, and Bonney (2005) looked at learning in Cornell's Birdhouse Network project. Although their study indicated a significant increase in participant knowledge about bird biology, no significant changes were found in the areas of scientific process and attitude towards science, and the researchers recommended further study in these areas. Cohn (2008) also viewed developing a connection to the local environment as a valuable outcome of a citizen science project. Citizen scientists often become local experts in environmental issues and develop a sense of stewardship as well. Another project, the Melibee Citizen Science Program, stated that their volunteers reported learning basic ecological concepts (e.g., phenology, invasive plants, and pollination) and science process skills such as recording data and making scientific observations (Spellman & Mulder, 2014).

With reports coming in of these potential educational benefits to participation in citizen science outside of school, it is perhaps natural that classroom teachers would begin to involve their students in these types of projects. Over the past several years there have been several essays (Calabrese Barton, 2012; Mueller, Tippins, & Bryan, 2012; Weinstein, 2012) and many practitioner articles (Bestelmeyer et al., 2015; Green & Medina-Juarez, 2012; Jones, Childers, Stevens, & Whitley, 2012; Surasinghe & Courter, 2012) written about bringing citizen science into the formal classroom. The essays have been largely discussions about the various definitions of and democratic aspects of citizen science. The practitioner articles offer suggestions of projects for teachers to try and helpful hints for implementation.

Researchers are beginning to study citizen science projects situated in formal educational settings, although at this point, I have only found a few such published studies. Hiller and Kitsantas (2014) studied middle school students participating in a horseshoe crab citizen science project. Using a quasi-experimental design, the researchers compared achievement and career motivation in STEM between two groups of eighth graders—one group receiving traditional classroom instruction and one group participating in the citizen science project. Students in the citizen science group performed higher than the traditional instruction group on measures of science achievement and on all but one measure of career motivation. In another study, Ballard, Dixon, and Harris (2017) conducted a qualitative case-study analysis of two youth-focused citizen science programs in both formal and informal educational settings that examined, among other things, learning and stewardship outcomes for the student participants. These researchers found that through participation in three “key” processes during the programs, students developed environmental science agency (ESA). A group of researchers in Spain (Ruiz-Mallén, Riboli-Sasco, Ribrault, Heras, Laguna, & Perié, 2016) studied the experiences of a secondary students involved in a citizen science project and reported an increase in learning and interest in neuroscience from those who participated. Students in this study also gained insight into the social aspects of science and the challenges inherent in the scientific process. Finally, Wallace and Bodzin (2017) reported results from a quasi-experimental study indicating that ninth grade students who used mobile devices as part of a citizen science project improved their attitudes towards citizen science and interest in STEM careers. These students also strengthened their citizen science identity, the extent that they acted and saw themselves as citizen scientists. Stromholt and Bell (2017) examined the science-linked identities of fifth grade students analyzing water quality from a local polluted river. A learner’s science-linked identity is the extent that he or she sees “science as a desirable or accessible resource that contributes to who they are or who they want to be in the future” (p. 4). Using an ethnographic design, the researchers observed and interviewed nine students over the course of a school year, exploring how participation in authentic science practices impacted development of a science-linked identity. Findings from this study supported the idea that student engagement in authentic science practices can contribute to the development of a science-linked identity.

Citizen Science Participant Motivation & Experience

Another area of citizen science research is related to the motivations of project participants. People participate in citizen science for many reasons, and studies have revealed a variety of motives, including interest in and desire to learn about the project's topic, wanting to help, wanting to protect the environment, and a desire to contribute to scientific research (Bradford & Israel, 2004; Brossard, Lewenstein, & Bonney, 2005; Frensley et al., 2017; Geoghegan, Dyke, Pateman, West, & Everett, (2016); King & Lynch, 1998; Raddick et al., 2009). Additionally, one group of researchers attempted to find some basic underlying motivations using exploratory factor analysis (Reed, Raddick, Lardner, & Carney, 2013). The study's results revealed three basic factors related to volunteers' motivations to participate: social interaction, interaction with the website, and helping. Finally, a few studies have explored patterns in the involvement of participants, comparing how often and for how long participants stay with citizen science programs to various motivations for participation. For example, Tiago, Gouveia, Capinha, Santos-Reis, and Pereira (2017) surveyed participants in the Portuguese *BioDiversity4All* program and found that the motivations of "Interest/Enjoyment" and "Perceived Competence" correlated directly with frequency of participation. In another study, high-frequency participants in an online project *Old Weather* were motivated by social and competitive aspects of the program while those who participated infrequently reported more casual and intermittent curiosity and interest (Eveleigh, Jennett, Blandford, Brohan, & Cox, 2014).

Some researchers are looking beyond motivations and are exploring other aspects of participant involvement. Ganzevoort, Van den Born, Halffman, and Turnhout (2017) asked participants what they thought about data sharing and data ownership. About half of the participants surveyed considered project data to be public, but a smaller number felt that data sharing should not be unconditional. This concern for the thoughts and perceptions of participants is part of a growing focus on the ethical issues presented by citizen science. Although citizen science is often presented as a positive experience where both citizens and scientists benefit, there are concerns about the treatment of participants and the quality and use of the data produced. Riesch and Potter (2014) interviewed 30 scientists involved in the Open Air Laboratories (OPAL) project. These scientists expressed concerns about participant training and the resulting quality of data. They were also worried about making decisions regarding ownership of data and authorship of papers. A third area of concern involved the use of volunteers as simply free workers. Some scientists felt that volunteers were owed something in return for their help and even suggested that the use of volunteers was taking jobs away from professional scientists. Groups are working to address these issues by calling for an overall framework for the design of citizen science projects, including guidelines for how to treat project volunteers (Resnik, Elliott, & Miller, 2015).

Understanding the motivations and experiences of citizen scientists can help designers of citizen science projects create projects that are better-suited to the needs and interests of participants with the goal of increasing participation frequency and level of engagement. In a similar way, it is important to discover and understand the motivations and experiences of teachers who bring citizen science projects into their classroom. It is possible that some of the reported motivations and experiences of participants may be similar to those of teachers.

Summary

In reviewing the relevant literature for this study, it is clear that science teaching reform in the United States continues to emphasize inquiry-based instruction with students engaged in scientific practices, giving students the opportunity to engage in the same scientific processes as professional scientists and to see how science works—key elements in the development of scientific literacy. Incorporating authentic inquiry into classroom instruction can be challenging. Informal science learning activities may offer another option to teachers looking to give students an authentic science experience. Citizen science, typically an informal activity that involves authentic science practices, is increasingly finding its way into formal science instruction. Although this hybrid type of learning holds much promise, the research in this area, especially regarding citizen science, is just beginning.

This study will add to the research on citizen science as used in formal science instruction by examining teachers' motivations to use citizen science in the classroom and their perceptions of its impact. As this is, to my knowledge, the first formal study in this area, the qualitative methodology will facilitate the in-depth exploration of teachers' experiences and the emergence of new ideas, providing a base for future research.

Purpose of the Study

The purpose of this study is to investigate the perceptions of teachers currently using citizen science activities in their classrooms, their motivations for doing so, and what they perceive to be the impact of this experience. The study will also examine these teachers' perceptions of challenges involved in doing citizen science in their classrooms.

Research Questions

With this study, I expand the research into citizen science as it occurs in the formal education setting by examining the motivations and perceptions of middle school teachers who use or have used citizen science projects in their classrooms. I was guided by the following research questions:

1) What motivates experienced middle school science teachers to use citizen science programs in their classrooms?

2) What do experienced middle school science teachers perceive to be the impact on their students as a result of using citizen science in their classrooms?

3) What do experienced middle school science teachers perceive as the challenges in using citizen science in their classrooms?

1) *What motivates teachers to use citizen science programs in their classrooms?* Most teachers are inundated with the basic activities of teaching--planning and conducting lessons, grading papers, serving on committees, sponsoring extra-curricular activities, tutoring students, talking with parents—and have little extra time in which to add more classroom activities, and teachers often report the large amount of time required for inquiry-based activities (Hong & Vargas, 2016). School curricula are more and more crowded as new standards and other initiatives add to what must be taught (Lohman, 2006). With all of these demands on their time and energy, why would teachers decide to implement a citizen science project with their students? What value do teachers who do

citizen science in the classroom see in such an activity, and how do they expect it to affect their students?

2) *What do teachers perceive to be the impact on their students as a result of using citizen science in their classrooms?* The experience of bringing citizen science into the classroom may have many perceived impacts, both expected and unexpected. Perceptions of impact may include but not be limited to changes in student learning, behavior, attitudes, engagement, identity, and interests, and these impacts may be perceived as positive or negative. Teachers may notice more general impacts such as changes in classroom atmosphere, topics of student conversation, and questions and comments from parents, colleagues, and administrators. Since there is very little research on this phenomenon, it will be important to let the teachers speak freely about their experiences.

3) *What do teachers perceive as the challenges in using citizen science in their classrooms?*

Incorporating citizen science activities into an existing science curriculum brings potential challenges and requires extra effort and time on the part of the teacher. If teaching with citizen science shows promise and expands in scope (i.e., is implemented in more classrooms across the United States), it will also be important to understand the difficulties of using citizen science from the teacher's perspective. Teachers are the key to the success of any teaching reform or innovation.

Chapter 3: Methodology

In this chapter, I outline the basic research design for the study, describe participant recruitment and sampling, and explain my positionality as researcher. I describe the data collection and analysis methods as well as strategies to enhance credibility and consistency. Finally, I discuss the main ethical issues that pertain to this study and how they were addressed.

The purpose of this study is to explore the use of citizen science within formal education settings, focusing on middle school teachers' motivations to use citizen science and their perceptions of how engaging in citizen science in the classroom impacts their students. I investigated the following research questions:

1) What motivates experienced middle school science teachers to use citizen science programs in their classrooms?

2) What do experienced middle school science teachers perceive to be the impact on their students as a result of using citizen science in their classrooms?

3) What do experienced middle school science teachers perceive as the challenges in using citizen science in their classrooms?

Research Design

This was a basic qualitative research study. As described by Merriam and Tisdell (2016), basic qualitative research is an interpretive process that aims to discover how participants "understand and make sense of their lives and experiences," yet it does not have the "additional dimension" of qualitative research types such as ethnography, grounded theory, or phenomenology (p. 23). My purpose was to discover and understand teachers' motivations and perceptions of impact and challenges related to their use of citizen science in their classrooms.

A basic qualitative approach is appropriate for an exploratory study such as this one. Relatively little is known about teachers who use citizen science in the classroom, and employing a strictly quantitative approach would risk missing concepts that are key to understanding these teachers' experiences. Also, a qualitative design allows for the researcher to be open to unexpected ideas and developing themes. Finally, a qualitative methodology will let the participants' (i.e., the teachers') voices be heard through the analysis and reporting of their own words. Since teachers are most likely the ones initiating, managing, and evaluating this classroom activity, they will be able to provide a rich and detailed description of their perceptions of its impact.

In Phase I of the study, I used a short online screening survey as a tool to recruit participants for Phase II. The survey consisted of seven closed-response questions, with the final question requesting participation in a follow-up interview. With this survey, I was able to obtain some basic demographics as well as a pool of volunteers from which to select my interviewees.

Then, in Phase II, I conducted semi-structured interviews and collected artifacts and documents. During the interviews, I asked teachers about their motivations for using citizen science in their classrooms and their perceptions of its impact. I used thematic analysis to look for themes in the interview data. Thematic analysis is an appropriate tool for a basic qualitative study, as it is not tied to a particular type of qualitative research and can be used with a range of theoretical frameworks (Braun & Clarke, 2006). Furthermore, thematic analysis, as described by Braun and Clarke (2006), offers a guide to describing a study's analytical methods in a more explicit way, enhancing the transparency and credibility of the process.

I planned to collect artifacts and documents such as lesson plans, classroom handouts, examples of data collection and data collection guides, teacher blog posts, and student pictures (taken by teachers) related to citizen science activities. Similar to the interviews, these were to be analyzed using a basic thematic analysis and the findings used to complement the interview analysis, providing illustrative examples and a means of triangulation. However, I did not receive enough of these items in time and so could not include them in the study.

Participants and Sampling

Participants for this study were self-identified middle school science teachers (current or former) in the United States who have used or are using at least one citizen science program in their classroom. As an experienced K-8 teacher, I felt that middle school teachers are typically more comfortable with teaching science compared to elementary level teachers and often have greater flexibility in doing so compared with high school science teachers. Also, teachers with more teaching experience may be more comfortable with and better able to try a new type of activity in their classrooms. By focusing on experienced middle school science teachers, I hoped to maximize my chances of finding participants who had experience using citizen science with their students.

In Phase I, participants completed a short online screening survey about their use of citizen science. The survey was offered to any middle school science teacher (public or private institution, charter or traditional) who had used or was using citizen science projects as part of their classroom activities.

The survey participants were recruited in several ways. First, I posted a recruitment message (see APPENDIX A) on the main citizen science listserv in the United States—CitSci-discussion-L@cornell.edu. This listserv is a venue for discussion related to all forms of citizen science and is used primarily by project coordinators, educators, and researchers, although it is open to anyone with an interest. I also posted the message on the National Science Teachers Association (NSTA) discussion listserv for middle school teachers and on NSTA state chapter listservs, when possible. In each of these cases, many individuals offered to forward the message on to others who they felt might be interested. Lastly, I took advantage of social media (Facebook, Edmodo, Twitter) to reach educators as well as citizen science project directors. See APPENDIX B for a list of recruitment venues.

Throughout the period of the study, in order to increase survey response, I emailed personnel at citizen science projects asking for their support in encouraging teachers to participate. Additionally, several of the participants offered to pass along the survey link to their colleagues. Finally, since interactions on social media can be fleeting and unpredictable, I re-posted my recruitment message periodically to Twitter and Facebook.

In Phase II of the study, survey respondents who indicated they would be willing to take part in a semi-structured interview (either face-to-face or by phone/video) were selected using a purposeful sampling strategy (Maxwell, 2008) to allow for some stratification (e.g., online vs. field-based programs) yet limit the variability in the sample (e.g., selecting only participants experienced in citizen science). With this type of sampling strategy, I would be able to choose participants who could provide the most detailed and in-depth information about their experience using citizen science in the classroom.

Even though, I planned to interview a relatively homogenous sample of experienced (in teaching and in citizen science) middle school science teachers, I found that the wide variety of citizen science programs, teacher training and background, schools, and classroom environments represented by these teachers still made my participant pool fairly diverse. I chose to interview a few participants who did not have many years of teaching experience, in case they still had an interesting citizen science experience to share. Ultimately, data saturation—"the point at which the data collection process no longer offers any new or relevant data" (Dworkin, 2012, p.1319)—would determine the number of participants needed.

The concept of data saturation as the key factor impacting the number of interview participants needed in a study has been discussed by several qualitative researchers (Dworkin, 2012; Guest, Bunce, & Johnson, 2006; Mason, 2010; Morse, 2000). These authors describe the many variables at work in reaching saturation such as the scope of study and type of research questions, the interview structure, the experience and skill of the interviewer, the familiarity of the topic of study by the participants, the quality of the data, and the level of expertise of the participants. Also, operationalizing saturation is difficult. Although some researchers have tried to develop methods to do this (Guest, Bunce, & Johnson, 2006), the variables listed above still must be considered. Given that reaching saturation depends on many variables, and that with a large enough sample size something new in the data is likely to turn up eventually, it is left to the researcher to decide when a reasonable level of saturation has been attained. Merriam and Tisdell (2016) offer a “rule of thumb,” stating that “the data and emerging findings must feel saturated; that is, you begin to see and hear the same things over and over again, and no new information surfaces as you collect more data” (p. 246). Therefore, although with semi-structured interviews I could expect to conduct on the order of 30-60 interviews (perhaps fewer if the data quality is high) (Morse, 2000), the final number of 22 depended on when saturation is reached.

In order to be interviewed, a participant needed to complete the screening survey, volunteer to be interviewed, provide contact information, and speak English. Selected volunteers were sent email requests to be interviewed either face-to-face, if possible, or by phone or Skype/Google+ Hangout. See Figure 1.0 for a timeline of research tasks.

	2016			2017	
Event	Spring	Summer	Fall	Spring	Summer
IRB Process					
Prepare and file application	■				
IRB approval	■				
Renew IRB approval				■	
Online Survey					
Develop & pilot survey	■				
Activate survey/collect data		■	■	■	
Analyze data			■	■	■
Teacher Interviews					
Develop protocol	■				
Interview teachers			■	■	
Transcribe/analyze data			■	■	■
Participant checks					■

Figure 1. Timeline of Research Activities

Instruments

The first part of the study involved a short online screening survey composed of seven closed-response items. This instrument allowed me to gather some very basic demographics and, more importantly, to purposefully select a pool of participants who were willing to be interviewed in the second part of the study. Basic descriptive statistics were used to analyze the demographic data, as this survey served as more of a recruitment tool than a data collection instrument. Then, I developed an interview protocol containing 14 questions. This protocol guided the main data collection of the study. I also collected artifacts and documents (e.g., lesson plans, handouts, and photos of students' work) to support the interview data.

Screening survey. I used UMSL's Qualtrics platform (umsl.az1.qualtrics.com) to develop a 7-question online survey that collected basic demographics and facilitated participant selection for interviewing. The questions asked about use of citizen science—both as a teacher and personally--and, (if yes) the name(s) of the citizen science project(s) used, teaching level and experience, location of school, and willingness to be contacted for an interview about their experience using citizen science. I piloted it with ten individuals having various backgrounds in science education including high school and middle school teaching, education research, qualitative research, and citizen science. I asked each individual to take the survey as if they were a middle school teacher and look for any unclear or confusing questions as well as any technical glitches. Piloting took place over six weeks.

Each piloter sent feedback to me either within the survey itself or by email. Several suggestions involved modifying language to be more specific, for example specifically asking for "years," "hours," and "weeks" instead of just "time." A few piloters advised that better formatting (i.e., using drop down menus for response choices, using bullet points, limiting the amount of text on a page) would improve readability and understanding and increase the chances that a respondent would complete the entire survey. I incorporated all of these suggestions into the final version of the survey. Two piloters offered possible additional questions for the survey, both questions asking why one had not done citizen science before this. I did not add these questions as I felt they were outside the focus of this project. I placed the finalized screening survey on Qualitrics and activated it on August 5, 2016. See APPENDIX C for the final version of the screening survey.

Interview protocol. I used the motivational theory of expectancy-value (Atkinson, 1957; Wigfield, 2000) to develop a semi-structured interview protocol for phase II. Expectancy-value posits that people are motivated to engage in a task according to their expectations of the outcomes of participating in that task plus the value that they place on those outcomes. For example, a teacher may expect that having students participate in an inquiry-based activity will help the students develop a deeper understanding of a scientific concept or a higher proficiency in performing a science task. Furthermore, the teacher may expect that incorporating inquiry in the classroom may result in a better evaluation from an administrator. If the teacher values these expected outcomes, it is more likely that he or she will actually choose to use an inquiry-based activity with students.

Using this theory as a guide, I created a set of questions to elicit the teachers' motivations about using citizen science in their classrooms in terms of the value they attached to the activity and their expected outcomes. In order to gather some context for their perceptions, I also asked them to describe themselves as a teacher and/or to describe their classroom and a typical science activity that they have used with their students.

Knowing that teaching is a complex, multi-faceted activity, I asked the teachers about challenges they encountered when doing citizen science in their classroom. Finally, I asked the teachers to describe what they would tell a teacher who was thinking about doing citizen science, but wasn't sure, as this advice might contain a critical synthesis of the teachers' perceptions about their experience.

The interview questions were designed to be open-ended and to serve as a guiding path for the interview. Follow-up probes were used as necessary, in order to get a more detailed, rich response and/or to clarify any confusion surrounding a question. Within these guidelines and within reason, I allowed participants to steer the interviews to issues and stories that were important to them, honoring their voices and the exploratory nature of the study. In general, I followed the order of the questions in the protocol but also allowed for the interview to proceed according to the topics brought up and discussed by the participants. The final question, other than a last chance "is there anything else you'd like to add" opportunity, was always the request for advice for a teacher thinking about trying citizen science. My hope was that just having the conversation with me would help to bring up ideas and perceptions about their experience, as interviewees sometimes discover knowledge about themselves during the interview process (Merriam & Tisdell, 2016, p. 262) and that by the end of the interview, they would be primed to give a meaningful summary of their thoughts. The interview protocol may be found in APPENDIX D.

Data Collection

Screening survey. I activated the screening survey on August 5, 2016. It remained active throughout the study in case there was the need to select additional interview participants as the analysis proceeded in order to reach a reasonable level of data saturation as discussed above. I placed a message on the Cornell University citizen science listserv asking for survey participants. I also put a message on my personal Twitter feed and sent email messages to state chapters of the National Science Teachers Association (NSTA). Several people from the citizen science listserv offered to pass on my request directly to teachers that they were working with. And a few teachers who became participants also offered to pass along the survey link to their colleagues. Twelve participants completed the survey on the first day, and there was steady to sporadic participation through December 2017. The last 100% completed survey was dated February 28, 2017, and I did a final download of the survey data on June 21, 2017.

Interviews, artifacts, & documents. Phase II involved an in-depth look at the motivations and perceptions of teachers using citizen science in their classrooms. Using a semi-structured interview protocol, I asked participants to describe their reasons for using citizen science activities, what they expected from the experience, and what they value about the experience. Additionally, I asked them to describe how they feel the experience has impacted them and their students and what types of challenges they perceive. The interview format allowed me to be flexible and enabled me to respond to a variety of participant experiences and to new ideas that emerged (Merriam & Tisdell, 2016, p. 111). Whenever possible, I asked the interviewees if they would electronically share items like lesson plans, newsletters, or pictures that related to their classroom citizen science activities. In collecting these artifacts and documents from my participants, I was often able to obtain additional detail about the teachers' experiences. The combination of interview and artifact data provided a rich, multi-faceted picture of these teachers' involvement with citizen science.

From the screening survey responses, I compiled a list of suitable volunteers to interview. Out of 76 teachers who responded that they used citizen science in the classroom, 46 agreed to be interviewed. Of these 46 respondents, I sent email interview invitations to the 42 who provided their contact information (See invitation text in APPENDIX E). Within two weeks, thirteen respondents had replied with possible dates and times for an interview. I sent a second email invitation to those who did not reply within two weeks. From August 2016, when the screening survey was activated, through January 2017, I made arrangements for and conducted 22 interviews, ending the data collection at that point since I had achieved saturation.

Each interview lasted from 30-50 minutes and was audio-recorded for later transcription. I conducted three of these interviews using Google+ Hangouts video chat, one using Skype video calling, and 18 using a cell phone. Although a face-to-face interview would have been possible for the one local (to me) teacher, she and the rest of the interviewees preferred the convenience and flexibility of a phone interview. After each transcription was complete, I imported the individual file (Microsoft Word Document) into a password-protected project file that I created using NVivo qualitative analysis software (http://www.qsrinternational.com/). I used NVivo to organize the analysis of the transcripts.

At the end of each interview, I asked the participant if they would be willing to share any pictures, lesson plans, news articles, etc. that would be an example of their citizen science experience with their students. Although all participants said they would be happy to help with this aspect of the interview, many were unsure about what to share. A few participants, who were not currently teaching, stated that it would be difficult to locate these items. As a result, I did not receive any artifacts or documents immediately after the interviews. I asked for artifacts again as part of my email request for a follow-up interview (see APPENDIX F) and subsequently received pictures, lessons, blog posts, and news articles from six participants. However, these arrived too late to be included as part of the analysis.

Data Analysis

Screening survey. After removing my five previews of the survey, there were 247 responses, with 210 completed and 37 unfinished. Of the 210 completed surveys, three did not have a response to the consent question, two others responded with a "no," and two others were not middle school teachers. Then, I looked for duplicate responses. The Qualtrics platform prevents "ballot box stuffing" by only allowing one survey per IP address. Although that is not a perfect solution to the problem since someone could simply use a different computer at a different location, there is very little reason for people to take a survey of this type multiple times. I did not remove any other responses, leaving a final N of 203.

Then I used basic descriptive statistics and frequencies to create a picture of the participants, including whether or not they personally participate in citizen science outside the classroom, the percentage that use citizen science in the classroom, willingness to volunteer for an interview, average number of years teaching middle school, and approximate number of classroom hours doing citizen science. Last, I created a spreadsheet of contact data (email and phone) for participants volunteering to be interviewed.

Interviews. I employed a basic thematic analysis in order to identify concepts and develop themes from the interview data. As described by Braun and Clarke, (2006), thematic analysis is a way to identify, analyze, and report themes in qualitative data. It involves six steps: familiarization with the data through transcription and rereading, generating initial codes, looking for themes, reviewing themes and creating a thematic map, defining themes, and a final analysis in reporting the results. Utilizing this framework of steps helps to strengthen the credibility and consistency of the study since it gives readers a clear and explicit explanation of the process. However, it is important to note that this is not a strictly linear process; the analysis proceeded by moving back and forth through the steps, with many steps overlapping and often taking place concurrently at many different times. This is typical for qualitative research.

Furthermore, although thematic analysis provides a step-by-step approach to qualitative analysis, it still requires many decisions and judgments to be made by the researcher. For example, researchers need to determine what counts as a theme in terms of prevalence and significance, whether or not the analysis will attempt to describe the entire data set or only a certain aspect of it, if coding will be inductive or theoretical, if coding will take place at a semantic or latent level, and what epistemological approach will be taken (Braun & Clarke, 2006).

In this study, I used a combination of inductive and deductive coding. Although I used the theoretical framework of expectancy-value to guide and provide a context to the study, the exploratory nature of this research required that I be open to any theme that I may find, whether or not it seemed to fit inside a pre-established framework. I used the theory to guide but not restrict the analysis as I looked for concepts, identified and labeled these concepts as codes, and finally created themes. Some of my interview questions directly asked and/or probed about expectations and values (e.g., How did you expect your students to respond to the citizen science activity?) while others allowed for a more general, participant-driven response (e.g., What would you tell a teacher who is thinking about bringing citizen science into their classroom?).

Deciding what was and was not a theme depended on the pattern, prevalence, and significance of codes that I identified in the course of my analysis. Some codes appeared (to a greater or lesser extent) in participant responses to several of the interview questions; some codes were related to each other or had some aspects in common. Some codes did not seem to relate to other codes or fit into developing themes. This is not something strictly quantifiable, but instead a judgment on what the potential theme adds to the understanding of the issue being examined and therefore to the answering of the research questions. I looked for themes throughout the entire data set in an attempt to capture any unexpected concepts. I coded at the semantic level, looking for meaning in the patterns of data at the surface rather than looking for theoretical constructs that may lie beneath the surface, as the latter is beyond the scope of this study.

In the following sections, I describe my analysis process in more detail, using Braun and Clarke’s (2006) six steps of thematic analysis as the outline structure.

Familiarization with the data. Conducting the interview was my first exposure to the interview data. As soon as each interview began, as soon as I heard the participant’s response, I also began to think about and process what was being said, the concepts being discussed, and the themes that might be constructed from the participant's words. In this way, I was not just gathering data; I was starting the analysis process as well. In this manner, data collection and data analysis occurred together.

As each interview progressed, I took notes on ideas and questions that occurred to me. Sometimes, these ideas were possible themes, but more often they were just interesting concepts discussed by the interviewee that seemed significant. I would note if it was a new idea or something that a previous participant had also discussed. Occasionally, I noted parts of the interview that would require further clarification at a later time. These were usually references to local towns or geographical features. Although the names were unfamiliar to me, they could be easily verified later through an Internet search—there was no need to interrupt the interview. All of these notes became memos to inform the analysis.

I transcribed each interview from its digital audio recording, using iTunes software to play the recording and creating a Microsoft Word document for each transcript. All audio files and text documents were saved in a secure Google Drive folder. Listening to the interviews again and transcribing the participants' words gave me another opportunity to become familiar with the data, another opportunity to consider concepts and possible themes. During this process, and by replaying sections of the interview, I was able to clarify text and pursue unfamiliar terms. When complete, I imported each transcript into NVivo for coding.

Generating initial codes. I began generating a list of codes as soon as I conducted the first interview. These codes represented concepts or ideas contained in the participants' responses to the interview questions, for example, "making connections" or "meaningful experience." Some of these codes were the participants' words—"in vivo" codes—and others were my own synthesis of participants' words. During each subsequent interview, I added to the list and made a note of codes that were repeated and those that overlapped with or related to earlier codes. No codes were combined or eliminated at this point.

After I imported a transcript into NVivo, I was able to code more systematically and more thoroughly. NVivo software allows for highlighting specific pieces of text and attaching a code or codes to each piece. It also tracks the number of times a particular code is used throughout all the transcripts as well as the number of transcripts that have each code attached. This tracking gives an initial quantitative look at how the coding is developing, although it would not be the sole reason that a particular code rises above the others or is eliminated.

When the initial coding process was completed, I had a list of 50 codes. For each code, I created a short working definition to use throughout the analysis. This definition helped to clarify each code's meaning and ensure that there was minimal overlap among codes (APPENDIX G).

Searching for themes. The creation of themes overlapped with the interviewing of participants and the generating of codes. As I wrote down possible codes during the interviews, I also began to think of ways that these codes might be grouped together. Some seemed to be examples of others, some were basically the same concept stated a different way, and some codes were related so that they might be grouped together under a broader, higher-level theme. From my final list of codes, I created a concept map in order to visually see possible connections between codes and developing themes (Figure 2).

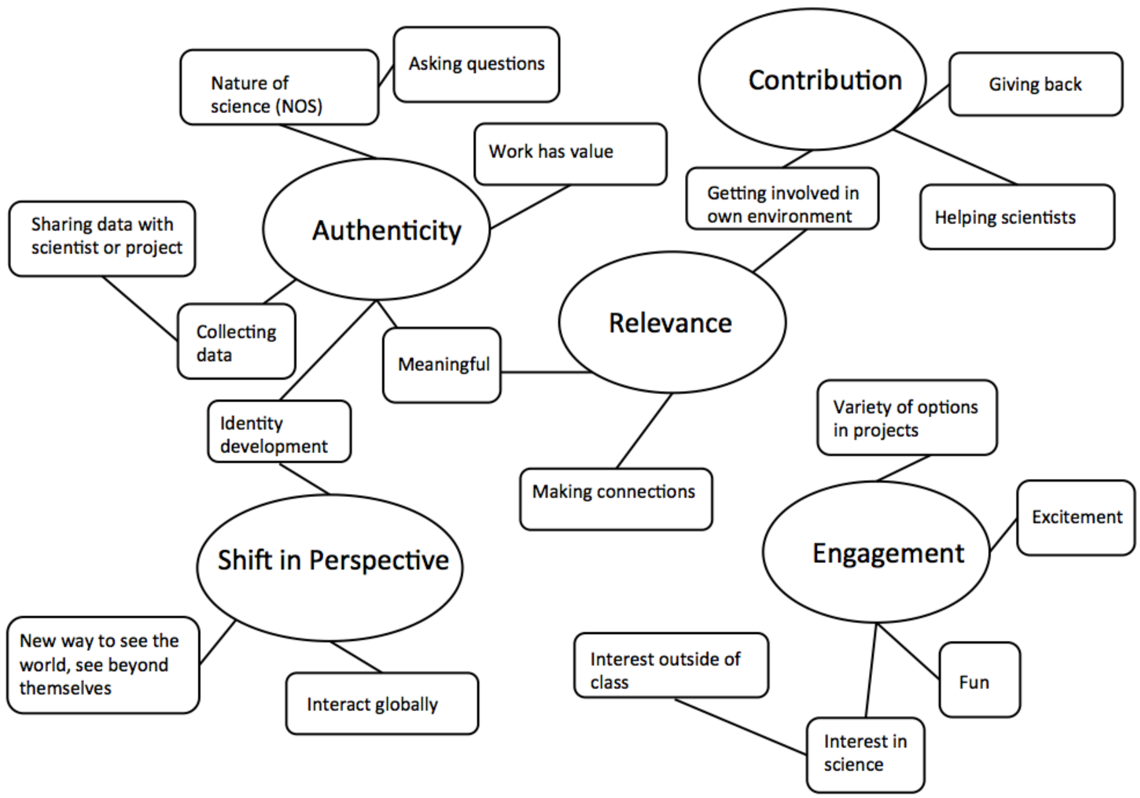

Figure 2. Initial concept map of five potential main themes and associated subthemes

In considering my list of codes and thinking back over the participant interviews, I created the five themes of authenticity, relevance, contribution, engagement, and shift in perspective. The theme of authenticity related to citizen science activities and included scientific processes like data collection and analysis, plus the extra step of sharing findings with a scientist. Participants often used the word "authentic" when speaking of citizen science in general as well as the particular projects and activities that they used. Authenticity was often connected with activities that had meaning, purpose, and value to students. The theme of relevance also included the concept of *meaning*, but in a more personal way. Relevance was a characteristic of activities that had personal meaning to students and were situated in the students' local environment. These activities also allowed students to help others—chiefly people in their community and the project scientists. The theme of engagement described how students felt when doing a citizen science activity. They seemed interested and excited, and many continued to be involved in the project outside of class. The fifth theme, shift in perspective, described a perceived change in the students after participating in citizen science. Students interacted with people in locations outside of their own, learning about new places and cultures and resulting in a broader view of the world around them. These ideas seemed to indicate a growth or development in identity, with students not only starting to see themselves as scientists but also as citizens of the world. The concept of identity development was also related to the theme of authenticity. Many teachers spoke about the authentic experience of citizen science helping students to see themselves differently, either as scientists or at least as someone who could do science.

Reviewing themes. In this part of the analysis, I examined and refined my first set of themes. For each theme, I read through the transcript excerpts that were coded at that particular theme, looking for any inconsistencies or pieces that didn't seem to fit with the rest. If the data for a theme seemed to form a coherent pattern, I kept that theme. If some pieces did not seem to fit, I considered moving them to another theme; or, if there did not seem to be a good fit elsewhere, I put them in a miscellaneous category for possible later consideration. I also looked at the themes (and subthemes) themselves, thinking about how to better define them with less overlap and clearer relationships.

The five main themes still seemed to represent the data well, so I worked to refine the subthemes so that they better illustrated each theme. When possible, I collapsed two closely related subthemes into one. For example, under the theme of authenticity, I combined *asking questions* and *collecting data* to form the more general subtheme of *science processes*. A few subthemes were put under a different theme as I thought more about how to distinguish the main themes from each other. I moved *meaningful* over to relevance (and added "to students" to the name) since the concept had a more personal, student-focused aspect to it. Similarly, I moved *getting involved in own environment* from *Contribution* to *Relevance*, as the opportunity to impact one's immediate surroundings should have a high degree of personal relevancy but may or may not have a sense of contribution to it. The subtheme of *making connections* fit better under *Shift in Perspective*. According to many teachers, it was often making a connection to other people and places that generated a broader perspective in their students. Finally, I removed two subthemes that did not fit. The subtheme *variety of options in projects* was a characteristic of citizen science and not of the students' responses to participating in citizen science, so it did not support the theme of *Engagement*. *Identity development*, connected both to *Authenticity* and *Shift in Perspective,* seemed a complex enough concept to rise above the level of a subtheme, but I was not sure that there was enough data to support it. After making these changes, I revised the concept map (Figure 3).

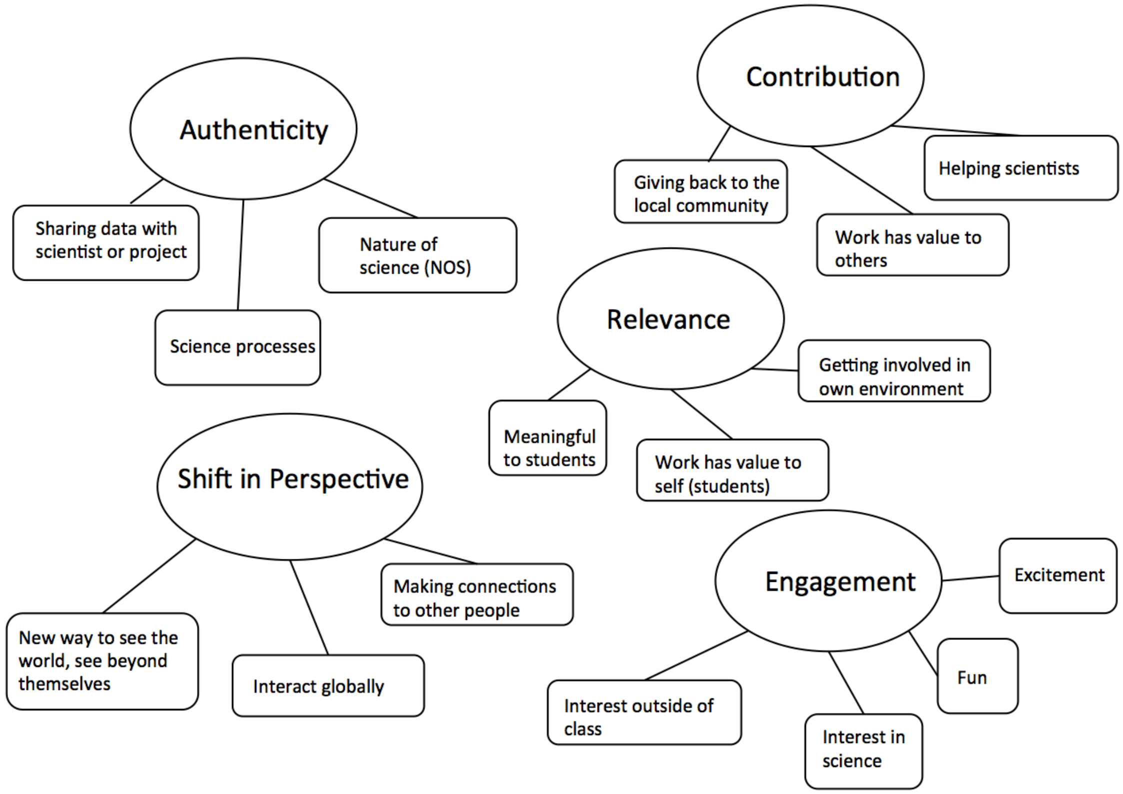

Figure 3. Concept map of further development of potential themes

Further analysis involved consideration of the themes in relation to all of the data as a whole. At this level, I considered whether or not my developing themes captured the meanings situated in the overall data, and, as I read through the transcripts again, whether or not any data was missed and still needed to be coded. I also considered the significance of each theme in the overall picture, the contribution that each theme made to my understanding of why a teacher would choose to use citizen science activities in their classrooms and of the perceived value resulting from that choice. What were the teachers seeing in citizen science that they did not see in other science activities?

Out of the five themes, *Engagement* told me the least about why a teacher might use citizen science. A teacher may certainly desire a classroom activity that fosters high student engagement, but there are a variety of activities, as well as teaching strategies, that can help teachers do this. What is more helpful, perhaps, is exploring teachers' ideas about why they feel that citizen science activities engaged their students particularly well, and I felt that these ideas could be found within the other four themes. Although "engagement" was an important idea for the teachers, it didn't reveal enough about motivation to use citizen science to be kept as a theme.

The remaining four themes each said something meaningful about citizen science and how students can be impacted by experiencing it. Two themes—*Authenticity* and *Relevance*—described aspects of citizen science itself. The other two—*Contribution* and *Shift in Perspective*—pertained to the students, an outward action and an inward change respectively. With the exception of *Authenticity*, each theme's subthemes were a mixture of citizen science characteristics and student actions and impact.

Since the experiences of the students were the focus of the teachers' stories, I decided to modify my thematic map to reflect this. I took the themes that were about citizen science itself, *Authenticity* and *Relevance*, and fitted them and their subthemes within *Contribution* and *Shift in Perspective.* These remaining two themes represented actions (contribution) and views (perspective) of the students. Next, I added a "social interaction" subtheme to *Contribution,* since that was another important type of action engaged in by the students during citizen science activities. Since "contribution" referred to students taking action to change their environment, I renamed this theme as "environmental interaction." Finally, I created two general yet distinct themes that captured the experience of the students as perceived by their teachers: *Broadening Perspectives* and *Building Agency*.

Then, to address my third research question, I examined my initial list of codes again, considering how some of them might fit into a theme of *Challenges*. As a result of this deductive analysis, I created two subthemes: *making the task meaningful* and *experiencing the whole scientific process*. Teachers considered these aspects of citizen science to be challenging because they require time, effort, and intentionality on their part to ensure their occurrence. Teachers often needed to help students understand how their citizen science task fit into the "big picture" of the larger scientific study and what to do in the case of negative or unusual results. Also, teachers felt it was often difficult for their students to participate in the entire science process from asking questions to presenting results. Sometimes participation was only possible sporadically or at certain stages of a project. Many times a project ended early or continued beyond the timespan of a school year, resulting in students missing significant parts of the process. As a result of this deeper analysis, I created a final concept map (Figure 4).

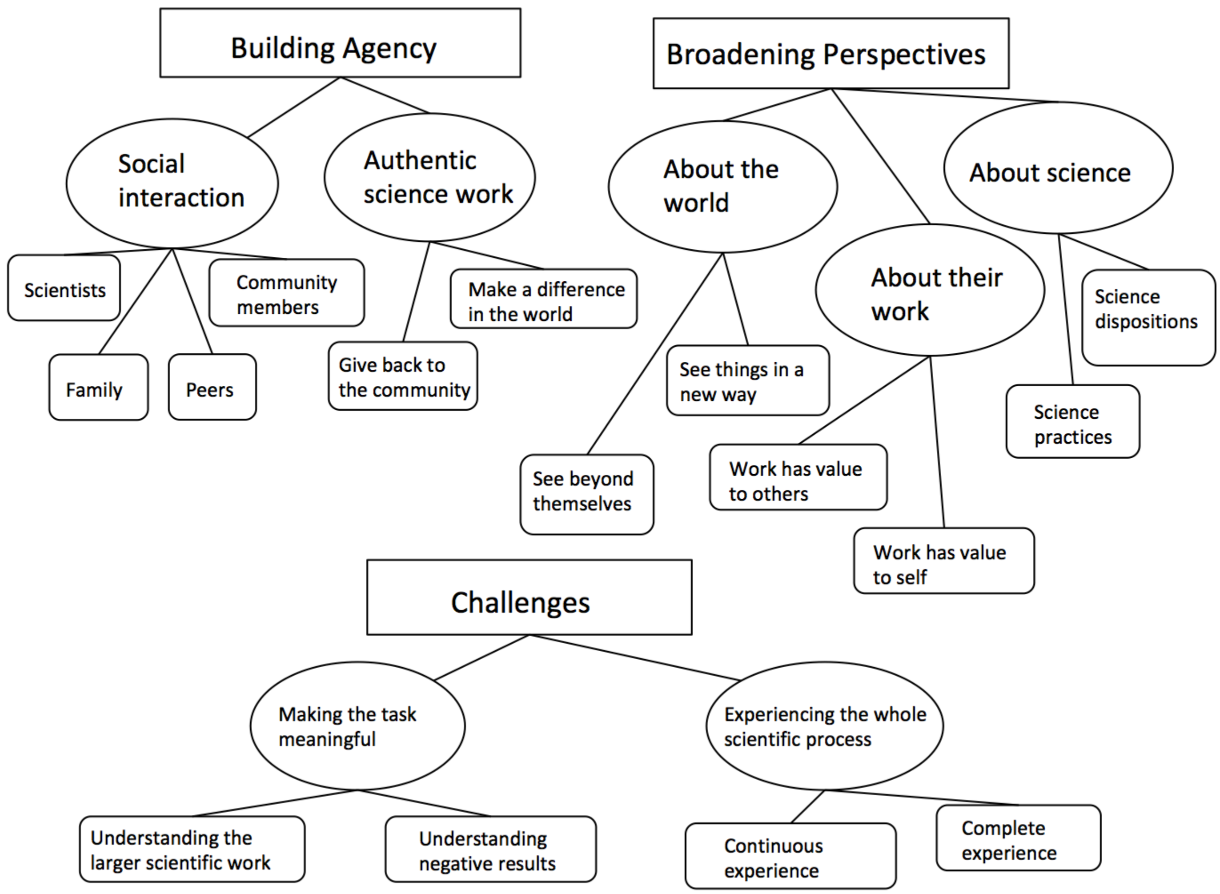

Figure 4. Final concept map of themes and subthemes

Defining themes. In this phase of the analysis, I re-examined the coded data extracts looking to see how they fit the reworked themes. I considered how the extracts could now be used to compose a narrative that would tell the story of the two main themes and their subthemes, illustrating the relationships among the themes and telling the overall story of the data. Also, I continued to refine themes and subthemes so that I would be able to clearly define each one, explaining clearly what it is and what it is not. I created a codebook containing each theme, its sub-themes, inclusive and exclusive definitions, and an illustrative example from the data (APPENDIX H).

Producing the report. The last phase of thematic analysis involves writing the final, complete story of the data, including compelling evidence for the themes and illustrative data extracts placed within the narrative. This can be found in Chapter Four.

Credibility & Consistency

In a qualitative study, the idea of credibility is used when speaking of how closely a study's findings match its participants' understandings of their reality, of their environment (Merriam & Tisdell, 2016, p. 243). In the case of this study, credibility relates to how accurately I have captured my participants' motivations and perceptions regarding their use of citizen science. I have maximized this study's credibility through the use of several strategies that help to achieve these two main goals: to conduct the study so that "the probability that the findings will be found to be credible is enhanced" (Lincoln & Guba, 1985, p. 296) and to show that the findings are credible by having them "approved by the constructors of the multiple realities being studied" (Lincoln & Guba, 1985, p. 296). To accomplish these goals, I employed member checking throughout data collection and analysis. This involved not only taking parts of my analyses back to the participants to see if they agreed with my interpretations, but also taking time during the interview process to clarify vague responses.

To accomplish the member checking, I took time during the initial interview to ask for clarification and examples when needed. I also often paraphrased a response and asked the participant if I that was what they had meant. This also served the purpose of enriching the data with more detail and illustration. Then, at the end of the interview, I asked the participant if they would be willing to do a short follow-up call a few months later in order to talk about my interpretations of their responses to the interview questions.

I also took this opportunity to explain a little bit about my research process and how this follow-up call would help to enhance the validity of my findings.

Each follow-up call lasted approximately 15 minutes. During this time I reminded the participant of some of what we had discussed and then presented two or three of the prominent themes that I had found. I gave the participant an opportunity to comment on my interpretation, correct it if necessary, and then to give an example of or add details to my interpretation. I audio-recorded these follow-up calls, but did not transcribe them unless they contained an excerpt that added significant insight or clarification to the initial interview data.

Another strategy to strengthen credibility is to reach saturation of the data; I continued to interview until the data collection was not adding anything significant to the analysis, and enough data was collected overall to provide rich, detailed accounts of the participants' understandings. As the data collection and analysis proceeded, I was also watching for negative cases, those data that seem to contradict previously established themes, but did not encounter any.

Consistency can be established through the use the above strategies, but also through the use of an audit trail, a detailed account of "how data were collected, how categories were derived, and how decisions were made throughout the inquiry" (Merriam & Tisdell, 2016, p. 252). I provided an audit trail by keeping a research log that includes dates and descriptions of tasks and events that occurred during the course of the study and by writing memos that are more reflective in nature and help to make my thinking and decision-making process more explicit and transparent. Furthermore, the phases of thematic analysis, as described in the previous section, make much of the data collection and analysis process explicit.

Researcher Positionality

Foote (2011) describes researcher positionality as the researcher's worldview, a perspective that is built from the researcher's prior knowledge and experience and that impacts the choices and interpretations made by the researcher during a study. In a qualitative study, especially, the researcher often plays a very active role in the research process and has a responsibility, therefore, to explain to the reader some of his/her background as it relates to the study (Merriam & Tisdell, 2016, p. 187). This transparency is critical to understanding the findings from qualitative research since "understanding and making explicit one's positionality as a researcher illuminates what one potentially sees or does not see" (Foote, 2011, p. 47). Therefore, in this section, I describe some relevant aspects of my background and experience, hoping to "illuminate" my research process in this study.

First of all, I was a K-8 teacher for thirteen years. I have always enjoyed teaching science and worked to provide my students with as many hands-on lessons as possible. I believed that performing actual science practices—data collection, analysis, and presentation/publication—was a necessary part of science learning. Moreover, I believed that teachers had an important--perhaps the most important--role in helping the students to make sense of these experiences, to help students see how the classroom activities related to the larger scientific endeavor, and to connect all of these experiences to their own life. So, as a teacher myself, I was certain that the way in which the classroom teacher presented and guided the students through a citizen science activity was critical to its success. I also have a social constructivist approach to learning, the idea that knowledge is constructed by the learner through everyday interaction with people, places, and things. Finally, learning occurs within a context, whether it be a formal classroom with a teacher and classmates or a solitary experience in an informal setting.

Second, I am a scientist who studies volunteer participant motivation related to citizen science. My interest in citizen science began in 2008, seven years before the start of this study. At that time, I was completing a Masters of Physics degree and, as part of my thesis work, examining the motivations and needs of participants in the online citizen science project GalaxyZoo. Although I did not take part in GalaxyZoo or any other citizen science project personally (i.e., as a citizen scientist), I was part of many "behind the scenes" discussions—both face-to-face and through the project's online forums—concerning the benefits, the challenges, and the future directions of this growing project. Many of these discussions centered around the educational potential of GalaxyZoo and of citizen science in general. With my 13 years of teaching experience, I was not convinced that a strictly online citizen science experience like GalaxyZoo could be successful in the classroom as a science learning activity. A few members of the development team and I began to think about this, and about educational activities that could assist teachers interested in using the project with their students. I spent a few months working on lesson plan development until I graduated and left the project. Currently, I am a member of the Citizen Science Association, a newly formed organization in the United States, and am part of its Education Working Group.

Overall, I feel that citizen science has great potential to enhance classroom science teaching. In conducting this study, I needed to be aware of and take steps to control this bias. One step involved a strategy to maximize consistency described in the previous section: member checking. By taking my interpretations and analyses back to the participants, I could get a sense of whether or not my own feelings and opinions had overshadowed their understanding of the experience. I also gave participants the opportunity to add to or "fine tune" my interpretations, in case they were uncomfortable with disagreeing with me. A second step that I took to control my bias was to be skeptical about my analysis and my findings, to constantly question the codes and themes that I was developing, and to purposefully look for data that did not support the patterns that I was seeing. For example, even though most participants had positive experiences with citizen science, two teachers were very disappointed by their experience and were somewhat hesitant to be interviewed, feeling that they did not have any helpful information to share. I reassured them that their unsatisfactory experiences would still be extremely valuable, and I was able to conduct both interviews. As a final check on my bias, I periodically sought feedback from members of my committee.

Ethics

Regarding this study, I addressed ethical issues in two areas: conducting the overall study and the treatment of participants. In conducting the research, my decisions and actions as the researcher needed to be trustworthy and needed to instill confidence in the reader that the study has integrity (Merriam & Tisdell, 2016). Many of the credibility and consistency issues discussed above played a large role in establishing this study as an ethical one. In that sense, my strategies to maximize the credibility of the study, especially the detailed description and documentation of my research process, also served to demonstrate that I have conducted the study in an ethical manner.

Furthermore, since this research involves human participants, I took a number of steps to ensure that they were (and continue to be) protected and treated with respect at all times. These steps included obtaining informed consent to participate in the study, protecting the privacy of the participants by using pseudonyms in the final report, and emphasizing the participants' autonomy by assuring them that participation is voluntary, that they may leave the study at any time, and that any one part of the study (e.g., a particular interview question or any comment they may have made) may be omitted at their discretion. During the course of this study, a few participants asked for clarification of questions or more time to consider a question, but no one stated that they were uncomfortable with a question or refused to answer a question.

Finally, the Institutional Review Board (IRB) at UMSL approved all data collection procedures and instruments. The IRB designated this project exempt from full committee review on March 9, 2016, and I submitted an annual continuation report for the project, which was subsequently approved, in February of 2017. The IRB application and approval documents, including a copy of the consent form, may be found in APPENDIX I.

Chapter 4: Findings

The purpose of this study was to explore middle school teachers' perceptions about using citizen science in their classroom. In this chapter, I present results from the screening survey as well as qualitative findings from the thematic analysis of interviews. The purpose of the screening survey was to recruit participants for interviewing and to provide context and background for those selected interviewees and for the larger population of teachers from which they were recruited. The interviews provided an opportunity for a more in-depth examination of a smaller group of survey respondents. Results from the survey are described first.

Screening Survey

The online screening survey asked respondents about their experience with teaching and with citizen science, both personally and as a classroom teacher. The survey was active throughout the duration of the study, with data collection occurring from August 5, 2016 through February 28, 2017.

Experience with citizen science & teaching. A total of 203 middle school teachers completed the screening survey. The majority of respondents (57%) indicated that they had never personally (i.e., outside of the classroom environment) participated in citizen science, and a larger majority (62%) indicated that they had not used citizen science in their classrooms (Table 1). This suggests that citizen science is not a commonly used classroom activity by middle school science teachers in the United States.

Table 1. Screening survey responses

Survey Question (*N*)	Responses			
	Yes	No	Yes (%)	No (%)
Have you ever personally participated in citizen science? (*203*)	88	115	43	57
Have you ever used citizen science in your classroom? (*202*)*	76	126	38	62
Are you willing to be interviewed? (*76*)**	46	30	61	39

*One respondent did not answer this question.
**Only those who used citizen science in their classroom were asked this question

Out of the 76 teachers who used citizen science in their classrooms, the average number of years teaching middle school was 15.3; however, many were relatively new to middle school teaching, with 22 having between one and five years of teaching experience. A slightly larger number of teachers (24) were more experienced, having between 11 and 20 years in the classroom, and only 14 teachers had more than 25 years of experience (Figure 5).

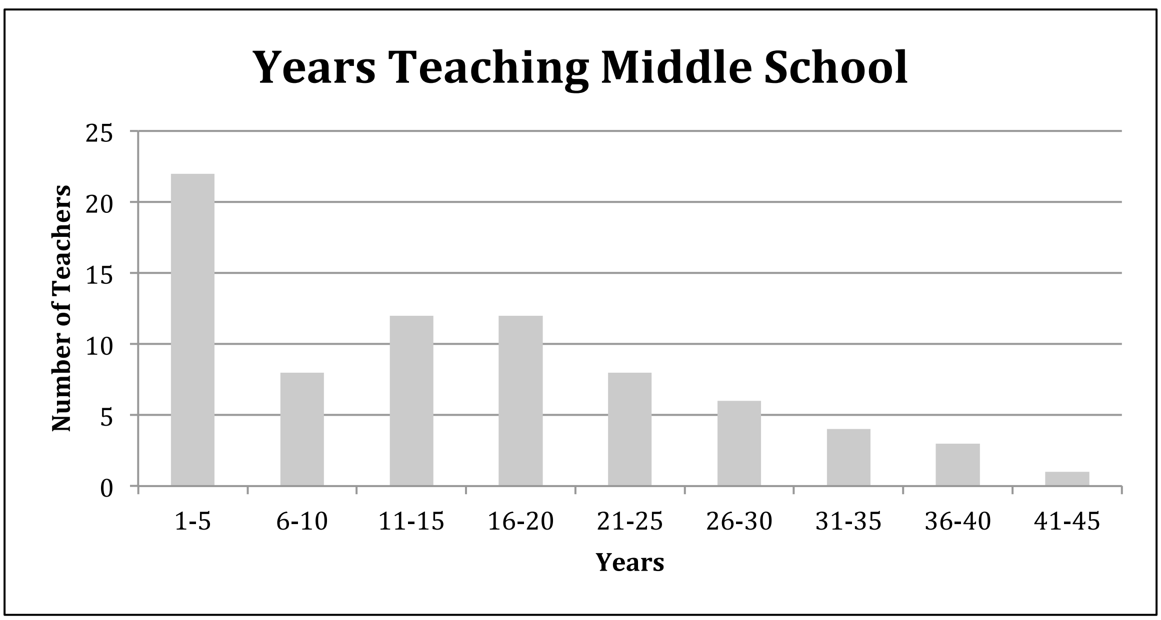

Figure 5. Survey participants' years of teaching, *N=76; mean=15.3, median=15, mode=15*

When asked to estimate the total amount of class time spent doing citizen science, teachers responded with a wide range of times. The majority (39) had spent between one and 25 hours doing citizen science in their classrooms at the time of the survey. Nine teachers gave times between 26 and 50 hours, and 15 teachers gave times ranging from 51 to 200 hours. Nine teachers gave times of over 200 hours, ranging from 280 hours to 1190 hours (Figure 6).

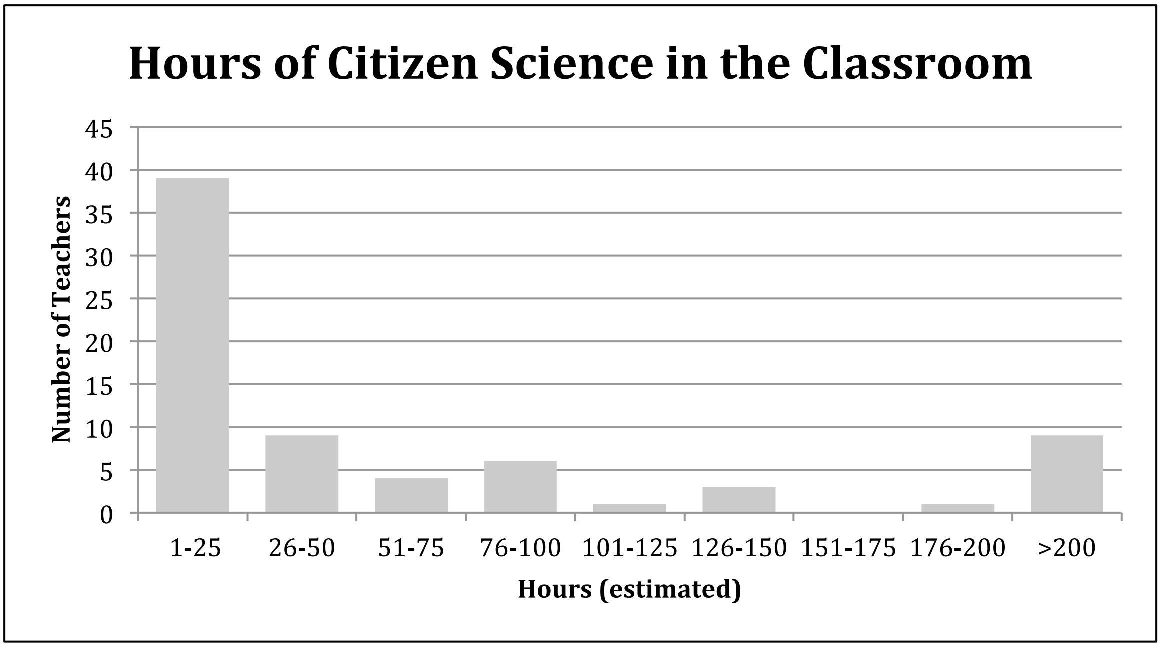

Figure 6. Survey participants' hours of citizen science in the classroom, *N=72*, mean=112, median=20, mode=10*

**Four responses were given as "years" and could not be included in the analysis*

Personal participation & classroom use of citizen science. Those who are already participating in citizen science themselves may have very different expectations about using it in the classroom compared to those who have never been a citizen scientist. Therefore, I wanted to examine how "participators" compared to "non-participators" in choosing to bring citizen science into their classrooms. To do this, I performed a chi square analysis of the survey respondents with "personal participation in citizen science" as the variable.

For survey responders (N=202), the number of personal participators who used citizen science in their classroom was 60 whereas the number of non-participators was only 16. The number of personal participators who did *not* use citizen science in the classroom was 27 while the number of non-participators was 99 (Table 2). However, based on these numbers, it would be expected that the number of personal participators who used citizen science in their classroom would be 33 and the number of non-participators would be 43. Furthermore, the number of participators who did *not* use citizen science in the classroom should be 54, and the number of non-participators should be 72 (Table 3). There is a difference in the actual and expected proportions, and, after performing a chi-square analysis, it is shown to be significant, χ^2 (3, N = 202) = 79.7, $p = 0.05$.

Table 2. Contingency table for chi-square calculation, actual survey sample

	Personal Participation	No Personal Participation	Total
Classroom Use	60	16	76
No Classroom Use	27	99	126
Total	87	115	202

Table 3. Contingency table for chi-square calculation, expected survey sample

	Personal Participation	No Personal Participation	Total
Classroom Use	33	43	76
No Classroom Use	54	72	126
Total	87	115	202

Therefore, there is a significant difference between personal participators and non-participators in choosing to implement citizen science projects in the classroom. There were almost twice as many personal participators who used citizen science in the classroom (60) as expected (33). This might indicate that teachers who find value in the citizen science experience for themselves also see that value as something they should provide for their students. Also, teachers who participate in citizen science outside of the classroom may feel more comfortable in bringing that type of activity into the classroom. Finally, there may be something inherently different about teachers who choose to participate in citizen science and also use it in their classroom (e.g., attitude towards science, philosophy of science teaching and learning, etc.) compared to those who do not personally participate.

Types of citizen science projects. Finally, I looked at the number and types of citizen science projects that the teachers used in class and participated in outside of class. A total of 104 different projects were reported for personal participation (APPENDIX J), and a total of 101 different projects were reported for classroom use (APPENDIX K). Many of these overlapped—personal and classroom. Almost all projects were in the life and/or environmental sciences, and most were field-based (i.e., participants traveled outside to the site of data collection) vs. online. Listed below are citizen science projects that at least three teachers reported using in their classroom (Table 4).

Table 4. Most commonly used classroom citizen science projects

Project Name (#teachers)	Website	Discipline	Online	Field-based
Vital Signs (19)	http://vitalsignsme.org/	Life Science		X
Monarch Watch (8)	http://www.learner.org/jnorth/monarchs	Life Science		X
GLOBE (6)	https://www.globe.gov/	Earth/Space Science		X
eBird (5)	http://ebird.org/content/ebird/	Life Science		X
Project Feederwatch (5)	https://feederwatch.org/	Life Science		X
Galaxy Zoo (4)	https://www.galaxyzoo.org/	Earth/Space Science	X	
Project Budburst (3)	http://budburst.org/	Life Science		X
S’COOL (3)	https://scool.larc.nasa.gov/	Earth/Space Science		X

Background of interview participants. The survey data gave me an initial look at the background of the interview participants. These 22 participants were middle school teachers from across the United States having varying amounts of classroom teaching experience. Their schools were located in 15 different states representing both coasts as well the interior U.S. Teachers had an average of 16 years of experience teaching middle school, did an average of 90 hours each year of citizen science with their students, and employed a wide range of citizen science projects in their classrooms. The majority of projects used by these teachers, as with the larger survey sample, were field-based and environmental in nature (Table 5.)

Table 5. Interview participants' school locations, years teaching, hours of citizen science in the classroom, and citizen science projects used

Participant Code #	School Location	Years Teaching Middle School	Hours of Citizen Science in the Classroom	Project(s)
1	Missouri	4	8	Monarch Watch, Project Budburst, contrails
2	Connecticut	5	31	OCEARCH, GLOBE
3	New Jersey	4	8	Cicada tracking, global heat index, science of soil
4	Wisconsin	10	35	StarCount, Zooniverse: GalaxyZoo, Cancer, Goldstone Apple Valley Radio Telescope (GAVRT) Program, Oceans
5	Florida	11	280	Monarch Health, Monarch Watch, Million Orchid Project, Growing food for space
6	New Jersey	9	100	Quail in the Classroom, Project Terrapin
7	Pennsylvania	27	600	NASA Long Duration Exposure Facility, radon project, beach measurement, satellite mirrors, polar satellite weather imagery
8	Maine	20	140	Vital Signs, beach grass project, Linder New Naturalist Project
9	New York	1	10	Billion Oyster Project
10	Hawaii	4	8-10	OPIHI (Our Project in Hawaii Intertidal)
11	Illinois	3	5	MoonMappers
12	California	15	30	eBird
13	Colorado	2	2	Penguin Watch
14	Washington	39	30 years	Yakima Basin Environmental Ed. Project
15	California	22	11	FLOW Program, White sea bass project
16	Maine	16	20	Vital Signs
17	Illinois	35	25	Journey North Monarch Migration
18	Maine	34	80	Vital Signs
19	Maine	13	20	Vital Signs (Macroinvertebrate Pond Assessment)
20	New York	14	20	Barcode Long Island, eBird, Billion Oyster Project, Project Pigeon Watch
21	New Hampshire	40	445	Forest Watch, GLOBE, eBird, FeederWatch
22	Wyoming	23	11	GalaxyZoo

Interviews

In analyzing the interviews, I developed two broad themes relating to how teachers perceived their students to be impacted by participating in citizen science and one theme capturing teachers' perceived challenges (Table 6). Each of these themes--*Broadening Perspectives*, *Building Agency, and Challenges*—and their subthemes will be discussed below, including illustrative quotes from participant interviews.

Table 6. Themes and subthemes.

Themes	Subthemes Level 1	Subthemes Level 2
Broadening Perspectives	About the World	See Beyond Themselves
		See Things in a New Way
	About their Work	Work Has Value to Self
		Work Has Value to Others
	About Science	Science Dispositions
		Science Practices
Building Agency	Social Interaction	Scientists
		Peers
		Family
		Community Members
	Authentic Science Work	Give Back to the Community
		Make a Difference in the World
Challenges	Making the Task Meaningful	Understanding the Larger Scientific Work
		Understanding Negative Results
	Experiencing the Whole Scientific Process	Continuous Experience
		Complete Experience

Broadening perspectives. For many middle school teachers, citizen science was an opportunity for their students to widen their view of the world and to get a sense of how they and their work fit into this bigger picture. Through their involvement in citizen science, students increased their awareness and knowledge of people and places as they shared data and compared their findings with other groups across the United States and beyond. They began to see how the work they were doing connected to and supported a larger scientific endeavor. The students also gained an awareness of what science is and what scientists do, leading to a greater interest in the citizen science projects and in science in general. The teachers felt that student participation in citizen science activities led to a broadening of students' perspective about the world, their work, and themselves.

Broadening perspectives about the world.

Seeing things beyond themselves. Many citizen science projects are global in scope. People from around the world are participating and sharing information, often through a project website. Students can see their own contributions and those of other groups, revealing to them that what they are doing in their classroom is a part of something bigger, something beyond their own school and local community. One teacher describes her students' experience with submitting their data to the *eBird* project:

> I think it just gives them a sense that they're part of something larger than them. When we log onto the real-time data submissions for *eBird* at 9 o'clock in the morning and there's already 7000 checklists that have been submitted around the world, they're like, "Wait, we're not the only ones doing this and we're helping, too. Let's get ours in before we see another dot in Africa," or "Let's get ours in and make sure it's right before we see another dot in South America." (Participant 12, line 215)

As the students see data coming in from other continents, they become aware that the activity is not just about them; they are just one group of participants of many around the world. In this case, this awareness sparked some competition with the other groups, and even a sense of urgency among the students to ensure that their data was included and that their work was represented.

Some students enjoy learning about other places as part of their involvement in citizen science, and they are fascinated by the differences they discover about locations far away from them. As one teacher describes:

> The kids love seeing data from different countries, particularly when we're looking at weather data and those sorts of things... They share data and see that there are different things happening around the world and everybody's experiencing something different from their locale. Like if they look and they see data from around Africa, they can compare... we're a lot colder. They're a lot warmer all the time because it was equatorial data or something, so being able to experience it... there's a lot of life beyond St. Louis, beyond Kansas City. (Participant 1, line 50)

In discovering how data varies around the world, the students see that others often have a very different experience than they do. They may be involved in the same project and collect the same type of data as students in another part of the world, but the results can be very different, revealing something new about the world they live in.

As students become aware that they are not the only ones doing citizen science, and that there is a diverse world beyond their own, they also begin to piece together their place in the world and move towards becoming 'global citizens.' The students move from being somewhat isolated within and focused on their own community to being more outward-facing and gaining a small understanding of things happening beyond themselves. These teachers describe the importance of helping students to go beyond their own personal world:

> You compare it to a larger, broader world; I mean you really can't get much better

> than that. Our kids are so isolated. These are kids that live 15 miles from Milwaukee, and they don't go there because... why would you? There's poor people there... and they're all on drugs. It's a very isolated community. So, ok, this is the condition in our world. What is it like somewhere else? And so it's neat to help them become more global citizens. (Participant 4, line 62)

For these teachers, citizen science activities provide an important part of their education: an opportunity to experience and learn about different worlds and different cultures and, as a result, gaining a broader perspective about a world beyond their own.

Seeing things in a new way. In addition to seeing new worlds outside their own, participation in citizen science often helps students to see their own familiar world in a new way. Students look at everyday things in their local surroundings as if they've never seen them before. One teacher describes how her students' eyes were opened to things on their daily walk to school:

> The biggest thing that I've heard from students is that doing this has opened their eyes to the natural world that's always around them. Because we live in the middle of the city, they don't even consider the fact that well, there's actually trees when they walk to school, and those trees have wildlife in them. And it's just all stuff that was previously invisible to them. (Participant 12, line 210)

Through their involvement in citizen science, students perceive aspects of their surroundings that had gone unnoticed before.

Even things in the environment that students had noticed and were aware of before doing citizen science were now viewed differently. For example, this teacher describes how her students' activities with oysters expanded their idea of "animal":

> Well, there was the fieldwork component of it when they were actually there and measuring the oyster shells and water quality, and I think that measuring the spat and seeing the baby oysters caused them to say, oh, they don't look like a typical animal that they're used to seeing at the zoo... like birds or things like that. So I think it kind of broadened their mind on what an animal is just by seeing them in person. (Participant 9, line 65)

This same teacher went on to tell of how her students now saw their local body of water in a new light:

> The other big component of it that caused an even bigger reaction was the sewer overflow issue. So, that was like... they reacted like "Wow, I can't believe this is happening. This is crazy that there's sewage in our harbor," and so that reaction was shock and disgust. (Participant 9, line 70)

As they engaged in citizen science, students began to perceive new aspects of the familiar things around them.

This broadening of perspective also applies to how students view the past and how they understand history, especially regarding how society and science interact. This teacher used data collected in the past to help students understand why people are worried about climate change now instead of years earlier:

> But for some of them, a lot of them have a really interesting way of looking at the world that they... They don't quite grasp certain aspects of their town's history or their country's history or even the planet as a whole. Well, why do we even care about climate change now... why didn't you guys care about it 10 years ago or 15 years ago? I've had that question. It helps them look at it from that aspect,

> because we look at a lot of the data from 10, 15 years ago where the trends were not as alarming. They were... ok, it's hot but not like the hottest year on the planet. Ok, it's not so bad... For them, what I think they start to realize through the citizen science projects, is that we were taught science a lot differently... their parents were taught science very differently than they're being taught science. Science is more accessible to them now than it was 10, 15, even 20 years ago. (Participant 2, line 231)

By examining data collected over time, students can begin to understand how scientific issues can change in urgency as time passes. This historical context helps students to make sense of what they're learning in science and also in other disciplines:

> It also leads to them sort of looking at the whole history of things a little differently, which I think helps in their ability to mature but also helps with their understanding of other subjects as well and to them it's sort of like when a light bulb goes off, that's kind of the most rewarding thing to them... oh, this makes a lot more sense now. (Participant 2, line 245)

Placing learning in context adds meaning to what the students are doing.

Broadening perspectives about their work.

Work has value to self. Students view their citizen science work differently than their traditional classroom science activities. By working on a project that is authentic, that has real-world implications, students see a value to what they are doing—a value that is lacking in the more traditional lab work of many science lessons. As one teacher said, "Citizen science is different for them because they'd never done anything with data that they've collected. I mean, who cares what you did in the science lab... it doesn't matter. And so they start seeing it matter" (Participant 4, line 74). This is real change in perspective. Another teacher described how getting outside and working on site helped students see the importance of their work:

> I think it's all about the real world experience. I mean, hooray for learning things in textbooks and definitions and all of that, and you do need that background knowledge to a certain extent, but it's nice to be able to go out and the kids can [see it and] say, why is this good to pick up trash from the beach, and why would this be great information for the state to have? Or it all turns out to be why should we care about our world and what we're doing to it? So, I think it's just a real application, real-world learning, a hands-on experience... I mean, how do you beat hands-on experience where they could actually go out and see what they're doing instead of watching a video on it? (Participant 15, line 213)

When the project is situated in the local community, the students' work takes on an even more personal value. This teacher noted that the students wanted to take care of things in the environment that they felt personally connected to:

> It's something that they care about, too. I think a lot of them say things like "I've kayaked on the Hudson River, but will we ever be able to drink out of the river?" And they think about, as people do, their own use of the harbor, and I think that's the biggest personal connection that gives meaning to doing this kind of project. (Participant 9, line 129)

In one case, a teacher implemented *Cell Slider*, a citizen science project involving the examination of tissue samples from cancer patients, and this work had a connection to the family members of two students:

> Well, I had a mom who had died of breast cancer in that class that I did that and another one who was undergoing treatment for breast cancer. You couldn't have made this any more personal. This was literally in their homes. So, I think they felt that they were actually contributing to knowledge... and they were.... and that was really cool. (Participant 4, line 79)

This personal connection can grow into a feeling of responsibility towards the project, and many teachers spoke of their students developing a sense of ownership regarding their citizen science work, especially in longer-duration projects that involved community members. This teacher worked with her students to communicate to the larger community about their citizen science work:

> I think it's really neat because they think that they have a job at school... they get to research it and send out professional emails. I think that feeling of having a project to take ownership of and feeling like it's kind of their job at school is pretty cool. (Participant 9, line 95)

In treating their work like a job, these students have taken an extra step to create roles for themselves that add an extra dimension of authenticity to the activity. In a similar way, these students took action when part of their project was destroyed. They had created their own project to address the problem of beach erosion in their town:

> The kids learned about it and planted more beach grass, and they actually made signs that said 7th grade beach grass restoration project. And within a couple of weeks the signs were vandalized. Then the kids... we wrote an editorial to the local paper... it just comes out once a week. But they wrote about how badly it

> made them feel and how important the beach was to the community and how important beach grass is to keeping the beach together. (Participant 8, line 72)

The students cared enough about their project to write a letter to the community about its value.

Work has value to others. For the teachers, the value that students see in their citizen science work is enhanced by the value that others see in it. Citizen science activities extend beyond the classroom through interactions with project scientists, community members, or other citizen scientists. Outsiders have many opportunities to see the work that students are doing. Teachers felt that this outside validation was an important and enlightening experience for students, reinforcing to them that what they were doing mattered.

The most influential group of "others" that valued the students' work was the scientists or other professionals involved in the citizen science project. The teachers often told the students that the scientists needed their help to collect or analyze data, and during the course of a project, students were often able to get feedback from or even communicate directly with a scientist about their work. Scientists provided an outside audience for the student work as well as an expert check on their results:

> Yeah, that's something that I forgot that really excited the kids... that there were real scientists on the other end of our results, and they checked and either approved or said go back to the drawing board about any results you posted. So when those emails came in from the scientists saying yep, we agree that you found viburnum or whatever it was... I mean the kids were pumped! Wow... I mean this is a real science person saying we were right, which was great... they

> love that part. (Participant 18, line 203)

Another teacher comments:

> The first thing that sort of surprised me, cause I wasn't really sure what to expect... I knew the kids would be involved in doing these kinds of things... is that somebody values their ability to collect real data and have it go into the system, and not just say, oh, it's just a bunch of 7th graders... they don't know anything. The work that the students do is highly respected. That was a real surprise to me. They're not high school students, they're 12-year-olds but they have a focus and an understanding of what they're supposed to be doing and they will monitor themselves and take care of each other. I was pleasantly surprised that when we submit data it was just as good as data collected by a high school or anything else. (Participant 14, line 174)

For many projects, students submitted data through a project website which then displayed the results publicly along with those from all other participants. This public display was exciting and meaningful to students, as it indicated that their contribution would be seen by people around the world. This teacher describes her students' reactions to sharing data in *Cicada Tracker*:

> You had to put them [detectors] in the ground at a certain level, and it would report out the temperature on the device that was underground. Then you would be able to enter the date when the cicada was going to emerge from the ground based on the ground temperature. They could see their little light on this map and see what was happening on the whole region, and when we reported seeing it first it was in parts of New Jersey and New York. So for them it was very exciting

> because it was on a website and was talked about in the news... (Participant 3, line 42)

Another teacher was surprised that her students were excited about getting their results from the *Vital Signs* invasive species monitoring program onto a website:

> What I didn’t expect them to be so excited about is that their data went up on a website... they just thought that was the coolest thing. They would go home and show their parents their report once it was approved by a scientist... show them the little marker on the map of Maine... this is the plant that I found, and this is the little marker for it... they were all about that.... I didn’t expect that at all. (Participant 18, line 60)

Parents and local community members provided another outside audience for students and their work.

> One of the pleasant surprises is that a lot of the parents... you’ll get emails and they’ll come in for something and they’ll want to volunteer to help out ... it ends up being more of a family affair... which is just awesome because then it becomes a whole community thing. Then it’s nice because even if they’re not coming physically to help out, they’ll send an email saying thank you so much... they’re so excited... Thank you for trying to do this... that’s certainly a big positive. (Participant 6, line 203)

Broadening perspectives about science.

Science dispositions. Working on a citizen science project often changes a student’s view of science, expanding their understanding of what it is, who can do it, and how they personally relate to it. Students who had previously not been interested in science, may show a spark of interest as they participate in a project and experience science in this authentic way. Some teachers saw citizen science as a fun way to “hook” those students who had a small interest in science, but just weren’t sure:

> I see a renewed interest in science. It is a way for them to do science while having fun, and for them, especially at the middle school age, that’s where you lose a lot of them in science. Not just the girls, but the boys, too. There were a lot of them that I could see just teetering on that edge point of “Well, I like science... maybe I want to be a scientist, but it doesn’t seem all that great so I’m going to do something that makes a lot of money.” Or something like that... It’s kind of depressing to say that, but that’s the way they think. To get them interested... [and have them think] oh, scientists can go outside all day... scientists can play with sharks... maybe being a scientist isn’t so bad. I want to pursue this a little further. Or, I want to learn a little bit more about this... It gets them to sort of be... even if it’s not something they choose to pursue, it’s something they can still be interested in down the road and want to care about, which at the end of the day was sort of my... ok, I don’t care if you want to be a scientist, but if you want to protect the Earth and the environment, that’s my bottom line. And, I think most of them did. (Participant 2, line 206)

By participating in citizen science, a student’s waning interest in science may be strengthened and sustained. Sometimes teachers see this interest sparked in students who are ambivalent about science but make a connection to something relevant in the activity:

> I guess I definitely think that it [citizen science] helps them kind of take whatever

> it is that we're learning about in school and have a direct application to it. Some of them just like science in general so whatever it is that you're talking about you're always going to have the kids that just... they're space kids... they love it.... they're into it... they're doing it on their free time so they're already off and running so when you get to that unit they're going crazy. But just like your average kid that's like more self-involved like most middle school kids are like, it's kinda neat to see them raise a hand and ask a question or they'll say I just had this idea... I just thought of this connection to what we talked about the other day about why this is important... why we were doing this. It's so nice for me to be able to see them come up with that on their own. (Participant 6, line 150)

As students see how science can apply to their own life, there is a good chance that their interest in it may increase. Often, this interest extends beyond the classroom as students continue their citizen science participation at home. For example, this teacher describes how her students built their own monarch way stations:

> I have many monarch taggers who have bought their own plants... and they might be on the 5th floor of an apartment building and I say, just stick them out there... the monarchs will come. Yeah, they have become monarch way stations up there on the 5th floor of these apartments. (Participant 5, line 153)

These students were interested enough to continue the activity on their own.

Science practices. Students also get plenty of experience with specific practices of science such as making systematic observations, collecting and analyzing data, and sharing their findings. This teacher describes the many science practices involved in her students' kelp project:

> We're going to put a GoPro down into the kelp forest, which is kind of sort of disappearing because kelp doesn't like warm water and our water got up to 74 degrees off of the coast this summer so it killed off all the kelp, and then you've got sea urchins and stuff that will come in and take the place of the kelp. We've got invasive species... there's a species of sargassum that will kind of take over the natural habitat, and so we'll see if it ever bounces back. We're looking to see the size of fish and what kind of fish are in the area. We're going to record that data from the GoPro and put it on flash drives and come back and analyze it in the classroom. They also send that off to the state. We have another water station where they're looking at lowering a secchi disc and seeing what the water visibility is like and then looking at pH and salinity (Participant 15, line 195)

In this project, students are gathering and analyzing data (Figure 7), and then sending it to scientists at the state level who are monitoring the water and invasive species. They are engaged in authentic science practices. Moreover, as this teacher notes, citizen science is often one of the first opportunities for many students to do this type of science, and it is their introduction to the methods and practices of science, "Just getting them to observe and start taking notice and start writing down data and bringing it back was the first start of them learning about how science works and what we do in science" (Participant 1, line 131). Teachers saw their students engage in the same practices as professional scientists in an authentic context.

This experience with authentic science practices also provides opportunities for students to learn about the need to be systematic and to think carefully about their work. Here, a teacher describes how she guides her students to think about an unusual data point:

> For the terrapins we have to do measurement, so for that, I kind of have to show them first, and kind of model it, then after that, trust them and just kind of be the guide... and if they get some weird measurements, and nothing matches up, I can go back and say uh... why don't we double-check this one, it doesn't seem quite right. Let's look at some of this other data... this seems weird that they grew 7 inches... (Participant 6, line 195)

In this way, students are introduced to a scientific way of thinking as they proceed with their data collection. Students also encounter other aspects of real science, like experiments that don't work out as expected:

> It made it more interesting for them as well... because it's real. Like I said it was the one advantage that I saw to what I was doing because for the most part everything I did was hands-on and involved real measurements, and if things didn't work out, that was science... it happens sometimes... that's science. Let's find out why. What are the variables that maybe we didn't control for or just goofy stuff that didn't work... (Participant 7, line 246)

Students learn that in science, the unexpected is often a chance to learn something new; problems are just puzzles to be solved. Working in the real world means dealing with these challenges and not giving up, even if it means starting over:

> Well, it's like sometimes this happens in science. Sometimes the ocean washes away with the project or sometimes there'd be a fire or... it just happens and we have to start over with what we can do. Collect our data, clean up that experiment and start another one. (Participant 5, line 349)

Students learn that science often requires persistence and determination. It also requires patience, as this teacher notes as she tells about her students' experience with the online project *Penguin Watch*:

> I would say one of the things that we kind of reflected on was patience... in some ways... because a lot of them kept getting the same penguin pictures over and over and over again... and they were saying, what is happening? And I said, yeah, what is happening, guys? You're looking for... they're trying to make this data as reliable as possible. And I don't think they ever thought about that because, you know we talk about in the scientific method how scientists have to do this over and over again... and I don't think it's concrete. They were kind of annoyed, but then when we talked about it, they understood and there was more of an ah-ha moment. (Participant 13, line 137)

In this activity, students experienced another aspect of science: increasing the reliability of results. Science can be unpredictable, frustrating, and even tedious at times, but also interesting, engaging, and meaningful.

Citizen science increases student awareness of the many different activities that scientists do as part of their work, giving students a more complete picture of what science—and being a scientist—is all about.

In summary, the main theme of *Broader Perspectives* reflected teachers' ideas about how participation in citizen science helped their students to expand their views on the world, their work, and themselves. Teachers felt that their students learned about other people and places, saw a value to their work, and became more aware of what science is and what scientists do.

Building agency. Teachers felt that as students were broadening their perspectives on science and the world around them through participation in citizen science, their inner sense of self—who they are and what they can do--was also changing. Through their experiences in citizen science, the students were able to interact with scientists, teachers, peers, and community members, building their confidence and being seen by others as knowledgeable, competent workers. Additionally, as they observed the outcomes of their work, they developed a greater confidence and capacity to independently impact their environment both near and far away. Teachers saw citizen science as a way to increase this student agency, this ability to take action. They wanted their students to see that they had the power to help solve a problem. Whether it was through an online project at a distance or through local activity, students could help make the world better by contributing to science. In some cases, the teachers described this as a form of altruistic behavior, a simple unselfish helping of others. In other cases, teachers spoke of students "giving back" to their local community through citizen science. Even when the project was not local, teachers made sure that students knew they were making a difference in the world.

Building agency through social interaction. During the course of most citizen science projects, students have many opportunities to interact socially. Often they work in groups to gather and analyze data, discussing what they see with their peers. There is also interaction with the teacher, who is often there not to provide answers but to be a guide or facilitator, letting the students take a larger role.

Interaction with scientists. In many cases, it is the project scientist who provides answers—or at least feedback—for the students, validating their results or encouraging them to try again, as described by this teacher:

> Once the kids post their observations to the Internet and whether they found what they're looking for or not, if they think they found it, then a scientist from the Gulf of Maine Research Institute or one of their people who's been working with this for a long period of time, will go on and comment about whether they think this is an accurate description or if students should look at something else. (Participant 16, line 80)

This teacher also felt that the scientist feedback was an essential part of the students' process of becoming citizen scientists:

> We're bringing up the next generation of citizen scientists. [We need] people who are able to say, yes... I understand where you're going with that, but you're reaching, and that isn't an appropriate conclusion for what you've got in front of you. (Participant 16, line 205)

Scientists can provide thoughtful, constructive feedback to the students, treating the students more like professional collaborators and less like students or kids. Many teachers noted that their students seemed to "rise to the occasion" and take on a more confident demeanor

when working with scientists on these projects. Even just knowing that scientists are "out there," expecting them to do their part accurately, is energizing and motivating for the students:

> Some of it is a confidence builder for kids, especially when you're taking part in

> projects where they know... the scientists that are running them are trusting everyone to be as accurate and reliable as possible so, it's kinda giving them that extra responsibility. You're 12 or 13, but you're still being held accountable to these high scientific standards. I think a lot of kids kinda take that and it kind of gives them a bit of a boost. (Participant 6, line 165)

The students are interacting with scientists as part of the same team, doing the same work. This is more than just a friendly encounter at a science museum or a one-time visit to a classroom; this is a real working relationship.

Interaction with peers. Teachers reported many opportunities for the students to work together during citizen science, often working as a team with each student having a role to play and a job to do. As this teacher describes:

> They [the students] have a focus, they have a job to do. Their team works together to do their job. It reaches every student no matter what their gender is, no matter what their ethnicity is, no matter if they're a special education student or a gifted student, everybody's contributing to the good. Everybody can do something in their own niche to contribute. (Participant 14, line 197)

Through this interaction, students see each other acting as scientists.

Interaction with family. Beyond peers, the teacher, and the scientists, there is often interaction with parents and family. Parents can provide assistance with activities, donate supplies, and even be a resource to help students take their projects beyond the classroom. This teacher spoke about a parent who had political connections and was able to work with the students to write a bill that would support their project:

> One of the parents of the students is a lobbyist, and he saw his son was pretty into the topic. He approached me and was like, I think we could go somewhere with this. So he came in and worked with one of the students as part of a green team, and they ended up partnering with the assemblywoman in our district and they're still working on writing a bill, which the assemblywoman is kind of taking and running with... The bill is to provide a tax incentive for restaurants in the district to donate their oyster shells to the *Billion Oyster Project*, so that they can build more reefs.

Not only do the students learn about how science works, but also, thanks to this parent, they get a glimpse of another way that they can impact their environment and work for change. When parents accompany students and show interest in the project, both parents and students benefit. This teacher's students are studying the impact of a river dam on the local salmon population:

> It's a very powerful experience, not only for the kids, but also for the parents who go along with us. We get a lot of jokes about our "dam project" that we're doing right now... oh that dam project... and the parents when we have open house and conferences that we just finished about a week ago, they're always laughing... "I hear you have a dam project going on..." Those are the kinds of feedback that we get. (Participant 14, line 120)

Interaction with community members. Often students were involved in local community projects and had opportunities to interact with and even develop relationships with community members. This teacher's students told their community about a problem with one of their projects:

> And within a couple of weeks the signs were vandalized. Then the kids... we wrote an editorial to the local paper... it just comes out once a week. But they wrote about how badly it made them feel and how important the beach was to the community and how important beach grass is to keeping the beach together. And that action rallied the whole community behind these kids and this beach grass. And now these three little tiny patches of beach grass have grown into a stretch that I would say is about 50 feet long and at least 3 feet wide in sections. Every spring we still go out and we plant more beach grass and the signs are there and they're not getting vandalized. (Participant 8, line 73)

The social interaction that is a part of these projects allows students to interact with others as scientists and be seen by others as scientists. This gives students some external validation of their role and what is possible for them to achieve by enacting that role.

Building agency through authentic science work. The opportunity to participate in an authentic science activity, one with meaning and real purpose, shows students that they can make a positive change in their community and in the larger world.

Giving back to the community. Citizen science projects that are situated in the local community are particularly relevant to students, and let students, as many teachers put it, "give back to the community." By helping their community, students are also helping themselves since they are future community members. Students can easily see how their work will benefit themselves others, and why it is important that they do it. This teacher linked her students' project of monitoring invasive species directly to the popular community activities of fishing and hunting:

> We talk about how they can get involved and how eventually they are going to be the community, and what do they want for their community? With the fishermen and the hunters that we have in our area, one of the hooks that I use is the idea that if the invasives take over, the deer won't have the fodder they need. My students need to understand that if we're going to continue to have the ability to hunt and to fish that we need to respect the natural world. I think that was my real drive behind this, to have the students take some ownership of maintaining and understanding the things they love. (Participant 16, line 127)

The students' work in citizen science would ensure that environment stays healthy enough so they can enjoy it when they are adults.

Another teacher had her students work on a project that involved monitoring water quality and sea life at a local beach. She wanted her students to see how they could make a difference in their local environment:

> I think the idea of being here in Hawaii and having that opportunity to go out in the field and having the students identify what they're seeing in the ocean when they go swimming was really important to me. I wanted them to see how the environment around them was being impacted and how they could make a difference. I know we weren't cleaning up environmentally but we were helping the scientists in the area see what was going on in the inter-tidal zone. (Participant 10, line 75)

The students worked to do species counts and measure water quality, knowing that the results of their scientific endeavor would help scientists to understand what was happening in that part of the ocean. They were playing an important part in keeping their beach healthy, a direct benefit to the community.

A final example of students acting to improve their local environment and help their community through their work in citizen science concerns monitoring the salmon population in a nearby river. In this project, students are working with scientists to study the health of the fish as well as the quality of the water. Then, as an additional feature of the project, the students helped to redesign one of the river dams so that the fish could pass through and reproduce successfully. As the teacher describes, this is part of a year-long science unit:

> So we start out the year studying the life cycle of salmon, because salmon are really important to our Native American populations here in the Yakima Valley. We end the year doing a comparative anatomy of the organ systems of salmon and humans. We take kids out; they go to the mountains to see Chinook salmon spawning, and we take them to a dam where they can actually see what a killer dam looks like and what they're doing to mitigate for that. So my students are involved with that, and right now we are engineering, or I should say re-engineering I should say current dams in the state of Washington to allow current passage for both adults and outgoing smolt. (Participant 14, line 20)

The students' work as citizen scientists connects directly to their work as citizen engineers,

allowing them to make a highly visible impact on the community. This connection to the community is a key aspect of citizen science for many teachers. As one teacher put it:

> And that's the whole point of citizen science, right, the whole community is getting together to help, and there's probably professionals in the community who are willing to help the students during their data collection. And, no matter...

> there's a lot of work to get it done, but it's so worth it to have the kids out there and collecting the data and being a part of the larger science community. (Participant 10, line 310)

Making a difference in the world. Many teachers spoke of their citizen science projects as having impacts beyond the local community. Through participation in citizen science, they believed that students can make a real difference in the world. When asked what she would tell a new teacher about citizen science, this teacher responded:

> I would tell them that it is one of the most powerful educational tools that they can invest in, and to help their students realize that they are valuable and they can make a contribution, and it's real work that they're doing... and they're making a difference in their world. Is it easy? Nope. Are you going to have to put in some extra time to set it up and arrange everything? Absolutely. But it's valuable time spent. (Participant 14, line 260)

Even though there may be more work involved in the implementation of a citizen science activity, the value of the activity to students and to the world makes it worth the effort. Giving students the opportunity to contribute something to the world, even at a young age, builds confidence and tells them that they have the power to act for change. Another teacher spoke of how these types of activities can empower young students:

> I think it all goes back to that empowerment and that they're making a difference now; they don't have to wait until they've graduated from high school or graduated college and finding a career... giving back to the planet in some way now is super important. Besides, having the kids know that they're making a difference now, and that this gives them more experience and opens their eyes to

> a whole new world... these are things that they'll never forget and will hopefully have an impact on their future forever. (Participant 15, line 217)

By participating in citizen science projects, young students can make a difference in the world, seeing what is possible in the "here and now," and building on that experience as they move into the future. Another teacher echoed that sentiment:

> I think that I want to help them recognize that there's a bigger world out there. They can have an impact in that world, even though they're 7th graders. They're 12 years old, they have a voice and they have a community, and they can contribute. (Participant 5, line 82)

As students become aware of a larger world beyond themselves, they can broaden their impact, moving from acting in the local community to working on projects worldwide.

In summary, the main theme of *Building Agency* reflects teachers' ideas about how participation in citizen science activities developed their students' abilities to have an impact on their environment. Through social interaction and engaging in authentic science work, teachers felt that their students became more confident and better able to take action in the world.

Challenges. It is perhaps no surprise that, when asked about the challenges involved with implementing citizen science projects in the classroom, teachers often spoke about issues with time, materials, and student management. Teachers face these types of problems every day, and these issues are often exacerbated whenever a new and somewhat complex activity is brought into the classroom. However, there are some challenges that teachers discussed that are particular to citizen science activities. These challenges concerned students' experiences with two aspects of citizen science:

participation in the citizen science task itself (e.g., observing monarch migration, mapping craters, or identifying invasive species) and exposure to the overarching scientific process that begins with the generation of a question and ends with the publication of results. Many teachers expressed a concern that if students only experienced an isolated piece of these two aspects, or if someone didn't help the student to reflect on the experience, there would be no benefit from their involvement in the citizen science project; and, possibly, there may even be a negative effect on students. Each of these subthemes is discussed below.

Making the task meaningful.

Understanding the larger scientific work. Teachers overwhelmingly described authentic data collection and analysis as two positive parts of citizen science involvement. When students engaged in the tasks of citizen science, they were engaged in authentic scientific activities that contributed to a larger scientific endeavor. However, the reasons for these activities, the connections to the bigger picture, were not always apparent to the students. Although students were participating, they didn't always know how their involvement contributed to the study. This teacher describes her students' disappointing experience with a mapping project:

> And with that one, they didn't see a result, they were just like, "Oh... that's it? Ok..." and they didn't realize that even counting craters was making a huge difference. So, I think if I would've been able to communicate that better to them, they would've been in a better place. (Participant 11, line 150)

For her students, the activity of mapping the craters on the Moon had no connection to anything meaningful. Students were expecting some type of response or result from their actions and received nothing. Without guidance or feedback, the citizen science project was simply a repetitive task without any meaning.

Understanding negative results. Negative data (e.g., not finding any evidence) was a particular challenge in two ways. First, students became frustrated or disappointed when they felt they should be finding a particular species or seeing some type of result and didn't. This often happened in environmental projects when students were trying to see an event or find certain animals or plants, as described by this teacher:

> I think sometimes when a particular student couldn't find certain things in their area, that they would be disappointed. So, in the case of the monarchs, the kids were coming from all over the city but yet only a certain number of kids got to see the monarchs because they travel in such a narrow path when they go up and down Kansas City. They're the ones who are disappointed when they didn't see it, when they didn't get a chance. (Participant 1, line 199)

Students may feel that they're missing out when they don't experience all aspects of a project, and it can be challenging for a teacher to help them overcome this disappointment and understand that not observing something is often just as important, scientifically, as observing it. Additionally, as in the case of invasive species or environmental contaminants, not finding something can be a very good thing, but still hard for students to be excited about, "Explaining to the students that not finding anything when you're looking for an invasive is a really good thing. That's kind of hard for them to get their heads around sometimes" (Participant 16, line 103).

Experiencing the whole scientific process. Many teachers described citizen science as an engaging way for their students to experience and come to understand the scientific process, to learn about science as a discipline—how it works and what it can do. In all citizen science projects, participants are doing some type of scientific work. Many teachers worried, however, that if their students didn't see (and, ideally, experience) the entire research process, any benefits of participation would not be realized.

Continuous experience. For example, if the students' participation consists of simply "checking in" to a project to add their observations and then "checking out" again, there will be no opportunity to see how their one piece fits into and supports the research study. Participation should not be sporadic or isolated from any context. This teacher shares a lesson she learned when her students tried an online citizen science activity:

> Don't make it a supplement or something to add to a lesson, try to give the students a storyline when you have them do something. Try to build it up so they're invested in it in some way, shape, or form... be intentional about the way you are presenting it... be intentional about the way you continue it with your students. (Participant 11, line 203)

Complete experience. Some teachers were afraid that students wouldn't learn about all the parts of scientific work such as formulating a question, designing a study, troubleshooting unexpected problems, reflecting on and sharing the findings. This teacher describes her frustration with some projects:

> A lot of them [citizen science projects] run out of funding and they can't continue the project or it just kind of filters out and you're not seeing anything being done with the data, which I think is frustrating. I think it can be frustrating for the students who understand that the logical ending to a research project is that you write a paper on it and someone reads about your research, whether it's your

> teacher reading it or just the scientific community at large reading it, they understand that that is the end. I think that is one of the big challenges is that a lot of these projects start out really great but then eventually lose the funding to follow through with their research. I've certainly been on that end of the spectrum, too, so I completely understand that. (Participant 2, line 262)

For this teacher, students needed to experience the entire research process, especially the culminating activity of sharing data with a wider audience. If a project doesn't help or allow students to somehow get this full research experience, the teacher may need to create classroom activities to fill in this gap as this same teacher did:

> But that's why... I think one of the ways to alleviate that is I always make my kids write a report at the end of whatever little project we were doing so regardless of whatever data we contributed to the project at large, any data that they contributed they have to write a report on. It was small and of course their trends were not noticeable, but it got them understanding and feeling that sort of closure for that particular project, even if they didn't get a full closure. (Participant 2, line 270)

This "full closure" is needed by students to feel that what they have accomplished matters and that they have truly made a contribution. Moreover, a final report on the activity helps students to connect their work to the bigger picture, to see how all the parts fit together. It is an opportunity for summarizing, reflecting, and receiving feedback—all important aspects of learning.

In summary, the main theme of *Challenges* reflected teachers' concerns regarding implementation of citizen science projects in their classrooms. The first subtheme, *making the task meaningful*, indicated that teachers often had difficulty helping students to understand the larger scientific work and understanding negative results. The second subtheme, *experiencing the whole scientific process,* showed that teachers were concerned about ensuring that students spent enough time with a project and that students were engaged in all aspects of the science process.

Chapter 5: Discussion

In this study, I explored the motivations and perceptions of middle school science teachers who have used citizen science activities with their students. I was guided by three research questions:.

1) What motivates experienced middle school science teachers to use citizen science programs in their classrooms?

2) What do experienced middle school science teachers perceive to be the impact on their students as a result of using citizen science in their classrooms?

3) What do experienced middle school science teachers perceive as the challenges in using citizen science in their classrooms?

In this chapter, I will discuss the findings of the study as they relate to these research questions. Then I will discuss how the findings connect to other current relevant research. Last, I will discuss limitations of the study and offer some recommendations for areas of future research.

Research Question One: Teacher Motivations

In order to elicit the teachers' motivations, I interviewed them about the value they perceived in citizen science and what they initially expected from the experience of using it in their classroom. First, the teachers valued citizen science as a way to provide their students with an opportunity to experience an authentic science activity, an opportunity for their students to engage in science practices that would contribute to a larger scientific work or study, either in the local community or further beyond. By bringing this authentic science work to their students, teachers hoped their students would find an increase in the meaning and relevance of science and see a purpose for their science activities. Second, the teachers saw citizen science as a way to help their students see that they could make a difference--in the world and in their community. These two ideas—*authentic science work* and *making a difference*—are subthemes of the main theme *Building Agency*. For teachers, these ideas not only motivated them to implement citizen science with their students but also were a part of what they saw happening in the classroom. The theme of Building Agency is discussed below as part of Research Question Two.

Research Question Two: Teacher Perceptions of Student Impact

The teachers perceived that participation in citizen science impacted their students in two general ways which I present as the two main themes of *Broadening Perspectives* and *Building Agency*.

Broadening perspectives. The teachers felt that participation in citizen science resulted in a broadening of their students' perspectives, changing the way the students viewed science, their work, and the world beyond them. According to the teachers, their students expanded how and what they thought about science, learning about science practices and dispositions. Students saw that their work had value and was valuable to others. Finally, teachers perceived their students noticing new aspects of their own environment as well as learning things about the wider world.

Building agency. Teachers perceived that participation in citizen science helped students to develop agency, a sense that they could take action in the world in a meaningful way. According to the teachers, through the authentic science work of citizen science, students saw that they could do science and the results of their science could make a difference in the world. This experience was most powerful when students were involved in local community projects where they could see the outcomes of their work in a direct way. Teachers also spoke of the opportunities for social interaction during these projects and how interacting with scientists, family, peers, and community members during citizen science activities helped students have the confidence to act as scientists.

Teachers perceived citizen science activities as impacting their students by building their agency and broadening their perspectives. Both of these themes involve a type of personal change, but one—broadening perspectives—focuses on changing the way one views the world beyond oneself; the other—building agency—focuses on changing the way one views the world within.

Research Question Three: Teacher Perceptions of Challenges

Teachers expressed two challenging aspects regarding the use of citizen science activities in their classrooms—making the citizen science task meaningful to the students and ensuring that students experienced the whole scientific process.

Making the task meaningful. Teachers were concerned that students might not understand why they were doing a particular citizen science task. The task itself might be fun and even exciting for the students, but the students may not know how it connects to the larger scientific study or how they should interpret the results of their activity, especially if they did not get the results they expected. They may not understand what the larger study is investigating and how it might be relevant to their world. Teachers felt that this critical part of citizen science participation didn’t usually happen by itself. It is up to the teacher to guide students in making meaning from these activities and to help students connect their tasks to the larger science study.

Experiencing the whole scientific process. Teachers were also concerned that students participating in citizen science might not experience all of the scientific process. They felt that it was a challenge to make sure that students participate in citizen science in a continuous or regular way, so that they are not just engaging in a project for a few minutes on one day and then not going back to it for a few days. Teachers felt that this sporadic type of participation doesn't allow for seeing the purpose behind the activity, and students who engage in this way are less likely to keep participating. Teachers also felt it could be challenging to ensure that students get a complete citizen science experience. For example, students might just be involved in data collection and not be able to experience other parts of the process. They may not see how their work is ultimately used. Often, this is due to the type and timing of projects. Some projects are set up just for data collection and analysis. Others may have a lengthy duration, lasting much longer than a typical school year. Teachers often found it difficult to have their students experience every aspect of the scientific process.

Teaching Experience & Hours of Citizen Science in the Classroom

The teachers interviewed for this study had varying years of experience teaching middle school (1-40 years) and reported a wide range of time using citizen science in their classrooms (2-600 hours). Since integrating a citizen science activity into a classroom setting in a meaningful way can be challenging, it may be that more experienced teachers are able to successfully navigate these challenges and, as a result, may spend more classroom time doing citizen science than teachers with less middle school teaching experience. For some teachers, having many years of experience in a school or district did seem to give them several advantages. These teachers spoke of having more autonomy overall, resulting in more freedom to make curriculum and scheduling decisions in their classrooms, and reported having a high degree of job security that let them try new things without fear of repercussions. Indeed, in comparing the six interviewed teachers with less than five years of experience teaching middle school with the four interviewed teachers having 34-40 years of experience teaching middle school, the high-experience teachers reported an average of 183 total hours spent doing citizen science in the classroom (although one of these teachers reported the time as "30 years" and so was excluded from the average). The low-experience teachers reported an average of seven total hours spent doing citizen science in the classroom. This difference in hours of citizen science in the classroom could simply be due to the difference in number of years in the classroom with the opportunity to do citizen science with students; but, although this is likely, there is no way to determine such a correlation from the data collected in this study. Also, there is no way to know when the hours of citizen science took place (e.g., recently or years ago), and likewise no way to know if the hours took place over the span of years, months, weeks, or days. However, the interviews suggested other aspects of these groups that can be considered when looking at why and how citizen science is brought into the classroom.

The type of citizen science project may play a role in the number of hours of classroom time spent on citizen science. Four of the six low-experience teachers used local, environmentally focused projects such as the *Billion Oyster Project* and *Our Project in Hawaii Intertidal* and reported a greater number of hours using citizen science (9-10) compared to the two teachers in this group who used online projects that had no local focus—*Penguin Watch* and *MoonMappers*—and reported using only two and five hours, respectively, of citizen science. The environmental projects involved time spent out in the field collecting data, plus preparation time and time traveling to and from the site. Online projects can be accessed from school, and most allow participants to “drop in and out” when time allows (i.e., spend short chunks of time participating in the project when convenient). This type of participation may be more suitable to many teachers’ schedules, but may also result in fewer hours of citizen science in the classroom.

Another factor that may impact the number of classroom hours spent doing citizen science is the amount of support received from people outside the classroom (e.g., school administrators, families, community members, professional scientists). Both low- and high-experience teachers having greater number of hours of citizen science spoke of having support and involvement of outsiders. Sometimes it was the principal of the school; more often it was community involvement. Teachers felt that the support of and interaction with people outside the classroom enhanced student engagement and interest in the project, and as a result, helped to sustain it.

A third factor that potentially impacts the amount of class time spent doing citizen science is the type of school. Some teachers in both the low- and high-experience groups taught at schools other than typical public middle schools. A few were teaching at small, parochial (i.e., Catholic) schools. Others taught at private schools with a particular focus or mission such as an Outward Bound school. For teachers with fewer years of teaching experience, these types of schools offered flexibility in schedules and curricula, and sometimes a focus that aligned well with doing citizen science, facilitating more time spent in doing these types of projects in the classroom.

Although having many years of teaching experience may offer some advantages to the successful implementation of citizen science in the classroom, other factors impact this as well. The type of citizen science project, the amount and type of outside support, and the type of school all play a role in determining how many hours of class time may be spend doing citizen science.

Student Science Identity Development

During citizen science activities, teachers in this study perceived that their students broadened their perspectives and built agency. Both of these themes involve a type of personal change, a change in the way one views the world beyond oneself and a change in the way one views the world within. These two aspects of personal change can be examined further by looking at the concept of science identity and its development. The findings from this study can be viewed through the lens of science identity development. The concept of "identity" has been studied extensively in the social sciences. Identity can be defined as "the 'kind of person' (i.e., 'science person') one is seeking to be and enact in the here and now" (Gee, 1999, p. 13). By this definition, identity can be a goal that one is seeking to achieve rather than what one is now or how one acts currently. For example, many of the teachers interviewed in this study spoke of wanting to help their students to become scientists, to be that kind of person in the future. They were, perhaps, helping their students to develop a science identity by involving them in citizen science. But how does one develop an identity? When can we say that we've achieved that identity?

To try to answer those questions, it may help to think about the different aspects of identity described by researchers. Gee (2000) outlined four ways that one could achieve an identity: it could be part of one's nature, it could come from one's social or professional position, it could come from others recognizing one's achievements, or it could come from experiences one has with certain groups. Banks et al. (2005) gives a similar description of the concept, but adds the elements of flexibility and individual choice, saying,

> Identities are both ascribed by others and asserted by individuals. They are heavily influenced by social groups and historical circumstances, but they are also situational, flexible, and determined by individual choice. People define their identities in many ways, such as by gender, age, and ethnic, racial, religious, or other affiliations. Many individuals have global, cosmopolitan, or multicultural belongings and identities. (p.22)

Finally, Carlone and Johnson (2007) posited that in order to be a certain kind of person, one needed to have a certain level of competence, to be able to demonstrate it, and to be acknowledged for it by others. They created a model of science identity to use in their study of the science experiences of women of color. This model has thee dimensions: performance, recognition, and competence. To develop a science identity, one must *perform* scientific practices, be *recognized* as a science person, and be *competent* in knowledge of science content. They also noted that a particular identity—in this case science identity—can interact with and be affected by other identities (e.g., racial, ethnic, and gender), making the development of a strong science identity particularly challenging for underrepresented groups.

Carlone and Johnson's model of science identity can be used to further interpret the teachers' perceptions of their students' experiences with citizen science. As students were broadening perspectives and building agency, they were also working on their science identities. For example, during their participation in citizen science, students were learning about science—its practices and its dispositions. They were learning to systematically collect and analyze data. They were learning how science works and what it can do. Although teachers more often emphasized the learning of skills, processes, and ways of thinking rather than science content, I would argue that this still falls under Carlone and Johnson's idea of "Competence." Students were becoming competent in working with data and interpreting findings.

In addition to learning how to do science practices, students involved in citizen science actually do the work. They "perform" authentic science, and they perform it with others, in a social context. As an example, teachers described their students as usually working in groups--working together to measure soil temperature or working as a class to upload data. Also, this social aspect offers opportunities for the discussion of findings, the proposing of explanations of unexpected events, and the consideration of new questions. In this way, students use the language of science as well as perform the practice of science.

The third part of the science identity model—recognition--is also social in nature, but has an individual aspect as well. Students develop a science identity, in part, when other people recognize them as a science person. These others could be classmates, family members, community members, or even professional scientists. As a student competently performs scientific work in the course of a citizen science activity, they may be working with other students, with scientists, or with others out in the community.

During this work, there is the opportunity for others to see the student as a scientist, or at least as a “science person,” and strengthen the student’s science identity.

However, even if others think of one as a scientist, that person may not think that about him or herself. According to Carlone and Johnson, part of being recognized as a scientist or science person means recognizing oneself in that way. Achieving this internal recognition may be the most difficult part of science identity work, perhaps because other identities (e.g., racial, ethnic, gender, age, culture, etc.) are interfering with the development of a science identity and the movement or transition of the student from his/her own world into the world of science (Aikenhead, 2001). A student may, for example, identify a scientist as an older white male in a white lab coat who works in a laboratory—a popular conception of a scientist. If a student’s racial, ethnic, gender, and age identities don’t match their idea of a scientist, their own science identity may be weakened. Even so, it is possible that the social interaction which is often part of the authentic science work in a citizen science project could, over time, help to change how students picture a scientist, as described by this teacher:

> I start out [the year] asking them what a scientist looks like... and they always draw the typical guy... in a lab with goggles, hair askew, lab coat on, and then by the end of the year they draw themselves as a scientist. I think they move from something really external to something intrinsic. (Participant 5, line 161)

After being involved in several citizen science projects throughout the year, her students could begin to see themselves as scientists, begin to see that a scientist is not someone that looks a certain way but someone who acts and thinks in certain ways. Part of science identity work may involve the reconciling of several identities that may seem to be at odds with one another, and participation in citizen science may facilitate that reconciliation.

This identity disconnect can potentially affect students' interest in science. Several teachers felt that participation in citizen science sparked or strengthened their students' interest in science, citing an increase in asking questions in class or participation in the project at home. A strengthening of science identity may be the mechanism by which this increased interest occurs. A student who doesn't identify with science or as a scientist would have little reason to be interested, as described by Stromholt and Bell (2017):

> When learners view what happens in formal science education as being systematically disconnected from their everyday lives, it can result in issues of identity conflict where learners find themselves disinterested in or unable to access science-linked identities. In other words, some learners do not see science as a desirable or accessible resource that contributes to who they are or who they want to be in the future. People try to engage in activities they see as part of who they want to be and avoid activities they perceive to be misaligned with who they see themselves as. (p. 4)

Students who initially do not see how science (or the outcomes of scientific studies) affects them or relates to them as an individual, may begin to see some connection as they participate in citizen science. This connection may come through discussion and other types of social interaction with others, through learning and developing expertise in science content, or through seeing the results of their completion of scientific practices. As students become more connected, they may begin to see science as a part of them, something relevant to their lives, something that they can be a part of and in which they could find interest.

Student Agency

Building Agency was a main theme developed during analysis of the interview data. Throughout many of the interviews, teachers repeatedly stated that they wanted their students to see that they could make a difference in the world, to understand that they could have an impact on their environment and in their community, even at a young age. This can be viewed as a type of agency—the ability to act on and influence people and places in the environment. According to Bandura (2006, p. 164), "to be an agent, is to influence intentionally one's functioning and life circumstances." People who are agents do not just stand to the side and watch, "they are contributors to their life circumstances, not just products." According to the teachers, as students participated in citizen science, they were making a contribution and having an impact. This impact is especially visible in the local environmental projects where there is a high degree of relevance and connectedness. The contribution and influence involved in non-local and online projects may not be as obvious to students, but teachers still felt that the students' impact was significant.

The contribution and influence made as an agent often happens as a result of a change of role for that person. For example, Sheridan, Clark, and Williams (2013) saw a connection between agency and role shifting in an informal education program for youth in Washington, DC. In this program, many of the young participants gradually took on roles of mentorship and leadership, which the authors interpreted as an increase in agency. There is some indication from teachers that students participating in some citizen science projects make a role shift from student to environmental advocate, from scientific novice to community science expert, depending on the type of project and the specific practices and social interactions involved. In one case, a teachers told of how as a result of their citizen science project, students took on the role of engineers:

> We take kids out; they go to the mountains to see Chinook salmon spawning, and we take them to a dam where they can actually see what a killer dam looks like and what they're doing to mitigate for that. So my students are involved with that, and right now we are engineering, or I should say re-engineering current dams in the state of Washington to allow current passage for both adults and outgoing smolt. (Participant 14, line 23)

These students were involved in an ongoing local community project and had many opportunities to interact socially and even develop relationships with community members, scientists, and engineers. These types of experiences can be critical in helping students to develop agency (Stromholt & Bell, 2017), which can be viewed as one aspect of the learning that happens during these projects: “learning is not just about knowledge acquisition, but is exemplified by shifting roles, knowledge and skills, responsibility, and power” (p. 3).

Agency has been posited as a fourth component to the construct of educational engagement--in addition to the behavioral, emotional, and cognitive aspects—and can be described as the ways that a student influences his or her teaching and learning experience by making suggestions, asking questions, and expressing their ideas (Reeve & Tseng, 2011). This “agentic engagement” is often present during citizen science activities when students have the opportunity to express their ideas regarding the type and amount of data to be collected, for example, or to suggest another question to pursue or another line of investigation to follow. In the course of a project that used satellite data, one teacher's student wanted some different options:

> One of my students brought up a really good question: "Well, wait a minute, how do you get the satellite back? How are we going to get it back?" I said, "Well, most of the time you don't get it back, you just let it go. Push it out of orbit and it just goes into space. And she said, "Well, that's not going to work. We have to do something else. We have to get it back." And she sat down and she came up with some ideas on how to do it. She ended up writing to NASA to apply for their camp. (Participant 2, line 217)

Although this type of student agency is possible during many types of classroom activities, this teacher felt that the interest generated by participation in the citizen science project inspired this student to want to take action.

Perhaps the aspect of agency most relevant to many citizen science projects (especially local field-based ones) sets students up as agents of social change. Stromholt and Bell (2017) studied a citizen science activity where students collected and analyzed data from a polluted river in their community. The researchers had worked with the teachers to design the activity so that its research questions related to the youth, their community, and how policy decisions are made. Using this approach, the students "have an opportunity to see themselves as community participants determining their local and global futures" (Stromhold & Bell, 2017, p. 5), an idea echoed by many of the teachers that I interviewed. According to them, participation in citizen science offered their students the opportunity to be agents of social change.

Connecting Formal & Informal Settings

The findings from this study indicate what is possible when the worlds of formal and informal science education are brought together. As middle school teachers integrate citizen science projects (typically informal in nature) into their classrooms (typically more formal in nature), they are working to design educational experiences that support and encourage learning across these two settings, integrating elements of formal and informal educational environments. Successfully fostering student science learning in both of these environments may lead to benefits beyond learning content and skills. Penuel, Lee, and Bevan (2014) describe how creating learning experiences that are rooted in both the formal and informal realms have the potential to make STEM education more equitable due to the many connections that can be made among people and places. This highly connected learning provides numerous opportunities for youth to engage in science (and STEM) practices that are relevant to their own interests and their everyday life. This emphasis on and value of relevance was found throughout the teachers' descriptions of local, environmental citizen science projects, with some mention of it when speaking of distant projects, too.

Other researchers have described impacts of this learning across settings in terms of students' science identity development, arguing that this type of learning affords opportunities for students to be seen as people who know about and can do science (Stromholt & Bell, 2017). For example, in Stromholt and Bell's study, students involved in a classroom project about a local Superfund site where they conducted background research and interacted with community experts, performed water quality tests and analyses, and authored a book containing their findings which they presented to the mayor. The researchers argued that involvement in these activities that were situated in both the formal and informal settings changed how students thought about science and helped to develop science-related identities. These types of opportunities for social interaction with community members and scientists, participation in authentic science practices, and the publication or presentation of findings also occurred over the course of many of the citizen science projects described by the teachers in this study. In this way, citizen science can be seen as a way to support and encourage student learning across settings.

Limitations

This study has several limitations related to participants and data collection. First, my sample of interviewed teachers was more diverse than I originally intended. Although I planned to recruit and interview middle school science teachers who had many years of teaching experience, seven of my 22 participants had five or fewer years of middle school teaching experience. Also, some of the participants were not currently teaching middle school, having either retired or changed grade levels. The teachers whom I interviewed taught at different types of schools, including private independent schools, parochial schools, and public schools. Finally, some of these teachers came into teaching through alternative certification programs and had worked in a science-related job before becoming a teacher. It is probable that this variation in the sample affected the number of interviews needed to reach data saturation; saturation may have occurred sooner with a more homogenous group of participants. Despite these variations, each of these teachers was able to give me a rich, detailed account of their experience with citizen science in the classroom, allowing for a deep exploration of their motivations and perceptions.

However, in one important way, the participants in this study were not diverse. Each teacher who was interviewed was enthusiastic about citizen science and spoke positively about the potential of citizen science activities to let students engage in authentic scientific work. This can be seen as a limitation, since talking with teachers who are skeptical about citizen science and have a more negative attitude regarding its use in the classroom would likely produce a different set of themes and subthemes. These teachers could be the focus of a future study.

Second, my interviews were conducted from a distance, either by cell phone or through an Internet video conferencing system. Often, parts of the conversation were difficult to hear due to poor phone reception or a slow Internet connection. Ideally, these interviews would have taken place face-to-face in a quiet, comfortable, and convenient place. However, the participants were located across the United States and talking by phone or over the Internet was the best option. I tried to make the interviews as convenient and comfortable as possible, giving participants the choice of talking during a break in their school day, during the evening, or over the weekend. When a part of the conversation was unclear, I asked the participant to repeat it or explain further, and I made sure to ask if they could hear me clearly. Nevertheless, face-to-face interviews might have involved fewer frustrations, allowed for a better rapport between interviewer and interviewee, and yielded richer data.

Third, I had planned to collect and analyze documents and artifacts to support the interview data, but these items proved more difficult to collect than I anticipated. During the interviews, most participants agreed to send pictures from their citizen science activities, some volunteered to send copies of lesson plans, and a few said they would share blog posts about their projects. However, I did not receive any of these items in time to include them in the data analysis.

Future Research

This exploratory study examined the motivations and perceptions of middle school teachers in the United States who have involved their students in citizen science projects. These teachers hoped that participation in citizen science would broaden their students' perceptions regarding science, their scientific work, and the world around them. The teachers wanted their students to feel that they could impact their community and even the world as they engaged in the social interaction and authentic science practices of citizen science. Although every teacher interviewed described challenges in the implementation of classroom citizen science, all were adamant that the benefits to students outweighed any difficulties. Since this study was exploratory in nature, there are several ways to expand and build upon this research.

First, the degree to which citizen science is implemented by teachers needs further investigation. The participants in this study were enthusiastic about citizen science and how it could impact their students. However, some reported spending hundreds of hours of class time doing citizen science and were involved in multiple projects, while others reported spending less than ten hours and only used a few projects. Some chose online projects while many more chose community-based projects. These differences could be the result of varying years of teaching experience. A veteran teacher may be more comfortable trying a new type of classroom activity, may have more contacts in the community, and most likely is not overwhelmed by the newness of teaching. Types of certification and background may also make a difference. Some teachers in this study had experience in science as a career before teaching. Some teachers were already participants themselves in citizen science. These teachers would be likely to do more citizen science in their classrooms. Finally, types of schools and school schedules may affect how citizen science is implemented. Schools that have greater flexibility in curriculum and in daily scheduling would allow for more use of citizen science activities.

Second, motivations and perceptions could be explored with teachers at the elementary, high school, and college levels. Teachers at these levels are also using citizen science projects in their classrooms, and it would be important to understand how different teachers implement citizen science project in a variety of classroom situations. The issue of vertical integration, or how citizen science experiences are connected and aligned in a meaningful way from Pre-K through the college level, could be investigated. Teachers of all levels outside the United States could be interviewed as well.

A third way to expand this study would be to focus in depth on the emerging constructs of agency and science identity, examining whether and how teachers perceived these developing in their students. What aspects of citizen science participation seem to encourage and support this development? How do students change their roles? How do the concepts of agency and identity intersect with interest?

A fourth possibility is to examine this topic from a critical or social justice perspective, looking at how participation in citizen science can be an opportunity for equitable and relevant science learning for students. How do underrepresented minorities in STEM experience citizen science?

Finally, one could shift from examining teacher perceptions to examining student perceptions. What do students feel they learn? Do they feel that they are becoming more like a scientist as a result of participation? Are they more interested in science because of citizen science?

The teachers in this study saw many benefits to their students from bringing citizen science activities into their classroom, despite encountering challenges. Future research, building on this study, can expand on and possibly strengthen this indication that citizen science holds promise as an effective way to improve STEM education for all students.

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APPENDIX A: PARTICIPANT RECRUITMENT MESSAGES

Greetings all,

I'm a former teacher now working on my dissertation in science education. I'm examining how teachers do (or don't) use citizen science in their classrooms, and I have a short survey for current or former middle school science teachers. Any middle school science teachers here willing to take the survey?

You don't need to have used citizen science to take the survey… I'd like to get a sense of how many do and how many don't. For those that do, I'm also asking for volunteers to be interviewed about their experience.

I've included the link below. The survey is truly short - 5 or fewer minutes.

I'm happy to answer any questions about this… many thanks in advance for your help.
Also, feel free to share off list.
Georgia

https://umsl.az1.qualtrics.com/SE/?SID=SV_7OQT8yZrfnEOPhX

P.S. Also happy to share results of all this, if anyone's interested.

Georgia Bracey, PhD Candidate
College of Education
University of Missouri-St. Louis
georgiabracey@gmail.com
glbyg5@umsl.edu

APPENDIX B: PARTICIPANT RECRUITMENT VENUES

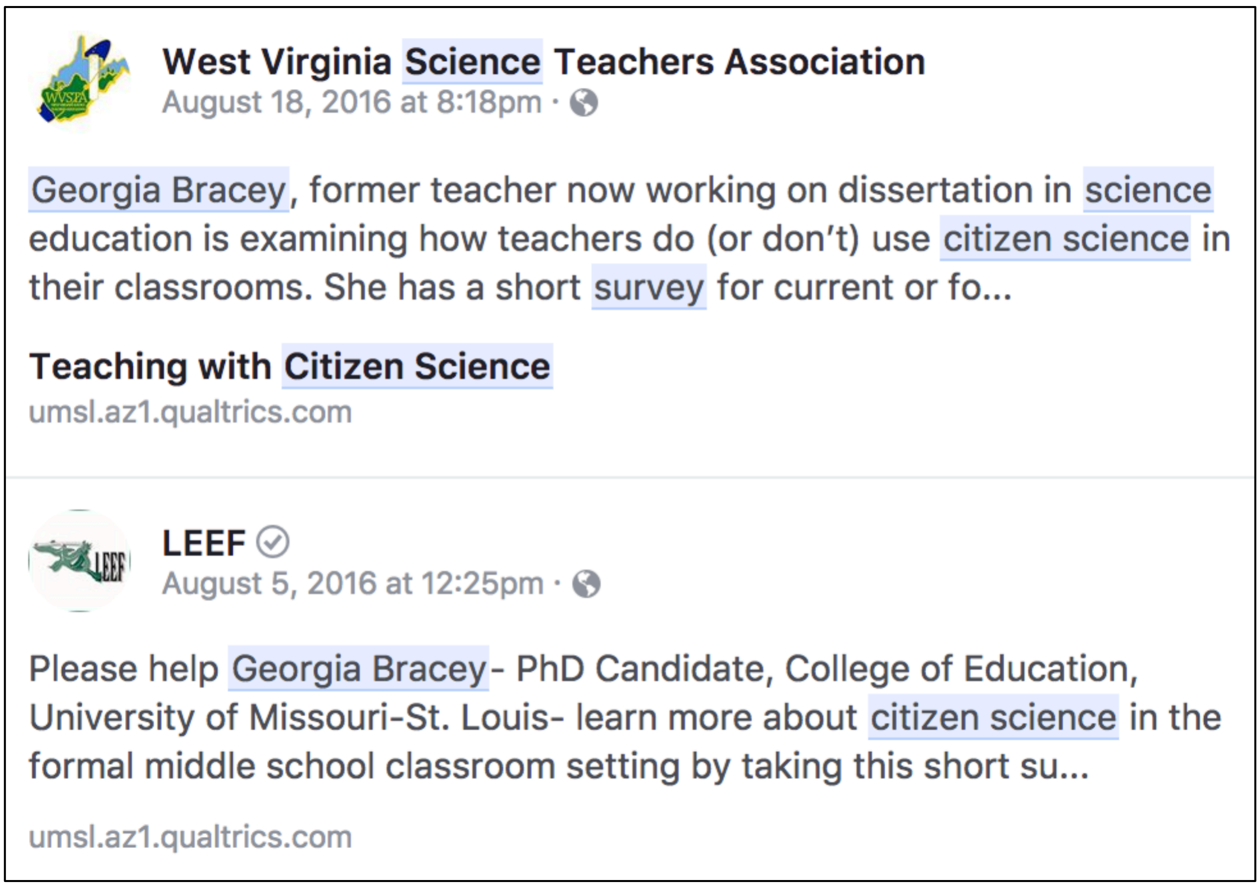
Listservs:

1. Citizen Science Association (CitSci-discussion-L@cornell.edu)
2. NSTA Middle School Teachers
3. Yerkes Observatory Teachers

Social Media:

1. Twitter

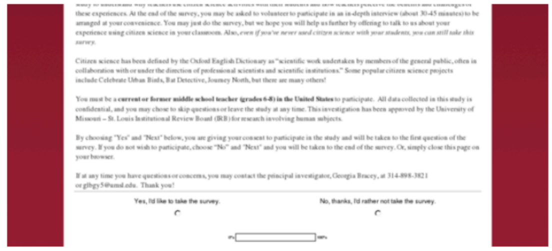
2. Facebook



3. Edmodo

Me to Science, Middle School

Hi everyone! Are there any U.S. middle school science teachers out there (former or current) who could help me with a survey I'm doing as part of my graduate studies in sci ed? It's about citizen science, but you don't have to be a citizen scientist do do the survey :-) It's very short... about 5 min. Thank you!! http://tinyurl.com/zq5eq8z Less...



these experiences. At the end of the survey, you may be asked to volunteer to participate in an in-depth interview (about 30-45 minutes) to be arranged at your convenience. You may just do the survey, but we hope you will help us further by offering to talk to us about your experience using citizen science in your classroom. Also, *even if you've never used citizen science with your students, you can still take this survey.*

Citizen science has been defined by the Oxford English Dictionary as "scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions." Some popular citizen science projects include Celebrate Urban Birds, Bat Detective, Journey North, but there are many others!

You must be a **current or former middle school teacher (grades 6-8) in the United States** to participate. All data collected in this study is confidential, and you may chose to skip questions or leave the study at any time. This investigation has been approved by the University of Missouri – St. Louis Institutional Review Board (IRB) for research involving human subjects.

By choosing "Yes" and "Next" below, you are giving your consent to participate in the study and will be taken to the first question of the survey. If you do not wish to participate, choose "No" and "Next" and you will be taken to the end of the survey. Or, simply close this page on your browser.

If at any time you have questions or concerns, you may contact the principal investigator, Georgia Bracey, at 314-898-3821 or glbgy5@umsl.edu. Thank you!

Yes, I'd like to take the survey. No, thanks, I'd rather not take the survey.

Teaching with Citizen Science

tinyurl.com

APPENDIX C: SCREENING SURVEY

Teaching With Citizen Science

Q1 Hello! Please help us learn more about citizen science in the formal classroom setting. This short survey (about 5-10 minutes) is part of a study to understand why teachers use citizen science activities with their students and how teachers perceive the benefits and challenges of these experiences. At the end of the survey, you may be asked to volunteer to participate in an in-depth interview (about 30-45 minutes) to be arranged at your convenience. You may just do the survey, but we hope you will help us further by offering to talk to us about your experience using citizen science in your classroom. Also, *even if you've never used citizen science with your students, you can still take this survey.* Citizen science has been defined by the Oxford English Dictionary as "scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions." Some popular citizen science projects include Celebrate Urban Birds, Bat Detective, Journey North, but there are many others!

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If at any time you have questions or concerns, you may contact the principal investigator, Georgia Bracey, at 314-898-3821 or glbgy5@umsl.edu. Thank you!

○ Yes, I'd like to take the survey. (1)

○ No, thanks, I'd rather not take the survey. (2)

Q2 Have you personally (i.e., outside of your role as classroom teacher) ever participated or do you currently participate in citizen science?

○ Yes (1)

○ No (2)

Q3 Please list the name(s) of the citizen science project(s) in which you've personally participated.

Q4 Have you ever used or are you currently using a citizen science project **in your classroom**?

- Yes (1)
- No (2)

Q5 Please give the name(s) of the citizen science project(s) you've used in your classroom and indicate the **total** amount of class time in **hours** (your best approximation) that you have spent on each project. If you have multiple years of involvement on one project, give the total for all years. If you've worked with more than six projects, please list the most recent ones.

Q6 What grade level(s) do you currently teach? Check all that apply.

- Grade 6 (1)
- Grade 7 (2)
- Grade 8 (3)
- Not currently teaching middle school. (4)
- Not currently teaching. (5)

Q7 Please give the school name, city, and state where you currently teach (or where you most recently taught) middle school:

Q8 How many years have you taught at the middle school level?

Q9 Would you be willing to be interviewed (by phone, audio/video Internet chat, or face-to-face if in St. Louis area) about your experience using citizen science in the classroom? The interview would last approximately 30-45 minutes and would focus on your reasons for using citizen science in the classroom, your expectations regarding citizen science, how you think it impacted yourself and your students, and any challenges and benefits of the activity that you perceived.

- Yes (1)
- No (2)

Q10 Wonderful! Please leave your contact information (name and email address) so I may arrange a time for your interview. Thank you.

APPENDIX D: INTERVIEW PROTOCOL

Interview Protocol for Teachers Using Citizen Science

Background

1. Tell me about yourself as a teacher... describe your classroom...
2. How do you define citizen science (CS)? *probe for definition/explanation of terms*

Motivation

1. Why did you decide to do a CS activity/program in your classroom? Which citizen science activity did you choose?
2. How did you expect your students to react to the CS activity? Administrators? Colleagues? Parents? *probe for behaviors, attitudes, remarks/language*
3. How did you think you, as the teacher, would react to the CS activity?

Impact

1. What do you think your students gained from the CS activity? *probe for behaviors, remarks/language*
2. How would you describe your role as teacher during the CS activity?
3. How was the CS activity different than you expected?
4. How was the CS activity similar to what you expected?
5. What surprised you about the CS activity?

Challenges

1. What were/are some of the challenges in using CS in your classroom?
2. What would be the ideal classroom/school environment for a CS activity?
3. What would you do differently next time?

Closing

1. What would you tell a teacher who is thinking about trying a citizen science (CS) activity for the first time?
2. Is there anything else you'd like to add?

APPENDIX E: INVITATION TO POTENTIAL INTERVIEWEES

Hello ________,

Thank you so much for completing my survey about teaching and citizen science and for agreeing to be interviewed about your experience. I'd like to arrange a convenient time for the interview; it will take about 30 minutes and could take place at just about any time that works for you—evenings, weekends, etc. **Please email me 2-3 preferred dates and times** (hopefully between now and Oct. 31), and I'll confirm things as soon as possible.

Also, as this is a research study, there is a consent form for you to read and sign. Essentially, it states that this is voluntary and confidential, but please read it through and don't hesitate to ask me any questions about it. I've attached it below. If you don't have any questions, please electronically sign it and send it back to me. If you have trouble digitally signing, let me know. You may also print out the consent form and then sign, scan/photo, and email it back to me.

Thanks again and I look forward to talking with you in the near future!

Georgia

Georgia Bracey, PhD Candidate
College of Education
University of Missouri-St. Louis

APPENDIX F: REQUEST FOR PARTICIPANT CHECK

Hi _________,

I hope your summer is going well! A while ago we spoke about your experience with citizen science, and I'm finally ready to schedule a quick follow-up conversation. So, I have two requests:

1. Would you be willing to talk with me again for about 15 minutes? I'd like to share my thoughts about the first interview and give you a chance to add or modify anything.

2. Could you email me a picture of something from your teaching experience (student work, sign, poster, materials, activity set-up, etc.) or a copy of a lesson plan, handout, flyer, newsletter, etc. that shows some aspect of the citizen science that you do with your students?

If this sounds good, please send me a few possible times to call you within the next couple of weeks, or as soon as fits your summer schedule.

Thank you, again, for doing the first interview, and I hope to talk with you again soon!

Georgia

Georgia Bracey, PhD Candidate
College of Education
University of Missouri-St. Louis

APPENDIX G: INITIAL CODES FROM INTERVIEWS

	Code Name	Description
1	Authenticity	Real, working as scientists
2	Giving back	Helping the local community (as a duty)
3	Meaningful experience	Understand why we do it
4	Making connections	Linking to another person or idea
5	Collecting data	Counting species, measuring, etc.
6	Sharing data with scientist or project	Data becomes part of the larger project
7	Get involved in own environment	Take action to improve where you live
8	Doing things	Active participation (counting, measuring, collecting, etc.)
9	Work has value	Has a purpose, is useful, is worth it (to themselves and to others)
10	Interest in science	Initiating or deepening an interest in science
11	Helping scientists	Assisting scientists in their work (because they otherwise couldn't get the data/analyses)
12	Fun	Enjoyable experience
13	Many ways and levels of involvement	Citizen science offers a variety of options for participation – individuals, groups, classrooms, do one aspect only or many aspects of project
14	Excitement	Enthusiasm
15	Interact globally	Connections with other countries, other areas of the world
16	Definition of science (NOS)	Learning how science works
17	Interest outside of class	Continuing some aspect of the citizen science activity at home or in the future
18	Questioning	Students are inspired to ask questions
19	New way to see the world	Change in perspective about the world
20	Variety of options in projects	Citsci projects related to many different content areas/disciplines
21	Interdisciplinary	Tying math, science, social studies together
22	Deeper or further learning	Learning at the analysis, application, synthesis, etc. levels. (i.e., beyond "basic knowledge")
23	Identity	Seeing oneself as a certain kind of person
24	Teacher autonomy	Teachers having the ability to make decisions independently, using their professional expertise
25	Teacher as facilitator	Not lecturing in front of the class; helping students to find things out on their own
26	Aligns with the way I was taught	Matches one's own learning experience (in college)
27	Time (scheduling)	Difficulty in finding time for activities
28	Family involvement	Students' families learning about and helping with projects
29	Better way to teach science	Students learn more/better by doing citizen science as a school project
30	Teacher flexibility	Citizen science needs varied amounts of time at different points in the school day/year
31	Contact with scientist	Interaction with project scientist
32	Making observations	One aspect of data collection—visually seeing and recording data
33	Become a science literate person	Understand "science" as a discipline... what it does, how it works
34	Results from other countries	Seeing and sharing data with locations outside the US
35	Open ended project	Activity where the answers are not known (usually by anyone) and the procedures are not set out like a "recipe."
36	Large class size	Difficulty in managing big groups of students, too many to ensure meaningful participation by everyone
37	Building student confidence	Students feel more sure about doing science and that their data is "good" the more they participate
38	Opportunity to learn together (teacher and students)	Related to open ended projects... the answers are not known by the teachers (or scientists)
39	Engagement	Students focused on the activity, invested in the activity
40	Negative results (lack of data)	Part of science, NOS, not finding something, not seeing an effect
41	Ownership (pride)	Feeling proud of accomplishing a task
42	Kids being responsible	Students have more responsibility for successfully completing the project
43	Lack of feedback or project closure	No final project (presentation) or sharing of data, no understanding of what finally comes out of a project

44	Supportive admins	Principals, superintendents, etc. that see the value in citizen science and facilitate it
45	Aspects of research design	How to create a good scientific question, how to increase data validity/reliability
46	Stewardship	Taking care of the land, the community
47	Accessibility	Participation possible for those with disabilities
48	Focusing the student discussion	Guiding the students in coming up with conclusions based on evidence
49	Classroom management	Keeping a large group of students on task and participating in a meaningful way
50	Curiosity	Wanting to find out more

APPENDIX H: FINAL THEMES FROM INTERVIEWS

Theme, *subtheme1*, subtheme2	**Description**	**Example**
Building Agency	Developing one's ability to act on/influence the outside world	
Social interaction	Working or having meaningful contact with someone	
Scientists	Having meaningful contact with the scientists involved in a citizen science project	There were real scientists on the other end of our results, and they checked and either approved or said go back to the drawing board about any results you posted. (18)
Family	Involvement or interest in the students' citizen science work by parents, siblings, guardians, caregivers, etc.	I would get parents that were really interested in what we were doing and they started looking for things, too. (1)
Peers	Working, discussing with other students	Students definitely took the reins on coming up with a project, they enjoyed collaborating together. I had them... they got into not just planning it but they did artistic drawing, they did google sheets, they did took pictures, we interviewed scientists from Rutgers and other places, so we did a Skype conference with other students. (3)
Community members	Having meaningful contact with local community members	And within a couple of weeks the signs were vandalized. Then the kids... we wrote an editorial to the local paper... about how badly it made them feel and how important the beach was to the community... And that action rallied the whole community behind these kids...(7)
Authentic science work	Working directly or indirectly within a particular geographical location	
Give back to the community	Working on a project situated in the students' town or region, helping to improve the local environment, solve a local problem	We talk about how they can get involved and how eventually they are going to be the community and what do they want for their community with the fishermen and the hunters that we have in our area, like one of the hooks that I use is the idea that if the invasives take over, the deer won't have the fodder they need. (16)
Make a difference in the world	Contributing to a project situated in a distant or larger location, helping to improve the world, solve a worldwide problem	I wanted them to see how the environment around them was being impacted and how they could make a difference. I know we weren't cleaning up environmentally but we were helping the scientists in the area see what was going on in the inter-tidal zone. (10)
Broadening Perspectives	Expanding one's views and ways of thinking	
About the world	Seeing careers, cultures, practices, and places in a new way or for the first time	
See things in a new way	Seeing the familiar in a new way	This has opened their eyes to the natural world that's always around them... there's actually trees when they walk to school, and those trees have wildlife in them. And it's all stuff that was previously invisible to them. (12)
See beyond themselves	Look outside one's personal experience	I think it just gives them a sense that they're part of something larger than them. When we log onto eBird at 9 o'clock in the morning and there's already 7000 checklists that have been submitted around the world, they're like, wait, we're not the only ones doing this... (12)
About their work	Students see their work as having value, making a contribution, making a difference.	
Work has value to others	An outsider values, respects, acknowledges the students' work	...is that somebody values their ability to collect real data and have it go into the system, and not just say, oh, it's just a bunch of 7th graders... they don't know anything. The work that the students do is highly respected. (14)
Work has value to self	Students see that their work is worthwhile, understand why they do it	They did a project of analyzing data of New York Harbor water quality, and that practice done randomly is kind of boring. But done in the context of a citizen science project, it actually seems somewhat important to them. (9)

About science	Learning that science is more than a collection of facts to be memorized	
Science practices	Processes/procedures that scientist often do as part of their research (e.g., collecting/analyzing data, sharing/communicating data, asking questions, etc.)	We were looking at different species, so we were tallying different species once we got better at identifying them. We also started looking at it according to time of day and temperature and wind conditions and then seeing... like charting it through the year and seeing how it changed. (12)
Science dispositions	Ways of thinking and knowing that scientists often employ in their work (e.g., taking repeated careful measurements, isolating variables, finding solutions based on evidence, learning from null/unexpected results); HOW something is done vs. WHAT is done	They definitely learned more about sampling techniques... actually how to collect data and how to do field work. (10); If things didn't work out, that was science... (7)
Challenges	Difficulties in implementation of citizen science	
Making the task meaningful	Ensure that students understand the purpose of their task, of the citizen science project	
Understanding the larger scientific work	Students understand how the citizen science project and its results fit into the larger scientific study, understand the purpose of the larger study	And with that one, they didn't see a result, they were just like, "Oh... that's it? Ok..." and they didn't realize that even counting craters was making a huge difference. So, I think if I would've been able to communicate that better to them, they would've been in a better place. (11)
Understanding negative results	Students understand that NOT finding something (e.g., a species of animal or plant) is as important as finding something	I think sometimes when a particular student couldn't find certain things in their area, that they would be disappointed. So, in the case of the monarchs, the kids were coming from all over the city but yet only a certain number of kids got to see the monarchs because they travel in such a narrow path when they go up and down Kansas City. They're the ones who are disappointed when they didn't see it, when they didn't get a chance. (1)
Experiencing the whole scientific process	Ensure that students have the opportunity to participate in every aspect of the scientific process (e.g., asking a question, designing a study, collecting & analyzing data, reporting results)	
Continuous experience	Students need to spend enough time engaged in the citizen science activity, not simply trying it occasionally	Don't make it a supplement or something to add to a lesson, try to give the students a storyline when you have them do something. Try to build it up so they're invested in it in some way, shape, or form... be intentional about the way you are presenting it... be intentional about the way you continue it with your students. (11)
Complete experience	Students need to experience presenting the results of their work to others so their findings are used	it just kind of filters out and you're not seeing anything being done with the data, which I think is frustrating. I think it can be frustrating for the students who understand that the logical ending to a research project is that you write a paper on it and someone reads about your research, whether it's your teacher reading it or just the scientific community at large reading it, they understand that that is the end. I think that is one of the big challenges is that a lot of these projects start out really great but then eventually lose the funding to follow through with their research.

APPENDIX I: Institutional Review Board Documentation

Office of Research Administration

One University Boulevard
St. Louis, Missouri 63121-4499
Telephone: 314-516-5899
Fax: 314-516-6759
E-mail: ora@umsl.edu

DATE:	March 9, 2016
TO:	Georgia Bracey
FROM:	University of Missouri-St. Louis IRB
PROJECT TITLE:	[855801-1] TEACHING WITH CITIZEN SCIENCE: AN EXPLORATORY STUDY OF TEACHERS' MOTIVATIONS & PERCEPTIONS
REFERENCE #:	
SUBMISSION TYPE:	New Project
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	March 9, 2016
REVIEW CATEGORY:	Exemption categories # *1, 2*

The chairperson of the University of Missouri-St. Louis IRB has APPROVED the above mentioned protocol for research involving human subjects and determined that the project qualifies for exemption from full committee review under Title 45 Code of Federal Regulations Part 46.101b. The time period for this approval expires one year from the date listed above. You must notify the University of Missouri-St. Louis IRB in advance of any proposed major changes in your approved protocol, e.g., addition of research sites or research instruments.

You must file an annual report with the committee. This report must indicate the starting date of the project and the number of subjects to date from start of project, or since last annual report, whichever is more recent.

Any consent or assent forms must be signed in duplicate and a copy provided to the subject. The principal investigator must retain the other copy of the signed consent form for at least three years following the completion of the research activity and they must be available for inspection if there is an official review of the UM-St. Louis human subjects research proceedings by the U.S. Department of Health and Human Services Office for Protection from Research Risks.

This action is officially recorded in the minutes of the committee.

If you have any questions, please contact Carl Bassi at 314-516-6029 or bassi@umsl.edu. Please include your project title and reference number in all correspondence with this committee.

College of Education
Educator Preparation, Innovation and Research (EPIR) Department

One University Blvd.
St. Louis, Missouri 63121-4499
Telephone: 314-516-4970
Email: glbgy5@umsl.edu

Informed Consent for Participation in Research Activities

TEACHING WITH CITIZEN SCIENCE: AN EXPLORATORY STUDY OF TEACHERS' MOTIVATIONS & PERCEPTIONS

Participant ________________________________ HSC Approval Number ___________________

Principal Investigator ____Georgia Bracey______ PI's Phone Number __314-898-3821_______

1. You are invited to participate in a research study conducted by Principal Investigator Georgia Bracey and Faculty Advisor Dr. Carl Hoagland. The purpose of this research is to study what motivates middle school teachers to use citizen science activities in their classrooms and to understand how teachers perceive these experiences.

2. a) Your participation will involve

   - completing a short online survey about using citizen science in classrooms and, if you choose,
   - participating in an interview (by telephone, audio/video Internet chat, or face-to-face) about your experience using citizen science in your classroom and, if you choose,
   - sharing with the researcher copies of selected teaching materials and student work related to your use of citizen science in your classroom.

   Approximately 400 teachers will complete the short survey; and of those, 50 will be interviewed.

   Participants for this study are being recruited in a variety of ways. For the initial survey, an invitation (including survey URL) has been posted on the listservs of the National Science Teachers Association (NSTA), the Citizen Science Association (CSA), and the National Association for Research in Science Teaching (NARST) as well as on the PI's social media feeds (Twitter, Facebook, Instagram, and Google+). Invitations have also been posted on citizen science related websites, including citizenscience.org, SciStarter.org, and many specific project sites. As part of the survey, participants will be invited to be interviewed and possibly share some classroom materials. The PI will select the first 50 participants who agree to be interviewed.

   b) The amount of time involved in your participation will be approximately 5-10 minutes to complete the online survey and approximately 30-45 minutes for the interview. You will not receive any payment for your participation in this study.

3. There are no anticipated risks associated with this research.

4. There are no direct benefits for you participating in this study. However, your participation will contribute to the knowledge about using citizen science in formal classrooms and may help society understand how to support and facilitate the use of citizen science in schools as one way to improve science education.

5. Your participation is voluntary and you may choose not to participate in this research study or to withdraw your consent at any time. You may choose not to answer any questions that you do not want to answer. You will NOT be penalized in any way should you choose not to participate or to withdraw.

6. By agreeing to participate, you understand and agree that your data may be shared with other researchers and educators in the form of presentations and/or publications. In all cases, your identity will not be revealed. In rare instances, a researcher's study must undergo an audit or program evaluation by an oversight agency (such as the Office for Human Research Protection). That agency would be required to maintain the confidentiality of your data. In addition, all data will be stored on a password-protected computer and/or in a locked office.

7. If you have any questions or concerns regarding this study, or if any problems arise, you may call the Investigator, Georgia Bracey (314-898-3821) or the Faculty Advisor, Dr. Carl Hoagland (314-516-4802). You may also ask questions or state concerns regarding your rights as a research participant to the Office of Research Administration, at 516-5897.

I have read this consent form and have been given the opportunity to ask questions. I will also be given a copy of this consent form for my records. I consent to my participation in the research described above.

Participant's Signature Date	Participant's Printed Name
Georgia Bracey Digitally signed by Georgia Bracey DN: cn=Georgia Bracey, o=University of Missouri - St. Louis, ou, email=georgiabracey@gmail.com, c=US Date: 2016.08.27 11:40:09 -06'00'	
Signature of Investigator or Designee Date	Investigator/Designee Printed Name

APPENDIX J: CITIZEN SCIENCE PROJECTS (PERSONAL)

	Project Name	Discipline	Online	Website
1	Snapshot Serengeti (Zooniverse)	Life	X	https://www.snapshotserengeti.org/
2	Condor Watch (Zooniverse)	Life	X	https://www.condorwatch.org/
3	Nature's Notebook/National Phenology Network	Life		https://www.usanpn.org/natures_notebook
4	Camera CATalogue (Zooniverse)	Life	X	https://www.zooniverse.org/projects/panthera-research/camera-catalogue
5	Old Weather (Zooniverse)	History	X	https://www.oldweather.org/
6	eBird	Life		http://ebird.org/content/ebird/
7	Frog Watch	Life		https://www.aza.org/frogwatch
8	Monarch Watch	Life		http://www.monarchwatch.org/
9	Journey North	Life		https://www.learner.org/jnorth/
10	Vital Signs	Life		http://vitalsignsme.org/
11	Salmon In Our Schools	Life		
12	Island Heritage Trust Beach Grass Restoration Project	Life		http://www.islandheritagetrust.org/
13	Coastal Maine Botanical Garden Lunder New Naturalist Project	Life		http://lnn.mainegardens.org/
14	The American Chestnut Foundation	Life		https://www.acf.org/
15	FLOW at Bolsa Chica	Life		http://www.amigosdebolsachica.org/flow.php
16	Gray whale census	Life		
17	White sea bass pen in Newport Harbor	Life		
18	Oregon CoastWatch	Life		https://oregonshores.org/coastwatch
19	King Tides project	Life		http://kingtides.net/
20	CoCoRaHS	Earth/Space		https://www.cocorahs.org/
21	NH fish and game turkey survey	Life		http://www.wildlife.state.nh.us/surveys/turkey.html
22	River Watch (Ashuelot River in NH)	Life		
23	Reef Environmental Education Foundation (Reef.org)	Life		http://www.reef.org/
24	Coral Reef Alliance	Life		http://coral.org/
25	Earthwatch	Life		http://earthwatch.org/
26	SeaNet (sea bird research)	Life		https://vet.tufts.edu/seanet/
27	Sanctuary Ocean Count in Hawaii	Life		https://oceanservice.noaa.gov/news/feb16/ocean-count.html
28	Monk Seal Response Network in Hawaii	Life		http://www.fpir.noaa.gov/PRD/prd_marine_mammal_response.html
29	Hawaii Marine Mammal Response Network	Life		http://kohalacenter.org/event/volunteer-training-west-hawaii-marine-mammal-response-network
30	Turtle Rescue in Hawaii	Life		
31	Rainforest Monitoring (Zooniverse)	Life	X	http://info.perunature.com/aerobotany
32	BirdSleuth	Life		http://www.birdsleuth.org/
33	Reef Watch	Life		
34	The Blue Line	Life		http://www.soest.hawaii.edu/coasts/sealevel/OahuBlueLineTour.html
35	GLOBE, all protocols	Life		https://www.globe.gov/

36	Project Learning Tree	Life		
37	Project FeederWatch	Life		http://feederwatch.org/
38	A WoodFrog observation activity out of Alaska, Fish and Game	Life		http://www.adfg.alaska.gov/index.cfm?adfg=citizenscience.woodfroginvolved
39	A Magpie observation activity out of University of Alaska, Fairbanks	Life		
40	ALISON: Alaska Lake Ice and Snow Observation Network	Life		https://web.iarc.uaf.edu/education-outreach/affiliated-projects/alison/
42	Science Gossip		X	https://www.sciencegossip.org/
43	Plankton Project	Life	X	https://www.planktonportal.org/
44	EteRNA	Life	X	http://www.eternagame.org/web/
45	Streamside Science	Life		https://streamsidescience.usu.edu/
46	OPIHI - Our Project Hawaii Intertidal	Life		http://www.hawaii.edu/gk-12/opihi/index.shtml
47	Tomatosphere	Life		http://tomatosphere.org/
48	I monitor water quality of streams in my community and report the results to the county park service.	Life		
49	Picture Post, Univ of New Hampshire			https://picturepost.unh.edu/index.jsp
50	I'm not sure if this technically qualifies, but I have a weather app that allows users to verify or report on current weather.	Earth/Space		
51	Social science projects through podcast Note to Self			
52	The Great Backyard Bird Count	Life		http://gbbc.birdcount.org/
53	Project Pigeon Watch	Life		http://celebrateurbanbirds.org/
54	Glacier NP CCRLC: Loon	Life		https://www.nps.gov/glac/learn/ccrlc.htm
55	Glacier NP CCRLC: Goats	Life		https://www.nps.gov/glac/learn/ccrlc.htm
56	Glacier NP CCRLC: Pika	Life		https://www.nps.gov/glac/learn/ccrlc.htm
57	Glacier NP CCRLC: Weeds	Life		https://www.nps.gov/glac/learn/ccrlc.htm
58	Glacier NP CCRLC: Raptor migration	Life		https://www.nps.gov/glac/learn/ccrlc.htm
59	Lil Miss Atrazine [Mississippi River project]	Life		https://www.unomaha.edu/news/2014/06/homepage/atrazine.php
60	Coastal program monitoring rockweed	Life		https://extension.umaine.edu/signs-of-the-seasons/coastal-field-guide/
61	Rouge Education Project (southeast Michigan ecological water quality assessment)	Life		http://therouge.org/rouge-education-project/
62	Coastal Cleanup with Save the Bay collects data as you do the trash collecting.	Life		https://www.savebay.org/icc
63	Christmas Bird Count	Life		http://www.audubon.org/conservation/science/christmas-bird-count
64	Contrail count	Earth/Space		https://www.nasa.gov/audience/forstudents/5-8/features/F_Contrails_5-8.html
65	Phytoplankton Monitoring Network NOAA	Life		https://products.coastalscience.noaa.gov/pmn/
66	Watershed Action Volunteer	Life		
67	Green Eggs and Sand	Life		http://dnr.maryland.gov/ccs/Pages/ges_actionprojects.aspx

68	Biofuels	Life		
69	Project Wet	Life		
70	Project Wild	Life		
71	Urban Ecology Engagement Initiative	Life		https://serc.si.edu/book/export/html/22160
72	S'COOL	Earth/Space		https://scool.larc.nasa.gov/
73	Trained Weather spotter for local NWS office	Earth/Space		
74	Moon Mappers	Earth/Space	x	https://cosmoquest.org/x/science/moon/
75	Marine Debris Mapping	Life		https://marinedebris.noaa.gov/research/marine-debris-monitoring-and-assessment-project
76	Intertidal Monitoring	Life		https://science.nature.nps.gov/im/units/nccn/monitor/intertidal.cfm
77	Monarch Health through the University of Georgia	Life		http://monarchparasites.uga.edu/monarchhealth/index.html
78	North American Bird Phenology Project	Life		https://www.pwrc.usgs.gov/MissionAreas/ClimateLand/NationalInternationLongtemScience/BPP%20factsheet.pdf
79	Project BudBurst	Life		http://budburst.org/
80	Cloud SAT ground verification for NASA's weather satellite.			http://cloudsat.atmos.colostate.edu/education/satellites
81	Missouri Stream Team	Life		http://www.mostreamteam.org/
82	San Diego coast keepers	Life		http://www.sdcoastkeeper.org/
83	Quail in the Classroom	Life		
84	Project Terrapin	Life		https://www.projectterrapin.org/
85	NJ Watershed Ambassadors	Life		http://www.nj.gov/dep/wms/bears/americorps.htm
86	Long Island Sound Harbor Seal Census	Life		
87	Long Island Sound Biodiversity Database	Life		http://tma.evendata.com/
88	BioBlitz	Life		https://www.nationalgeographic.org/projects/bioblitz/
89	Kalamazoo Nature Center projects	Life		https://naturecenter.org/ConservationStewardship/CitizenScience.aspx
90	Going Green			
91	Water Testing -- Illinois Water Watch	Life		
92	Project Squirrel	Life		http://projectsquirrel.org/
93	Starcount	Earth/Space		http://www.windows2universe.org/citizen_science/starcount/
94	Zooniverse: cancer study	Life		https://www.cellslider.net/
95	Zooniverse: Galaxy study	Earth/Space		https://www.galaxyzoo.org/
96	Yakima Basin Environmental Education Project E3 Washington-Yakima	Life		
97	Identify invasive species in our woods	Life		
98	I serve on the Bear Pond Improvement association and help to monitor water quality and the presence of invasive species.	Life		
99	INaturalist	Life		https://www.inaturalist.org/
100	Hawkwatch International out of the Goshutes in Nevada.	Life		https://hawkwatch.org/

101	Bowdoin College - Aquatic invasive species	Life		https://www.bowdoin.edu/coastal-studies-center/student-research/pdf/linton.pdf
102	Wells Reserve - W.E.T program	Life		https://www.wellsreserve.org/research/environmental-monitoring
103	Maine Audubon - Out in the Field	Life		http://maineaudubon.org/about/citizen-science/
104	York Land Trust - Habitat study	Life		http://yorklandtrust.org/offsitenews/habitat-for-rare-species-preserved-2/

APPENDIX K: CITIZEN SCIENCE PROJECTS (CLASSROOM)

	Project Name	Discipline	Online	Website
1	Alaska Lake Ice and Snow Observatory Network	Life		https://web.iarc.uaf.edu/education-outreach/affiliated-projects/alison/
2	Alaska Magpie	Life		
3	Alaska WoodFrog	Life		http://www.adfg.alaska.gov/index.cfm?adfg=citizenscience.woodfroginvolved
4	Allegheny College Creek Connections	Life		
5	Alpine Watch	Life		
6	B.C. Green Games	Life		
7	Barcode long island	Life		
8	Beach Measurement	Life		
9	Billion Oyster Project	Life		
10	BioBlitz	Life		https://www.nationalgeographic.org/projects/bioblitz/
11	BirdSleuth	Life		http://www.birdsleuth.org/
12	Bridging the Watershed	Life		
13	Budburst	Life		http://budburst.org/
14	Bumble Bee Count	Life		
15	Cicada Tracking	Life		
16	Classroom Feederwatch	Life		
17	Climate Change Warriors	Earth/Space		
18	CoCoRahs	Earth/Space		https://www.cocorahs.org/
19	Contrail Count	Earth/Space		https://www.nasa.gov/audience/forstudents/5-8/features/F_Contrails_5-8.html
20	CosmoQuest	Earth/Space	X	https://cosmoquest.org
21	Penguin Watch	Life	X	https://www.penguinwatch.org/
22	eBird	Life		http://ebird.org/content/ebird/
23	EPA Estuary Monitoring	Life		
24	EteRNA	Life		http://www.eternagame.org/web/
25	FLOW program	Life		http://www.amigosdebolsachica.org/flow.php
26	Forest Watch	Life		http://www.forestwatch.sr.unh.edu/
27	Galaxy Zoo	Earth/Space	X	https://www.galaxyzoo.org/
28	GAVRT			
29	Global Heat Index	Earth/Space		
30	GLOBE			https://www.globe.gov/
31	Globe at Night	Earth/Space		https://www.globeatnight.org/
32	Growing Food for Space			
33	Hawaiian Archeology Mapping			
34	Honeywell Educators at Space Camp			
35	iNatualist	Life		https://www.inaturalist.org/
36	IHT Beach Grass	Life		
37	Intertidal Studies with Vital Signs (GMRI)	Life		http://vitalsignsme.org/
38	Islesboro Islands Trust	Life		
39	Journey North	Life		https://www.learner.org/jnorth/
40	JTTU	Life		
41	KidsTeach Intertidal Education with Kindergartners			
42	LDEF			
43	Lil Miss Atrazine			https://www.unomaha.edu/news/2014/06/homepage/atrazine.php
44	LiMPETS			
45	Linder New Naturalist Project	Life		

46	Long Island Sound Biodiversity Database	Life		
47	Magpie Observations	Life		
48	Maine Phytoplankton Monitoring Program	Life		
49	Maine Shore Stewards Program	Life		
50	Make a Difference			
51	Million Orchid Project	Life		
52	Monarch Health	Life		http://monarchparasites.uga.edu/monarchhealth/index.html
53	Monarch Watch	Life		
54	MoonMappers	Earth/Space		http://cosmoquest.org/moonmappers
55	NASA Star Count	Earth/Space		http://www.windows2universe.org/citizen_science/starcount/
56	North American Bird Count	Life		
57	OPIHI - Our Projcet in Hawaii Intertidal	Life		http://www.hawaii.edu/gk-12/opihi/index.shtml
58	PA Sea Grant Great Lakes Great Stewards	Life		
59	Phenology Network USA	Life		https://www.usanpn.org/natures_notebook
60	Phytoplankton MN	Life		https://products.coastalscience.noaa.gov/pmn/
61	Picture Post			https://picturepost.unh.edu/index.jsp
62	Polar Satellite Weather Imagery	Earth/Space		
63	Project Bud Burst	Life		http://budburst.org/
64	Project Feeder Watch	Life		http://feederwatch.org/
65	Project Noah			
66	Project Pigeon Watch	Life		http://celebrateurbanbirds.org/
67	Project Squirrel	Life		http://projectsquirrel.org/
68	Project Terrapin	Life		https://www.projectterrapin.org/
69	Pulsar Search Collaboratory	Earth/Space		
70	Quail in the Classroom	Life		
71	Radon Project			
72	Re Leaf			
73	Reading for The Gambia			
74	Reforestation	Life		
75	River Studies with Vital Signs (GMRI)	Life		http://vitalsignsme.org/
76	River Watch	Life		
77	Rouge Education Project			http://therouge.org/rouge-education-project/
78	S'COOL	Earth/Space		https://scool.larc.nasa.gov/
79	Salmon In Our Schools	Life		
80	Satellite Mirrors			
81	Science of Soil New Jersey	Life		
82	Scistarter.com (independent student research projects)			http://scistarter.com
83	Snake Census	Life		
84	Snapshot Serengeti	Life	X	https://www.snapshotserengeti.org/
85	Snowpack Project - Acadia Institute			
86	The American Chestnut Foundation	Life		https://www.acf.org/
87	Tomatosphere	Life		http://tomatosphere.org/
88	Turtle Watch	Life		
89	UEEI			
90	Vital Signs	Life		http://vitalsignsme.org/
91	Vital Signs Macroinvertebrate Pond Assessment	Life		http://vitalsignsme.org/
92	Vital Signs- aquatic plants	Life		http://vitalsignsme.org/
93	Vital Signs- crayfish	Life		http://vitalsignsme.org/
94	Water monitoring	Life		

95	White Sea Bass	Life		
96	Wind Power Study with University of Maine	Earth/Space		
97	Woodfrog Observations	Life		http://www.adfg.alaska.gov/index.cfm?adfg=citizen science.woodfroginvolved
98	Yakima Basin Environmental Ed Project	Life		
99	Zooniverse - cancer cell	Life	X	https://www.cellslider.net/
100	Zooniverse- ocean one	Life	X	https://www.seafloorexplorer.org/
101	Zoonivierse		X	https://www.zooniverse.org