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This descriptive case study examined the meanings public elementary school teachers (N = 13) made of learning to enact citizen science projects in their schoolyards in partnership with a local Arboretum. Utilizing Engeström's (2001) framework of cultural-historical activity theory (CHAT), the Arboretum's outreach program for area Title 1 schools was viewed as an activity system composed of and acting in partnership with the teachers. The major finding was that teachers designed and mastered new ways of teaching (expansive learning) and transformed their citizen science activity to facilitate student engagement and learning. I highlight four important themes in teachers' expansive learning: (a) discussion, (b) inclusion, (c) integration, and (d) collaboration. Teacher learning communities formed when colleagues shared responsibilities, formed mentor/mentee relationships, and included student teachers and interns in the activity. This program could serve as a model for elementary school citizen science education, as well as a model for professional development for teachers to learn to teach science and Environmental Education outdoors.

MEANINGS TEACHERS MAKE OF TEACHING SCIENCE OUTDOORS

AS THEY EXPLORE CITIZEN SCIENCE

by

Aerin Workman Benavides

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Approved by

Samuel Miller
Committee Co-Chair

Catherine Matthews
Committee Co-Chair

I dedicate this work to my grandson, Diego; to my fifth grade students who first inspired me; and to the many friends and family who supported me along this journey, especially Birgit, Kasia, Jennifer, and Daniela, my sisters Audrey and Kippy; Cristina for incentive, Annick for encouragement, Martín for inspiration, my husband Diego for exemplary perseverance, my mother for my dreams, and my father for bringing magic to our treks to the parks and creativity into our minds and hearts. I am truly grateful. Thank you.

APPROVAL PAGE

This dissertation, written by Aerin Workman Benavides, has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

Committee Co-Chair	Samuel Miller
Committee Co-Chair	Catherine Matthews
Committee Members	Heidi Carlone
	Ye He

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CHAPTER I

INTRODUCTION

The future of school science lies outdoors. (Slingsby, 2006, p. 51)

Inspired by my experiences of learning to teach science (see Definitions) outdoors, and given the effective outcomes for my students of outdoor science learning, I became curious about how other teachers learn to teach science outdoors. The Experiences Promoting Learning Outdoors for Research and Education (Project EXPLORE) citizen science (see Definitions) outreach program sponsored by the Arboretum (a pseudonym) offered an opportunity to study elementary science education outdoors as teachers learned to implement citizen science projects. My qualitative descriptive case study (Merriam, 1988) of EXPLORE included 13 public elementary school classroom teachers, hereafter referred to as *primary participants*. They taught in eight Title I schools (with a high percentage of low-income families), in five school districts in the Southern Appalachian Mountain region of the Southeastern U.S. From this group of 13 primary participants I purposefully selected four teachers to focus on in the case study. I hereafter refer to these teachers as *focal participants* or *focal teachers*.

EXPLORE teachers engaged their students in citizen science projects by using their schoolyard as a platform for learning. Teachers learned to implement citizen science projects and teach science outdoors on a regular basis as required by their participation in Project EXPLORE. Funded by a GlaxoSmithKline Foundation two-year long grant and private donations, the Arboretum's Project EXPLORE offers teachers training in how to participate in citizen science programs with their classes by collecting data on their school campuses. The Arboretum educators hold on-site meetings at participating teachers' schools, where they conduct site-specific citizen science training. They make two one hour-long visits to each school each year. Teachers select one of three citizen science programs: eBird, Project Squirrel or Nature's Notebook (tree phenology) and during their first visit, the Arboretum educators explain this teacher-selected program in detail. Arboretum educators offer teaching materials, help teachers choose physical places for data collection on their school grounds, and model how to teach outdoors. Teachers and their classes then follow up by collecting science data in the schoolyard. The Arboretum expects teachers to collect data for 15 minutes at least once a week throughout the school year (with some exceptions) for their citizen science projects.

A total of 28 teachers (K-12) participated in Project EXPLORE in 2014–2015. Of the 28 teachers, 13 were public elementary school classroom teachers. Five of those teachers were new participants in 2014–2015; eight of those teachers participated in the project in 2013–2014 as well. The 2013–2014 teacher participants who continued in the second year of the program could act as mentors if there were new participants at the same school.

All 28 teachers were requested to present their class' citizen science research findings at the Mountain Science Expo held at the Arboretum on April 11, 2015. The Mountain Science Expo featured science exhibits from the EXPLORE schools, presentations from students across the region who participated in the Arboretum's summer Ventures program, exhibitions by the local Art Museum, The Environmental Quality Institute, a local Nature Center, a state BioNetwork, and the Great Smoky Mountains National Park and speakers such as Dawn Cusick, author of *Get the Scoop on Animal Poop: From Lions to Tapeworms: 250 Cool Facts About Scat, Frass, Dung and More!*

Research on innovative science teacher professional development programs, which focus on teaching science outdoors, is lacking. There is a need to know more about classroom teachers who teach elementary school science outdoors because fieldwork is a powerful pedagogical tool ((Dillon, 2014; Rickinson, et al., 2004; Slingsby, 2006). Fieldwork practices make science more accessible to a diverse student population; in part because its research designs are emergent and social interactions take on a central role in research (Bowen & Roth, 2007). Fieldwork practices can involve students in all phases of the research and this involvement engenders interest in science for a diverse student population. Findings from this dissertation study can inform the fields of science education and Environmental Education by giving us detailed descriptions of teachers' meaning-making of implementing outdoor citizen science projects. Using the school site for teaching outdoors is neither a common practice nor well documented in formal education settings in the U.S. (Cronin-Jones, 2000; Roth, 2014). The purpose of this study was to understand the meanings teachers made of learning to implement a citizen science project outdoors as they and their students participated in Project EXPLORE.

This study addressed the nature of the Arboretum's Project EXPLORE community as professional development and the meanings teacher participants made of learning to implement citizen science projects outdoors through practice (teaching) and reflection (thinking about teaching). I investigated the socially negotiated character of meaning as experienced by the people involved in the activity. Teachers' voices provided a deeper understanding of the EXPLORE activity and community overall, an understanding which in turn could provoke a shift in how science is taught in the future.

Learning to implement citizen science projects outdoors on a regular basis was viewed in this study through a sociocultural theoretical lens, allowing teacher voices (Engeström, 2001) to illuminate multiple truths (Glesne, 2011). This research was conducted with a sociocultural perspective of learning, where learning is seen to happen in community through the use of artifacts, such as language and symbols (Vygotsky, 1978; Wertsch, 1991). This sociocultural perspective was informed by activity theory, also known as cultural-historical activity theory (CHAT; Engeström, 1999, 2001), which examines learning as a network of relationships with "multiple systemically interacting elements" (Engeström, 1999, p. 9).

Teachers shared their meanings of learning to implement citizen science projects outdoors. Meanings do more than just describe behavior; they define behavior, justify behavior, and interpret behavior (Lofland & Lofland, 1995). Meaning making happens through participation; teachers make meanings of events and their experiences (Wenger, 1998). Such meaning making is important as "[t]he most fundamental aspect of a human social setting is that of meanings" (Krauss, 2005, p. 762). My goal was to explore, uncover, describe and interpret the meanings teachers made of learning to implement citizen science projects outdoors as participants in Project EXPLORE.

Importance of the Study

This study is important because it highlights examples of learning to teach citizen science and Environmental Education projects that address larger socioscientific issues and the global ecological crisis (Kelly, 2014). Science education is not privileged in the U.S. (Milner, Sondergeld, Demir, Johnson, & Czerniak, 2012) as it is in many other developed nations (Organisation for Economic Co-operation and Development, 2012). This study of teachers participating in an innovative program where they learn in context can contribute to the advance of the field of teacher professional development. We lack studies of teacher professional development that recognize "learning is embedded in professional lives and working conditions" (Opfer & Pedder, 2011, p. 376). While findings from this study are not necessarily generalizable, they offer specific empirical evidence that could be useful to initiating a shift toward privileging science and science education outdoors with all the benefits to students (descriptions to follow) contained therein. Despite the benefits, avenues such as citizen science and Environmental Education that do offer authentic science experiences incorporating bigger ideas for young students may not be easy for elementary school teachers to embrace because they may be afraid to try something new, outside of the accepted norm in their communities (Carlone, Haun-Frank, & Kimmel, 2010). This study describes a specific case of an innovative professional development program from the point of view of 13 teachers at Title I public schools acting in partnership with the Arboretum to implement outdoor citizen science projects that address aspects of the global ecological crisis.

Citizen Science and Environmental Education Address the Global Ecological Crisis

Children today will need to make decisions and take action in the future to protect the environment worldwide (United Nations Educational, Scientific, and Cultural Organisation [UNESCO], 1978) because of projected damaging effects of global warming (Adams, 2013), deforestation, and 'defaunation' (Dirzo et al., 2014). Dirzo et al. coined the term 'defaunation' in a recent article in *Science* to describe the fact that there are fewer and fewer animal species and smaller and smaller populations of animals in the natural world. We are currently in one of the largest periods of mass extinctions on land and sea in the history of the earth (Dirzo et al., 2014; McCauley et al., 2015; McKinney & Lockwood, 1999). "We live in a global wave of anthropogenically driven biodiversity loss" (Dirzo et al., 2014, p. 401), and environmental degradation (United Nations Secretary-General's High-level Panel on Global Sustainability, 2013). Therefore, our best efforts as science educators might be offering avenues for students to learn to use evidence to address socioscientific issues (Kelly, 2014)—although, environmental and socioscientific issues are complex (Robottom, 2012).

Global responses. Such complexity is seldom addressed in formal science education (Robottom, 2012). Scientists and environmentalists call for a convergence of the two fields of science education and Environmental Education (Adams, 2013; DeBoer, 1991; Robottom, 2012; Slingsby & Barker, 2003; Wals, Brody, Dillon, & Stevenson, 2014) in light of the current ecological crisis. These two fields "have become increasingly distant from each other" (Wals et al., 2014, p. 583), but citizen science and fieldwork are ways to link science education and Environmental Education (Wals et al., 2014).

The new norm of the outdoor world for children today has fewer animals and fewer wild places (Dirzo et al., 2014). Not only are birds disappearing from sight, so are the memories of them. It will be more and more difficult to create those memories again for the next generations and preserve a place for learning about the natural world. Our very existence depends upon the natural world—and this world as we know it is disappearing. Children need knowledge of the natural world with all its complex issues and children need scientific knowledge and scientific skills in order to meet the global challenges of their future. Many nations worldwide include scientific fieldwork and some version of Environmental Education in their curriculums (e.g., Scotland, Finland and Australia). However, internationally, fieldwork is under threat due to multiple barriers at many levels of policy and instruction (Dillon et al., 2006) and it has been found to be in decline (Australian Curriculum, Assessment and Reporting Authority, 2010). Barker, Slingsby, and Tilling (2002) feared fieldwork was headed for “extinction.”

Local responses. In the U.S., the *Next Generation Science Standards* make no specific mention of fieldwork as a context for science learning (NGSS Lead States, 2013). In general, teachers in the U.S. do not even privilege science instruction of any kind at the elementary school level (Milner et al., 2012) because “[f]or many years, the teaching of science has been minimized in elementary schools in favor of more emphasis on reading and mathematics” (p. 111). Milner et al. reported that although most elementary school teachers and their students had positive feelings about and attitudes towards science, teachers were teaching science less as a result of No Child Left Behind (NCLB) federal legislation (see Definitions). “When the majority of instructional time is dedicated to a few tested topics, the rest of the time becomes a fought-over commodity. The left-over subjects are moved, removed, and reduced as schools struggle with an overloaded school day" (Jones, Jones & Hargrove, 2003, p. 30). However, this instructional shift to teaching less science in the U.S. may not have been directly in response to NCLB. Milner et al. (2012) also found that teachers' beliefs about teaching science were more influenced by their perceptions of what peers and administrators thought they should be doing than by policy changes mandated in NCLB.

There are some states in the U.S. that, despite this decline in science teaching, do privilege science and Environmental Education instruction. Maryland includes fieldwork and environmental literacy (see Definitions) requirements for high school graduation in formal schooling (Lyons, 2011). North Carolina has an Environmental Literacy Plan (Department of the Environment and Natural Resources, 2014) written to comply with the proposed No Child Left Inside Act (see Definitions). The No Child Left Inside (NCLI) initiative was incorporated into the recent Every Student Succeeds Act (ESSA) (2015) (see Definitions) that includes federal funding for Environmental Education as part of the state K-12 school curriculum until the year 2020. The Environmental Literacy Plan has not yet been adopted in North Carolina, but geography and environmental literacy were added to the revised state social studies curriculum (Public Schools of North Carolina State Board of Education Department of Public Instruction, 2015) as the Environmental Literacy Plan was being written (Sarah Yelton, Personal communication, January 17, 2015). North Carolina curriculum requires science and social studies (which includes environmental literacy) instruction in grades K-5. However, my personal experience as a North Carolina teacher educator is that science and social studies are not privileged and are often taught less and at less optimal time periods than reading and mathematics, which consume much of the typical elementary school instructional day.

Teachers' performance assessment linked to standardized testing. There is an emphasis in the U.S. curriculum, and especially in our state, on preparation for standardized testing. Students' end of year test scores are linked to teacher evaluations (Department of Public Instruction, n.d.), evaluations that in turn affect job and salary status. The importance of student performance on mathematics and reading tests upon teacher evaluation leave little to encourage most elementary school teachers to teach science until fifth grade (when it is included in standardized testing) or social studies at all (because it is not tested grades K-5). Likewise, elementary school principals are not apt to encourage social studies or science instruction either for these same reasons.

Teachers' avoidance strategies in science instruction. "Science is a relatively new elementary curriculum area with low priority" (Appleton, 2007, p. 495). According to Appleton, Nature Study was taught to children before World War II, and elementary school science instruction began at the time of the war. Despite efforts to improve and increase time for elementary science instruction, Appleton found that this instruction had not changed in decades. Appleton (2007) identified six science-teaching avoidance strategies employed by teachers: (a) teaching as little science as possible, (b) teaching topics where confidence is greater (e.g., more Biology than Physical Science), (c) stressing process outcomes rather than conceptual outcomes, (d) relying on the textbook or prescriptive work, (e) using expository teaching versus questions and discussion, and

(f) avoiding equipment that can malfunction and all but the simplest practical work. Appleton reported that the following factors influenced the avoidance of teaching science: lack of resources, time, personnel, and perceptions of the unimportance of science in the elementary school.

Appleton (2007) indicated that appropriate strategies for teaching science at the elementary school level would not restrict science activities to reading textbooks that " . . . severely limit children with reading disabilities" (p. 503) and would include science experiences—at least three to four experiences—in order to commit something to long term memory (Nuthall, 1999). There is little doubt of the critical importance of generating enthusiasm and interest in science at the elementary school level. From varied research perspectives we find that adult career choice has roots early in childhood (van Tuijl & Walma van der Molen, 2015). Maltese and Tai (2010) found that most scientists reported that their interest in science began before middle school. The benefits to students of generating enthusiasm and interest in learning science by going outdoors to do fieldwork could be a motivating factor for teachers to incorporate citizen science fieldwork into science instruction.

EXPLORE citizen science programs with Environmental Education components. School science outdoors with an Environmental Education component, which broadly investigates climate change and biodiversity loss, not only generates interest in science, but it exposes children first hand to the natural world, authentic science, and the bigger environmental challenges we face. All three of the citizen science programs (eBird, Project Squirrel, and Nature's Notebook) that teacher participants in

Project EXPLORE chose to participate in have an environmental component to data collection and analysis.

The citizen science program eBird tracks bird populations and species ranges. Data gathered and reported can show biodiversity gain or loss as well as population increase or decline. These data can show bird habitat shift due to changing climate as well. The website is fairly user friendly, colorful and attractive with photographs, something that may interest children. It is easy for teachers and students to understand the downloadable report of the total number of species of birds reported, and the total number of data uploads by citizen scientists. See Appendix A for a sample of an eBird data report.

Project Squirrel tracks populations and species ranges for squirrels. Data from Project Squirrel can show biodiversity gain or loss as well as species population increase or decline. Unfortunately, this website does not offer the teacher the option to download a report of the data the class collected and uploaded. Nature's Notebook data are collected on trees in Project EXPLORE, and can show changes in the dates each year that trees in each class's study area sprout leaves, bloom, and lose their leaves. Scientists, by comparing data, can track dates of seasonal changes from year to year, as well as examine how changes in season's dates affect different species of trees in different ways and in different geographic locations. Or, observations in the winter/early spring may mean that data reports are 'null' because there are not any buds yet. The website can generate a data upload report for users, but these are pages of spreadsheets of data without summary totals for users. This data report may be difficult for small children to understand; see Appendix B.

Project EXPLORE, as stated in the grant application, “fulfills the need for frequent exposure to Environmental Education that engages the greatest resource children have in their lives—the adults that are already regularly engaged in their education [their teachers].”

EXPLORE as innovative professional development. Teachers, acting as role models, can facilitate childhood experiences outdoors for their students that may encourage future actions in favor of the natural environment. Childhood experiences in nature with a role model were found to encourage environmental action in adults (Chawla & Cushing, 2007). An elementary school teacher can designate a space for science and Environmental Education on the school grounds, and then use this place to conduct science research outdoors (Wals et al., 2014). Biologists in the United Kingdom (UK) interested in finding ways to defend science education outdoors, “. . . soon realized that in biology fieldwork we had a model of good science, and that the best way to defend it was, in fact, to promote it more widely as something with much to offer the teaching of the whole of science” (Slingsby, 2006, p. 51). “We found substantial evidence to indicate that field work, properly conceived, adequately planned, well taught and effectively followed up, offers learners opportunities to develop their knowledge and skills in ways that add value to their everyday experiences in the classroom” (Rickinson et al., 2004, p. 5). However, teachers seldom have the pedagogical knowledge and experience needed to implement science fieldwork (Tal & Morag, 2009).

Project EXPLORE has many of the characteristics of an effective program for teacher learning that Wei, Darling-Hammond, Andree, Richardson, and Orphanos (2009) recommended. Teachers learn through their own activity. They learn to implement citizen science projects in their schoolyards as part of EXPLORE. This includes the supervision of collecting and reporting of scientific data for scientists, as well as facilitating student learning. The following characteristics of EXPLORE differentiate it from more common forms of professional development: (a) Participation is voluntary (versus not voluntary); (b) Teachers learn by doing (versus a lecture or 'training' workshop style learning experience); (c) The program is held outdoors or through one-on-one contact (versus in teacher groups indoors in classrooms or assembly rooms); (d) The program is done in context (versus out of context away from students, school and/or school grounds); (e) The program includes students as well as teachers (versus no students present); (f) The program has a broad scope (versus a narrow scope); (g) The program is long term, over the course of a school year (versus short term, sometimes as short as a few hours long); and (h) The program offers continuing e-support (versus no continuing support) (Tallerico, 2014).

The benefits of science education outdoors. One of the strongest reasons for teachers to choose to implement citizen science projects outdoors with EXPLORE is because these projects can be beneficial to students. There are many benefits to students from learning outdoors (Dillon, 2014; Dillon et al., 2006; Rickinson et al., 2004). The benefits of outdoor learning include knowledge and skills acquisition as well as benefits to health and well-being such as the development of self-confidence, physical and social skills, and improved attention (Chawla & Cushing, 2007; Dillon, 2014; Dillon et al., 2006; Eaton, 2000; Louv, 2005; Malone, 2008; Rickinson et al., 2004; Taylor & Kuo, 2011; Wals et al., 2014).

Hiller and Kitsantas (2015) found that mentored citizen science project fieldwork helps students develop scientific skills as well as offers other benefits. “According to research studies, the interaction with field experts in developing scientific observation skills has far reaching benefits in terms of student development of metacognitive skills, motivation, achievement, and STEM career pathways” (p. 193). Despite mounting evidence of the benefits of learning outdoors, children are not getting out into the natural world enough, according to Louv’s (2005) *Last Child in the Woods*. Louv described children as suffering from ‘nature deficiency.’

Children residing in low-income areas where the outdoors is sometimes unsafe do not often get to be outdoors (Louv, 2005) but citizen science fieldwork in the schoolyard makes science and science careers more accessible to diverse cultures and races as well as to students from families with low incomes. Fieldwork also makes complex science and far reaching socioscientific ideas accessible to teachers at a very low cost (using the schoolyard), which is a great benefit to students in low-income area schools. Most teachers (especially elementary school teachers) do not take advantage of the schoolyard for teaching science and Environmental Education outdoors on a regular basis (Cronin-Jones, 2000). Cronin-Jones found that most research on outdoor science instruction focuses on short one-day field trips despite findings that repeated exposure to natural settings is effective in significantly improving environmental attitudes.

In conclusion, this study is important in that it presents a model of science instruction that addresses our global environmental crisis. Findings from this study, which describes specific incidences of a convergence of science and Environmental Education, could help promote a shift in how school science is taught in the future. This research is important in that it presents, from teachers' points of view, learning to implement an innovative citizen science program with Environmental Education components in partnership with an Arboretum to benefit their students, communities, and society in general.

Theoretical Framework

The research for this study was conducted using sociocultural theory. I viewed reality voiced by the individual teacher as socially constructed. I used a CHAT (Engeström, 2001) theoretical framework to inform sociocultural theory. This qualitative case study research sought to discover the meanings teachers made of learning to implement citizen science projects outdoors.

These phenomena were studied using a sociocultural (Vygotsky, 1978; Wertsch, 1991) lens. Vygotsky's (1978) sociohistorical theory of learning is now known as *sociocultural* theory (Wertsch, 1991). Sociocultural theory situates learning socially, in a community context, where learning is mediated by language and symbols (Vygotsky, 1978). For this research, this sociocultural perspective was informed by activity theory (Engeström, 2001; Engeström, Engeström & Suntio, 2002). ". . . [A]ctivity theory . . . [is], above all, a framework for understanding transformations in collective practices and organizations" (Engeström et al., 2002, p. 211).

Activity Theory or Cultural-Historical Activity Theory (CHAT)

A key concept of activity theory, or CHAT, that is particularly relevant to this study is expansive learning. Engeström and Glăveanu (2012) explained *expansive learning* as learning by the acts of both designing and mastering a new way of doing things. Such learning occurs through questioning, modeling, and experimenting (Engeström, 2001). Expansive learning involves creating new artifacts and practices through acts of collaboration (Engeström et al., 2002) in the activity system or between interacting activity systems. An activity system is the unit of study in CHAT.

Activity. While the word activity is commonly understood in education as work for a particular goal, Engeström (1999) explained that the term ‘activity’ in the English language does not express the full deep philosophical meaning of activity for a purpose (or object) as the term *activity* in activity theory does. As Engeström (1999) described it, the term activity in CHAT denotes a superior level of systemic analysis. In this theoretical framework, activity is a structure that has many interacting components, or elements, such as subject, artifact, object, rules, tools, division of labor, and community (see section to follow, Activity system elements), that are interrelated (Plakitsi, 2013). Activity, in an activity system, as defined by Roth and Lee (2007), “is not to be equated with relatively brief events with definite beginning and end points (characteristic of school-based tasks) but an evolving complex structure of mediated and collective human agency” (p. 198). Activity, as it applies to activity theory, is a multi-layered systemic community enterprise in a cultural context oriented towards a shared purpose.

Activity systems. An *activity system* can be defined as a bounded community engaged in an activity with a common purpose. In the CHAT theoretical framework the collaborative community of Project EXPLORE was viewed as a large activity system. This large activity system was a bounded community mainly composed of the Arboretum as an institution, the Arboretum educators as representatives of that institution, and teachers and their students who were participants in Project EXPLORE. Each participating elementary school teacher's citizen science classroom project (N = 13) was seen as an embedded activity system, which interacted with the larger EXPLORE activity system. The smaller activity systems were viewed as bounded communities mainly composed of the school and school system as institutions, teacher(s) and their students, parents and volunteers, and Arboretum educators.

Activity system principles. Engeström (2001) identified five principles that constitute a bounded activity system: (a) a process where artifacts mediate the collective purpose or meaning (object) of the activity; (b) community with multiple points of view where participants have their own diverse cultural histories; (c) a system that forms over time and thus has a history; (d) a system of contradictions or tensions as sources of change or development; and (e) a system that can foster transformations and deviations from previously established norms. Project EXPLORE has representative principles as described below that qualify it as a bounded activity system as described by Engeström.

The activity system (Engeström, 2001) is oriented towards an object (or the meaning or purpose of the activity system). The object or purpose precedes and motivates the activity (Plakitsi, 2013). The purpose (object) of the EXPLORE activity system, corresponding with CHAT principle (a), is "[t]o promote science in [the region] through recurring outdoor educational opportunities" (Marchal, 2014). Learning via recurring outdoor educational opportunities is mediated by artifacts (such as language, symbols or tools to be explained later in this chapter).

The community in Project EXPLORE, corresponding with CHAT principle (b), is a collective social network, where participants share varied relationships with each other (Engeström, 2001). Project EXPLORE is a community of teachers participating in citizen science programs and teaching science in their schoolyards with assistance from Arboretum educators. Some schools had more than one teacher participating in EXPLORE. These teachers formed partner or mentor-mentee relationships, even sharing the task of taking the class outdoors for data collection.

EXPLORE is a system that has formed over time and thus has a history, corresponding with principle (c) for an activity system (Engeström, 2001). The Arboretum's grant application for funds to support Project EXPLORE described the history behind the proposed program and the rationale the Arboretum had for establishing the program in 2013–2014. Project EXPLORE was developed to fill a need in the larger educational community by reaching out to nearby schools that could not come on a field trip to the Arboretum. As part of my data collection, I inquired into the string of historical events that led up to and included participation in EXPLORE. The Arboretum expanded the notion of a field trip from a school visit to the Arboretum to include visits by Arboretum educators to schools.

My investigation of Project EXPLORE uncovered systems of contradictions/tensions corresponding to CHAT principle (d). Contradictions inevitably occur (Brown & Cole, 2002) and may have to be faced and overcome to allow for teachers' creative agency (Wells, 2002). Generally, public schools in the U.S. do not require outdoor academic instruction time, so the very act of initiating such an activity, teaching science outdoors, may be a contradiction to normative practices in schools and may cause conflicts in public elementary schools. Contradictions tend to be very complex, but one example would be when a teacher creates a mathematics lesson related to Nature's Notebook and takes a class outdoors during assigned mathematics time to measure the circumference of trees. The other teachers at the school teaching mathematics indoors at that time may perceive this time outdoors as additional recess time (Broda, 2007). They may wonder, to themselves or to the school administrators, why another teacher would be allowed to give students recess during mathematics time. A teacher may feel isolated implementing citizen science projects outdoors and creatively integrating it with other subjects (such as mathematics in this example) and fear if they were to leave the school the practice would not continue without them. And, without systemic changes in favor of the new creation it may only live as long as particular individual teachers sustain it, unless the transformation spreads to the activity system as a whole (Engeström et al., 2002).

Activity system. A system that can foster transformations and deviations from previously established norms is principle (e) of a CHAT activity system (Engeström, 2001). Such systemic transformations, which may also change the people in the activity system or the purpose (object) of the activity system, are referred to by Engeström and Glăveanu (2012) as expansive learning. Teachers would conduct the required data collection activities outside with their students for Project EXPLORE. Going outdoors instead of teaching science indoors is a deviation from established norms and could lead to systemic transformation of teaching practices.

A part of my investigation was to identify, describe, and analyze the relationships between the different elements of the EXPLORE activity system as teachers learned to teach and taught citizen science programs outdoors (Engeström, 1999, 2001; Plakitsi, 2013; Roth & Lee, 2007). Examining the relationships between activity system elements using the CHAT framework created a deeper understanding of Project EXPLORE and the teachers' meaning making of events and experiences. The seven elements of the CHAT activity system are: subject, artifact, object, rules, tools, division of labor, and community (Plakitsi, 2013). Each of these elements is discussed below.

Subject. The subject of the larger Project EXPLORE activity system in this study is the group of 13 elementary school teacher participants. "The subject of an activity system is the individual or group whose viewpoint is adopted" (Plakitsi, 2013, p. 2). The primary participants who were the focus of this study brought with them their own cultural histories (see Definitions). I was most interested in the teacher and what the teacher learned from being a participant and what a teacher learned from enacting the EXPLORE curriculum (teaching). Project EXPLORE offered teachers who had not taught citizen science programs outdoors in the past an opportunity to do so with the support of the Arboretum. While I studied all 13 elementary school teachers, four of those teachers were focal participants and so data about those four teachers is more extensive.

Artifact. In the case of the larger activity system of Project EXPLORE, artifacts that mediated teacher learning were language, symbols, and tools. “The mediating artifacts include tools and signs, both external implements and internal representations such as mental models” (Engeström, 1999). Artifacts can be in constant flux; an internal artifact can become externalized through speech or language. What an Arboretum educator knew (internal artifact) and said (externalized with speech) about citizen science during a school visit mediated learning for the teacher and students. For example, the Arboretum educators used the terms snag (dead tree), scat (animal droppings) and drey (squirrel’s nest), which were often unfamiliar, words to teachers. Teachers then used and explained the same terms to their students, allowing for more robust science endeavors.

Object. The object of the larger activity system of EXPLORE is the broad long-term purpose, or meaning, for the activity (Engeström, 2001). An object of an activity system is like a horizon the activity strives to reach but “the object is never fully reached or conquered” (Engeström, 1999, p. 381). To understand the object of the activity system, Roth (2009) notes we need to understand the totality of the relationships between all the interrelated elements. In the case of EXPLORE, the teachers might see the object (purpose) of the activity system as addressing the learning needs of students, or perhaps addressing the problem of global warming or defaunation (Dirzo et al., 2014), by offering a citizen science project in which students collect relevant scientific data for use by scientists.

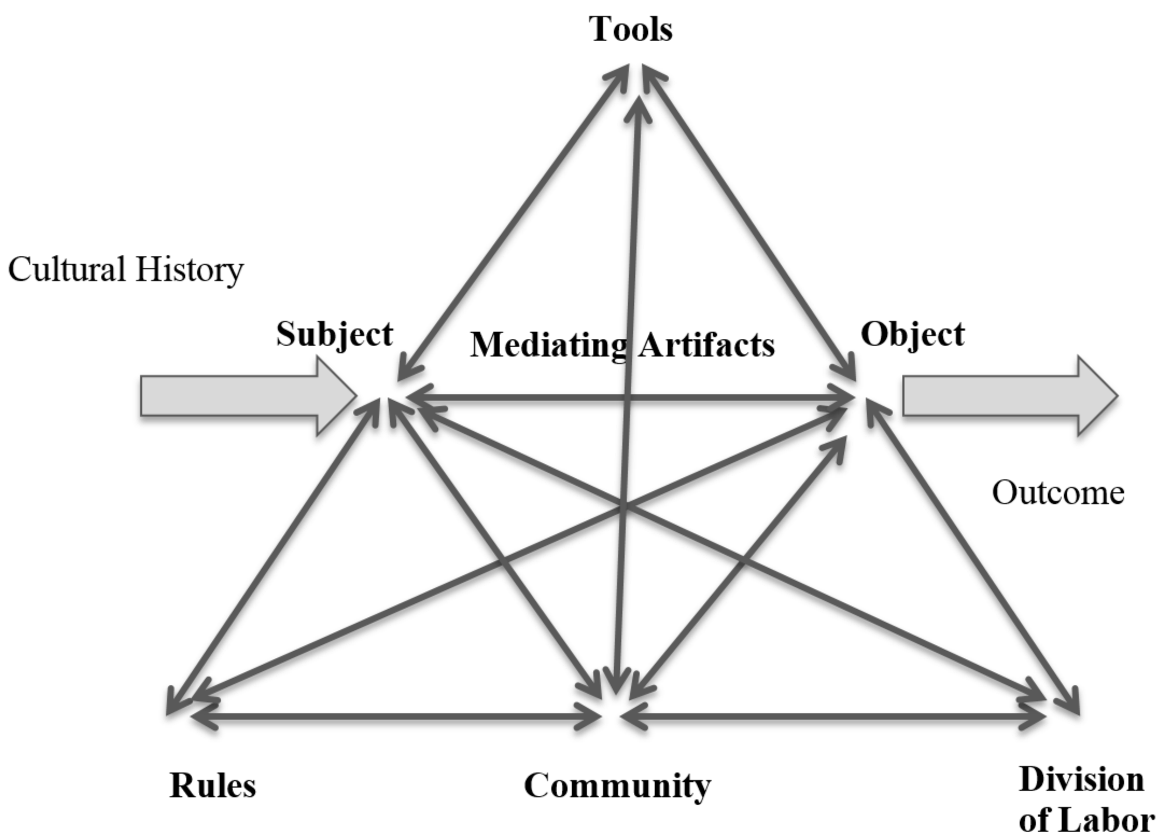
Rules. An activity system is regulated by *rules,* implicit and explicit norms, which regulate the activity (Plakitsi, 2013). The larger activity system of EXPLORE encompasses community members from school systems. Teaching science is required in the elementary school curriculum. Participating teachers voluntarily chose to be a part of EXPLORE and implemented citizen science as a way to teach science. In the larger activity system of EXPLORE there were requirements (rules) to participate, such as to collect data weekly for upload to citizen science databases and to display data on a poster at an exposition in the spring.

Tools. In a CHAT activity system tools are artifacts that mediate learning. By the use of tools in the larger activity system of EXPLORE an object is molded into an outcome, and tools can be physical or symbolic; tools can be external or internal to the learner (Plakitsi, 2013). For example, in EXPLORE, external Arboretum educator tools were the data collection sheets (see Appendix C) used to help young students record data for upload to the Project Squirrel citizen science website and a set of binoculars for the class.

Division of labor. There is a division of labor, a division of tasks and roles (Plakitsi, 2013) seen in the relationships between people in the larger activity system. Project EXPLORE exemplifies several ways in which the distribution of power is significant. For example, in the past century while primarily scientists 'did' science, the opportunities for citizens to 'do' science have expanded the notion of who 'does' science. Additionally, while access to computers was limited, now elementary school students are able to collect and upload data to national and international science databases on school computers. This broadens the scope of who does science, includes those who were formerly excluded from doing science, and values the work (the doing of science) of teachers and their students.

Community. In the larger activity system, the EXPLORE community is composed of people who share the same object (purpose) (Plakitsi, 2013). The teachers and Arboretum educators shared the same meaning or purpose of the activity: to promote science through recurring outdoor educational opportunities for children. As teachers participated in Project EXPLORE, I identified, described, and analyzed the relationships between and among community members and the other elements of the activity system.

I have described the interrelated elements of the EXPLORE activity system as I defined them, and they can be visualized as interrelated points on a triangle (see Figure 1). This triangular graphic representation of CHAT, often called the activity theory triangle, helps us visualize all of the elements of CHAT as situated in a community (Engeström, 2001). Through my interviews with key informants, supporting participants, (e.g., principals, district science coordinators, parent volunteers, librarians, student teachers, and other specialty teachers like garden teachers or academically gifted teachers) and through my observations of EXPLORE activities, I gained insights into teachers' meanings of learning to implement citizen science projects with their students. From teachers' reflections in essays on their applications and on an initial questionnaire, interviews, and self-recordings, I was able to further investigate teacher meaning-making of their Project EXPLORE teaching and learning experiences.



Adapted from Engeström (2001). Elements are bolded.

Figure 1. Cultural-historical Activity Theory as an Analysis Framework.

Research Questions

My research questions are:

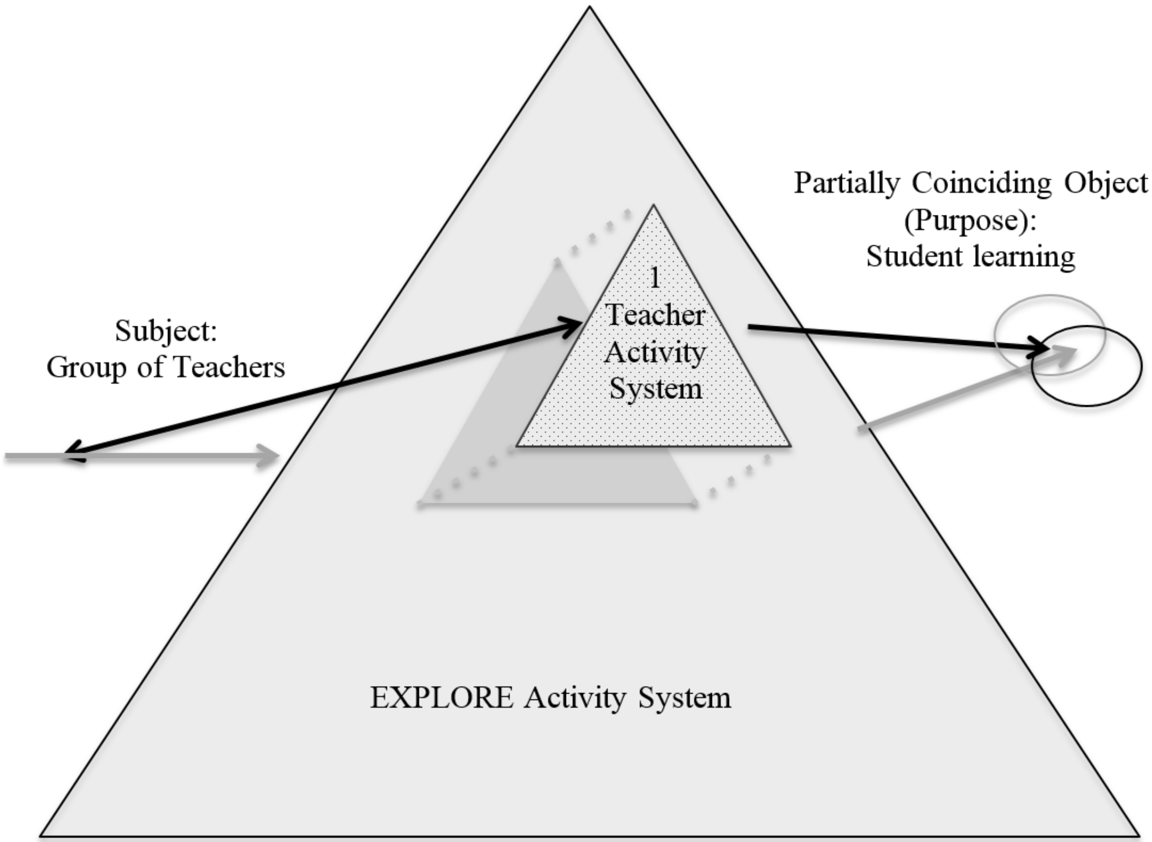
1. What is the nature of the Arboretum's Project EXPLORE professional development for public elementary school teachers when viewed as an activity system (Engeström, 1999, 2001; Engeström & Glăveanu, 2012)?
   a. How and in what ways is there expansive learning in this activity system?
   b. What are points of contradiction in this activity system?
   c. How does this activity system transform or change over time?

2. What meanings do public elementary school teachers who are participants in Project EXPLORE make of learning to conduct a citizen science project outdoors in practice?
3. What meanings do public elementary school teachers who are participants in Project EXPLORE make of learning to conduct a citizen science project outdoors in reflection?

These research questions were informed by CHAT (Engeström 1999, 2001), which views learning as complex transformations involving communities over time. Teachers in these communities are interacting with experiences in implementing citizen science projects outdoors.

To answer the first research question, I described the nature of the program, Project EXPLORE, as a bounded unit or large activity system in which the group of elementary school teachers (N = 13) was the subject of study. Learning is seen in this study as a process influenced by a network of relationships between the elements that make up the activity systems. To answer the second and third research questions I explored, described, sought to understand, and interpreted teachers' meanings of learning to implement citizen science projects outdoors. I examined teacher learning through my observations of their teaching and through teachers' reflections in interviews and self-recordings. The second and third research questions in this study focused on the meanings teachers made of learning to implement citizen science projects outdoors in reflection and in practice. As Merriam and Heuer (1996) described, meaning is created by people and is not inherent in events, but events only become meaningful when people interpret them as such. “Meaning is self-made” (p. 245). Through teachers’ reflections upon events and experiences, they voiced their meanings of learning to implement citizen science projects outdoors as participants in Project EXPLORE. I viewed teacher meanings and teacher practices (teaching) through a sociocultural lens informed by CHAT.

In the second research question, I examined teachers’ meanings of learning through evidence from my observations of teachers teaching. I explored the connections teachers made between their own practices as a learner in Project EXPLORE and their own practices as a teacher while conducting citizen science projects with their students on their school grounds. These teachers’ meanings of learning were influenced by the Arboretum educators and by the interrelated elements of the activity systems (such as subject, artifact, object, tools, rules, the division of labor, and the community) of science education outdoors at their school sites. While I spent time with all primary participants, I identified and focused my efforts on four teacher participants. Each individual focal participant was viewed using the CHAT theoretical framework as part of a smaller bounded activity system interacting with the larger activity system of Project EXPLORE (see Figure 2).



The patterned triangle represents one teacher's activity system in EXPLORE using CHAT. This drawing was adapted from Engeström (2001).

Figure 2. Cultural-histoCrical Activity Theory (CHAT) Conceptual Framework for EXPLORE.

Researcher Positionality

Positionality according to Glesne (2011) in *Becoming Qualitative Researchers: An Introduction* encompasses social, geographical, and ideological placement with relation to the phenomenon of study, and the research participants in it. As Glesne described, I, as a researcher, have little control over my own personal cultural history, but I can make choices such as: entering the research with an open mind; being curious; and desiring to interact with the participants in a collaborative way. I always tried to take on the role of the research participant, 'put myself in her shoes,' and tried to understand how my positionality affected my meaning making and interpretations of teachers' voices. I kept a researcher journal to constantly remind myself of my positionality as a collaborator in research, and through the journal I explored how I may have affected the research, the participants, and my understandings of the research by my positionality.

Limitations of the Study

As the purpose of this qualitative research study was to explore, describe and interpret teachers' meanings of learning to teach citizen science projects outdoors, the study results cannot be generalized. I am only one researcher and had limited resources, and limited time to complete data collection (February-May, 2015). There were limited study sites I could visit. Data collection was bounded by my ability to gain access to teachers and schools, school administrators, and school districts. Geographical distances and weather conditions limited my ability to collect data as often as I would have liked. There were eight days when schools were unexpectedly closed or had delayed entry due to snow conditions, and classes did not go out to collect scientific data in the rain.

Nevertheless, I observed each class ($N = 13$) at least once and each focal participant's class ($n = 4$) at least four times and up to six times, all while outdoors. When weather conditions caused teachers to cancel outdoor data collection I would return to observe another day when the weather was better. I helped some teachers meet their weekly data collection requirements on occasion by supervising small student groups during outdoor data collection.

Definitions

For the purposes of this study the following definitions of terms will be used:

Citizen Science—Citizen science engages non-professionals of all ages and backgrounds in the process of observing and reporting data to be interpreted and utilized by professional scientists, specifically biologists and natural resource professionals, (as defined in the EXPLORE grant application).

Cultural History—A series of developmental events in the past (Vygotsky, 1978).

Environmental Education—Environmental Education is a learning process that increases people's knowledge and awareness about the environment and associated challenges, develops the necessary skills and expertise to address the challenges, and fosters attitudes, motivations, and commitments to make informed decisions and take responsible action. (UNESCO, 1978, p. 2).

Environmental Literacy—

> According to Roth (1992), an individual's [environmental literacy] EL is the outcome of a number of interplaying components, which can broadly be grouped into cognitive, affective and behavioural. The cognitive domain refers to the individual's knowledge of ecological concepts and processes that provide the foundations for comprehending human impact on natural systems: environmental issues and environmental action strategies; as well as the cognitive skills for analyzing environmental problems and for the use of environmental action strategies. The affective domain refers to the individual's environmental awareness and sensitivity; attitudes, values and worldview regarding the environment; locus-of-control (sense of ability to influence a situation through personal behaviour, i.e., self-efficacy) and assumption of personal responsibility (sense of obligation toward the environment. i.e., personal commitment to environmentally corrective behaviors). Behavior is the ultimate expression of EL—the individual's EL should be reflected in his/her behavior concerning the environment. (Goldman, Yavetz & Pe'er, 2014, p. 371)

No Child Left Behind (NCLB)—

> The Elementary and Secondary Education Act (ESEA) was signed into law in 1965. In 2002, with bipartisan support, Congress reauthorized ESEA and President George W Bush signed the law, giving it a new name: No Child Left Behind (NCLB) . . . While NCLB put in place measures that exposed achievement gaps among traditionally underserved and vulnerable students and . . . started an important national dialogue on educational improvement, the law is long overdue for reauthorization. (U.S. Department of Education, 2015a)

ESEA legislation was passed in 2015 (see Every Student Succeeds Act [ESSA] in Definitions) in the U.S. Senate (Congress.gov., 2015).

No Child Left Inside (NCLI)—The No Child Left Inside Act was drafted, introduced to the U.S. Congress in July of 2013 (Congress.gov), and reintroduced with bipartisan support in July of 2014, as an amendment to the Elementary and Secondary Education Act (ESEA) (Chesapeake Bay Foundation, 2015). Representative John Sarbanes of Maryland "reintroduced the No Child Left Inside Act, as he has done in every Congress since 2007" (Johnson, 2015, para. 2). The renewed ESEA federal legislation in its final form did include aspects of the NCLI amendment; it did not require that Environmental Education be a part of the K-12 curriculum as a condition for applicable federal funding as the original bill sought to do, but allowed for funding for Environmental Education as part of formal K-12 schooling (see below).

Every Student Succeeds Act (ESSA)—This federal act signed into law by President Obama December 10, 2015, reauthorized the 50-year old Elementary and Secondary Education Act (ESEA) (U.S. Department of Education, 2015a). According to the North American Association for Environmental Education (NAAEE, n.d.; Bodor, 2015), under Title IV of this bill Environmental Education is eligible for federal funding through grants to states. In this bill such grants include hands-on, field based learning experiences to enhance the understanding of science, technology, engineering, and mathematics. “ESSA is a tremendous victory for advocates of environmental education who’ve fought long and hard to inspire the next generation of environmental stewards with outdoor, hands-on learning programs,” said U.S. congressman John Sarbanes of Maryland (as cited in Bodor, 2015, para. 6). The exact words “environmental education” are included in the *Every Student Succeeds Act* (2015) as a type of well-rounded educational experience for all students that may be included in state grant spending in Title IV, section 4104, State Use of Funds. Such grants will be awarded (as part of a $1.1 billion annual budget until 2020) to “support and grow local innovations—including evidence-based and place-based interventions developed by local leaders and educators” (U.S. Department of Education, 2015b, para. 2).

Science—

> Science is the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence. (The Science Council, n.d., para. 1)

Summary of the Introduction

As a former elementary school science specialist, I experienced the effectiveness of teaching science and Environmental Education outdoors on student science learning. As a teacher educator and researcher, I search for effective models of professional development that encourage teachers to teach science outdoors. I studied all of the 13 public elementary school teacher participants in the Arboretum's Project EXPLORE program. Additionally, I spent more time and focused upon four involved and accessible participants from this group of 13 participating teachers. In addition to their involvement and accessibility, a list of criteria used to purposefully select focal participants is provided in Chapter III. I sought to explore, understand, describe, and interpret the meanings teachers made of learning to conduct citizen science projects in their schoolyards. This research was conducted using a sociocultural theory. Analysis of data was informed by the cultural-historical activity theory or CHAT (Engeström, 2001).

Because of the critical importance of teaching science at the elementary school level, and in response to climate change and other environmental challenges, we as educators have a responsibility to educate the next generation to be environmentally literate as a part of science education, and citizen science is one way to do this (DeBoer, 1991; Robottom, 2012; Slingsby & Barker, 2003; Wals et al., 2014). The benefits for children of learning outdoors are well supported by research (Dillon, 2014; Dillon et al., 2006; Rickinson et al., 2004) and children with first hand experiences in nature are more likely to take action in favor of the environment in the future (Chawla & Cushing, 2007). Environmental literacy is already a part of the social studies curriculum and essential standards in North Carolina, and the North Carolina's Environmental Literacy Plan (which has not yet been adopted).

In Chapter II, I review the literature on the status of (a) science education, especially at the elementary school level, (b) science education outdoors (fieldwork), especially at the elementary school level, (c) Environmental Education, (d) citizen science, (e) the intersection of Environmental Education and citizen science with science education, and (f) professional development of teachers to address the lack of teacher preparedness to teach science outdoors and enact citizen science programs.

CHAPTER II

LITERATURE REVIEW

> Moving forward the [science education] research agenda needs to include evidence about how expert teachers learn from teaching. (Kelly, 2014, p. 366)

The purpose of this literature review was to help me understand how science education outdoors could be used to help teachers influence systemic educational transformation. As Engeström (2001) noted, if individuals begin to question and deviate from normative practices in an activity system, they can escalate their efforts into a new collaborative vision with broader implications for a larger system. In other words, individuals can initiate a "collective journey" (Engeström, 2001, p. 137) or a systemic expansive cycle in elementary science education, one that could potentially transform how we teach science in the elementary schools. Experiences Promoting Learning Outdoors for Research and Education (EXPLORE) could act as a vehicle for transformation of elementary school science education, beginning on a small scale. I argue that in citizen science, at the intersection of science and Environmental Education, teachers may find a remedy for declines in elementary science instruction and fieldwork. I further argue that because of a lack of teacher preparedness we need to better understand how teachers learn to shift science pedagogy towards the outdoors.

In the framework for my literature review, science education (SE) and science education outdoors (SEO) are first in sequence as they historically precede

Environmental Education (EE) and citizen science (CS) used for education (see Figure 3).

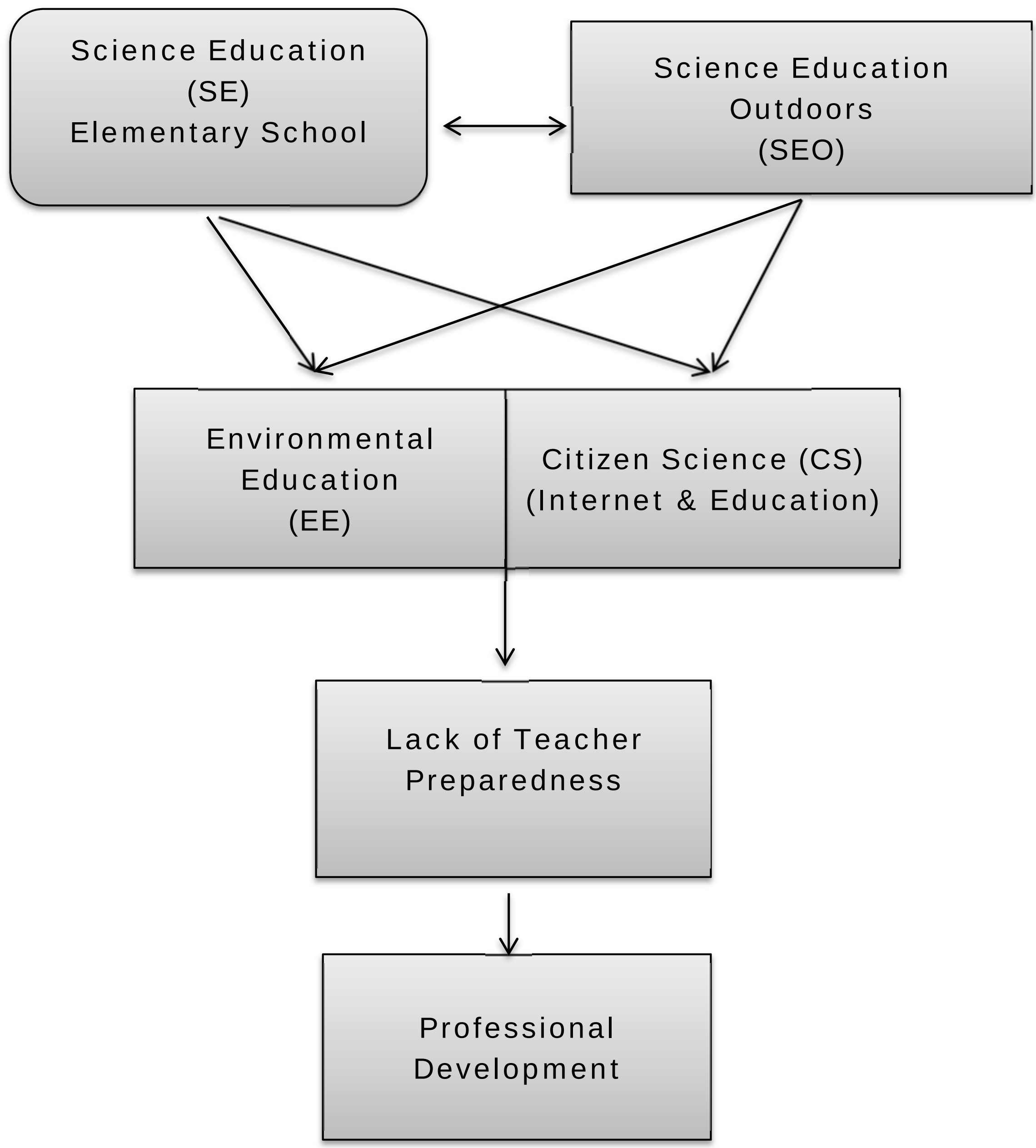


Figure 3. Framework for Literature Review.

I use this diagram to guide the organization of my literature review and begin with an investigation into the historical and current state of formal science education and science education outdoors. I found research supporting needed change in elementary science education. Science instruction is not privileged (Roth, 2014), and when teachers do teach science, the component of fieldwork is not typically part of their science instruction (Barker et al., 2002). I explore literature that found a decline in fieldwork (science education outdoors) at the elementary school level. I investigate the historical and current state of Environmental Education which does include outdoor lessons, and researched citizen science specifically as a point of intersection, blurring the boundaries between science, science education, science education outdoors, and Environmental Education. These are boundaries that persist, despite the fact that Environmental Education engages people in science as part of encouraging changes in environmental values and behavior (Wals et al., 2014).

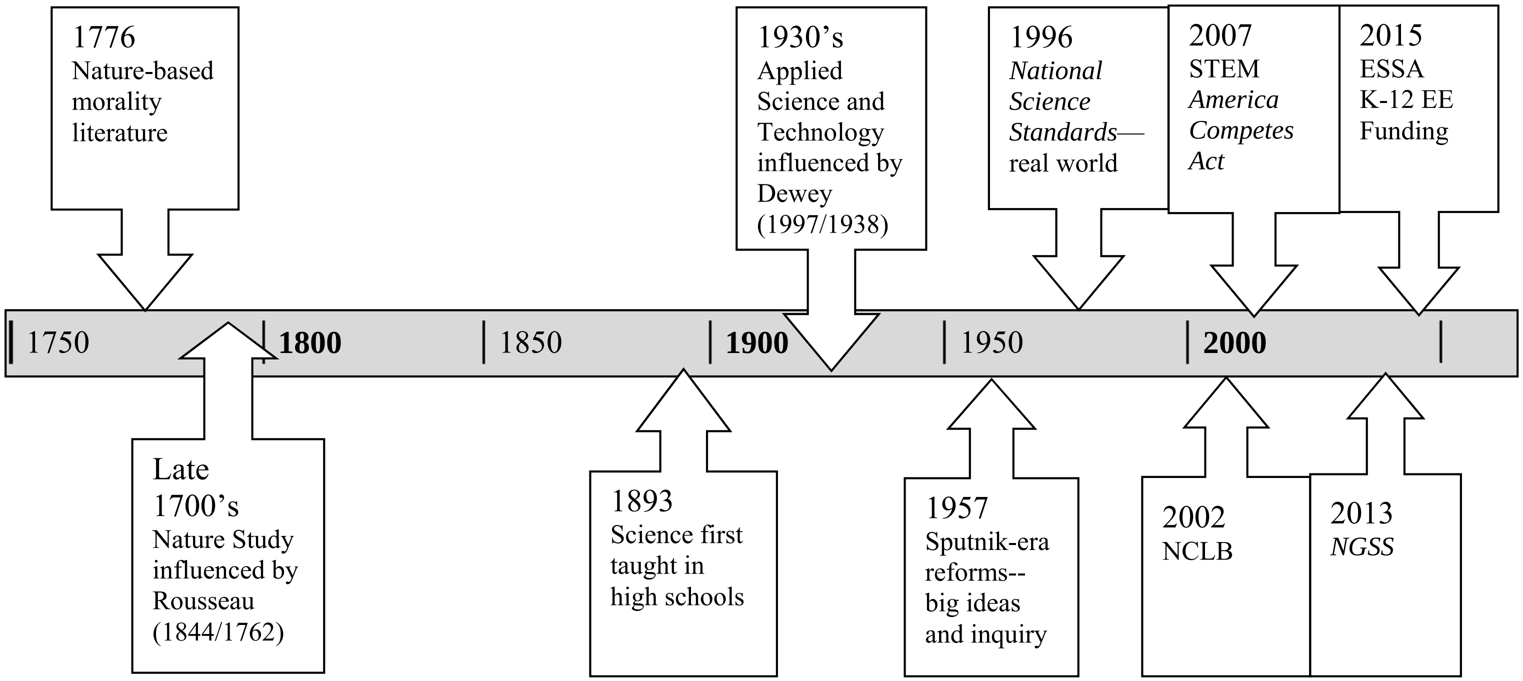
Additionally, I examine literature on the preparedness of teachers to enact science instruction at the elementary school level. A problem in the field of elementary school science is that teachers avoid teaching science (Appleton, 2007). A decline in fieldwork at the elementary school level presents a problem because first hand experiences are important to student learning (Lock, 2010). This decline, according to researchers, is situated at a time in history when it is essential to prepare scientifically and environmentally literate citizens who will be better able to respond to current ecological crisis (Kelly, 2014). A prolonged decline in science education and fieldwork at all levels of schooling means that teachers are less likely to have had learning experiences outdoors with ecology or whole organism biology and may enter science teaching without any fieldwork experience (Barker et al., 2002). The lack of teacher preparedness to teach elementary school science (Appleton, 2007; Roth, 2014) coupled with a need for instruction in teaching outdoors (Tal & Morag, 2009) leads me to examine, as the final theme of this literature review, teacher professional development.

This literature review informed my first research question which focuses on the nature of the EXPLORE program when viewed as a form of professional development for teachers. I discovered a lack of research on the type of professional development programs that are recommended by researchers (Wei et al., 2009). Especially lacking are studies of professional development programs, such as EXPLORE, that help teachers learn to teach science outdoors and that include (a) support from a local organization, (b) long term learning opportunities for teachers, and (c) a focus on their own school context and their own students.

Elementary School Science Education in the United States

A Brief History

Over time our science education for children in the United States has experienced reform efforts and changes that still affect us today. I trace important moments in history in chronological order (see Figure 4) beginning with the era of colonization and the birth of our nation. I then review the present state of science education, with special attention to the elementary school level.



Note. NCLB denotes No Child Left Behind U.S. federal education legislation; STEM denotes Science, Technology, Engineering, and Mathematics initiatives; *NGSS* denotes Next Generation Science Standards U.S. national science standards; ESSA denotes Every Student Succeeds Act (2015) U.S. federal education legislation; EE denotes Environmental Education.

Figure 4. Timeline of Science Education for Elementary Students in the United States 1776–2015.

Researchers Atkin and Black (2007) noted that science instruction began in the North American colonies for young children with literature rich with detailed descriptions of first hand experiences in nature and this children's literature was used primarily as a vehicle to promote moral virtue and religious ideals. This literature promoted the study of nature and was influenced by European authors such as Rousseau whose ideas crossed the Atlantic in the late 18th century.

> L'enfant qui lit ne pense pas, il ne fait que lire; il ne s'instruit pas, il apprend des mots. Rendez votre élève attentive aux phénomènes de la nature, bientôt, vous le rendez curieux; mais, pour nourrir sa curiosité, ne vous pressez jamais de la satisfaire. Mettez les questions à sa portée, et laissez-les-lui résoudre. (1844/1762, p. 181)

I translate this into English as:

> The child who reads does not think, he does no more than read; he does not instruct himself, he learns words. Make your pupil attentive to natural phenomena and soon you will make him curious; but to feed his curiosity never hurry to satisfy it. Put questions within his reach and let him solve them.

Based upon philosophers such as Rousseau who felt that true meanings came about through experiences in nature, primary schools encouraged children to study objects from nature that they brought to class (Atkin & Black, 2007). From the late eighteenth century until the early twentieth century Nature Study was prominent in the elementary school (Carter & Simmons, 2010).

1800–1899. George E. DeBoer (2000) observed that at the end of the 19th century, amidst a changing world affected by developments in science and technology, it was the scientists themselves who promoted the teaching of science in schools. DeBoer noted that the democratic ideal of independence of thought that arose in the scientific community was in conflict with the contemporary logic that the goal of education should be teaching the humanities in order to espouse worthy and noble virtues. The National Education Association's report in 1893, by the Committee of Ten chaired by a scientist and President of Harvard University, Charles Eliot, recommended that 25% of the high school curriculum be devoted to a relatively new subject—science (Atkin & Black, 2007; DeBoer, 2000). Thus an era of more widespread science education was born.

1900–1957. Science education, however, was still not accessible to the larger community even in the 20th century because secondary science education was not designed for all learners. It was aimed at college bound students and science was hardly taught at all in the elementary school (Karno & Glassman, 2013). Elementary school science remained in the curriculum essentially in the form of Nature Study until the decades following World War II (Appleton, 2007). Atkin and Black (2007) found that advocates of Nature Study appreciated that it elicited student interest and imagination, but Nature Study's preference for isolated facts over generalizing principles may have contributed to its decline in the 1930s. As Atkin and Black described it, science instruction began to focus on generalizations, such as geologic time on Earth. In addition, Atkin and Black noted that the goal of science teaching in public schools became more attuned to helping students understand the applications of science and technology in their everyday lives, such as how a car motor worked. Columbia University Teachers College and Dewey's experiential philosophy of education influenced these changes (Dewey, 1997/1938).

According to DeBoer (1991, 2000), in 1957, science education suffered a shock and revival because of a satellite, Sputnik, launched by the Soviet Union. This was a technological advance that represented a threat to the U.S. at the time because we were not the first nation to launch a satellite in the race to space (Lazarowitz, 2007). After Sputnik, science education experienced massive reforms to focus on the big ideas behind science (versus a previous focus on everyday technology and Nature Study) and science instruction was expanded to the lower grades (Yager, 2000).

1957–2000. As Robert E. Yager (2000) recounts, by the 1970's Sputnik-inspired science education reforms were fading. He noted that even though more open-ended inquiry was a prime focus of Sputnik era reforms, many lessons were taught by direct instruction using textbooks that were not questioned. Scientific knowledge for the purpose of education was often interpreted as static, and instruction remained for the most part didactic. Yager went on to describe that in the 1980's, in response to a perceived threat from countries such as Japan and Germany, countries that were seen to possess academic supremacy over the U.S., we began to focus on how children learn science (National Research Council [NRC], 1999). New national science education standards were established in 1996 by the NRC that cast science in more of a 'real world' context to help students connect their science learning to their prior knowledge (National Research Council, 2005).

2000. As researcher Cabe Trundle (2015) noted recently, traditional science instruction at the elementary level tends to be didactic, text-centered or workbook focused, and requires rote memorization. She found that these inappropriate pedagogies persist for early childhood science education. Cabe Trundle argued that these traditional pedagogies often cause teachers to forget what they know about children in order to comply with normative practices in science education. Normative practices in the 21st century are affected not only by tradition, but also by technological advances such as the World Wide Web, federal legislation like NCLB, private industry initiatives to integrate engineering like STEM, science educational standards at the national (NGSS*)* and state levels, initiatives to integrate socioscientific issues (SSI), and future government funding initiatives like ESSA.

Hope for significant changes in the future of science education exists in opportunities that have emerged since the late 20th century, such as advances in the World Wide Web and open access research tools online that encompass expanding information with varying perspectives that could work in favor of human progress (Karno & Glassman, 2013). The World Wide Web has emerged as a tool for research and discovery for PreK-12 science education and offers an opportunity for the sharing of information and perspectives which can engage students with the scientific community (Zoller, 2011). Web resources now have creative options for students to design and share their own participatory science projects—the path they may take online in science is not pre-defined. Students can define the path they will take in designing participatory science depending upon their area of interest. “[T]he web extends the classroom out into the larger initially undefined information universe” (Karno & Glassman, 2013, p. 928). But, online opportunities for inquiry can only be made available to students in elementary schools if teachers have the technology to use the Internet and time to teach science.

2002. In part due to No Child Left Behind (NCLB) federal legislation enacted in 2002, science education is less privileged at the elementary school level than subjects that are more frequently tested, such as reading and mathematics (Appleton, 2007; Milner et al., 2012; Roth, 2014). One of the negative effects teachers noted is that high stakes state testing promoted by NCLB federal legislation narrowed the curriculum by forcing teachers to put priority on subjects other than science (Jones & Egley, 2004). One teacher in Jones and Egley's study lamented that promoting a love of learning had to wait until the end of the school year—after standardized testing was over:

> Before FCAT [Florida standardized high-stakes testing] I was a better teacher. I was exposing my children to a wide range of science and social studies experiences. I taught using themes that really immersed the children into learning about a topic using their reading, writing, math, and technology skills. Now I'm basically afraid to NOT teach to the test. I know that the way I was teaching was building a better foundation for my kids as well as a love of learning. Now each year I can't wait until March is over so I can spend the last two and a half months of school teaching the way I want to teach, the way I know students will be excited about. (p. 15)

In Jones and Egley's study (2004) they reported teachers speaking out in favor of making science learning experiences exciting for their students.

A goal of NCLB enacted in 2002, was for all students to reach a set proficiency level in mathematics and reading on state tests by the year 2014. Each state developed its own proficiency leveled standardized tests (NSF, 2008). Findings from a survey of teachers (N = 236) in North Carolina indicated that teachers changed their instruction to include more time for test preparation in order to meet the demands of the emphasis on test scores in mathematics, reading and writing (Chapman et al., 1999). Chapman et al.

noted that teacher evaluation and pay depended upon students' test scores in North Carolina, and that state mandated standardized end-of-year scores were compared to other schools' scores using a public 'report card.'

In this same study (Chapman et al., 1999), teachers reported a drop in their morale. Chapman et al. also found that the high stakes testing caused a narrowing of the curriculum, as well as a reduction in science teaching time and quality. The public can easily understand reading and mathematics scores, Chapman et al. noted, but it is more difficult for the public to understand other concepts that are not reflected in students' test scores. Complex concepts, such as fostering an understanding of the nature of science, critical thinking, metacognition, character building, collaboration, or student motivation, as Chapman et al. (1999) suggested, may be hard for the public to understand.

The focus on statewide tests, according to Chapman et al. (1999), meant that the control of education was taken out of local hands. If the school scored too low on their report card at the end of the year, the state could close the school, putting teachers' employment at risk, and Chapman et al. reported they heard fear in teachers' voices. Students were also expected to meet pre-set levels of annual yearly progress (AYP) measured by end-of-year test scores (Public Schools of North Carolina, n.d.).

As early as 2008 in a publication titled, "All students proficient on state tests by 2014?" the National Science Foundation (NSF) determined that it was impossible to meet that goal by 2014, largely due to the fact that lowest performing subgroups determined the proficiency of the whole school, and those students slated to most benefit from the legislation were falling below expected gains. The NSF later found that results for science standardized testing were also below expectations: “Relatively few students at grades 4, 8, and 12 reached their grade-specific proficiency levels in science on the 2009 NAEP (National Assessment of Educational Progress) assessment” (NSF, 2012a, p. 1-4). These NSF findings of lower than expected student achievement in science coincided with a new initiative to integrate engineering as well as technology and mathematics with science instruction.

2007. The acronym STEM (Science, Technology, Engineering, and Mathematics) was used in 2007 to describe major federal educational legislation in the America Competes Act of 2007. This act addressed a growing concern that the U.S. was not preparing enough teachers, students and practitioners in the areas of science, technology, engineering and mathematics (Kuenzi, 2008). STEM initiatives in this act sought to integrate the regularly tested subject of mathematics with other marginalized subjects such as science, technology, and engineering. This form of science education had already been established by the 21st century in specialized STEM schools serving gifted and talented students (Kuenzi, 2008). At this time a STEM educational initiative was aided by public and private sector research and development initiatives. Venture capital investments from industry totaled $43 billion for research and development at the turn of the 21st century, and private industry was funding 62% of all research and development in the U.S. by 2009, despite economic downturns in 2008 (NSF, 2012c).

José-Marie Griffiths, a former national science board member recognized that the federal and state governments shouldered a responsibility for taking a leading role in “training the next generation of scientists” (para. 9). The NSF recognized that immigration policy also played a role in the number of scientists in the U.S. The idea was that if we cannot educate scientists from childhood (something NAEP assessments hinted at in 2009 [NAEP, n.d.]), we could retain foreign students at our universities who were studying science here in the U.S. with favorable visa and immigration policies.

The potential threat to the U.S. of a reduction in our capacity to innovate in science and technology was a strong NSF argument for STEM reform in science education. According to the NSF, private industries in the U.S. were concerned that we needed to prepare our students to enter the STEM workforce. Some private industries supported an initiative through Achieve, Inc., a private non-profit corporation, to establish new national science standards K-12, seeking adoption by all 50 states in the U.S.

2013. The Next Generation Science Standards (*NGSS*) are science curricular standards (K-12) with conceptual links to the practices of engineering and technology as well as crosscutting 'big ideas' in science. In a complex string of events, *NGSS* were established by an Achieve Inc. initiative for public education in an attempt to boost the STEM workforce (National Academies of Sciences, Engineering and Medicine, 2016). The Carnegie Corporation of New York, The GE Foundation, The Noyce Foundation, The Cisco Foundation, and DuPont were some corporations that sponsored Achieve, Inc. (NGSS, n.d.c). *NGSS* were released for adoption by states in 2013, and were adopted by 26 states.

The NRC's (2012) "Framework for New K-12 Science Education Standards" was used as a foundation for the *NGSS* standards. *NGSS* were structured differently from the original NRC “Framework” in that they were structured to encompass three dimensions of science education: crosscutting concepts, core ideas, and practice. For elementary school, *NGSS* list curricular connections for the science standards to the two other tested subjects: English/Language Arts and mathematics (NGSS, n.d.c). In a NRC institutional review of the *NGSS*, the science standards were found to be in alignment with the NRC’s vision (National Academies of Sciences, Engineering and Medicine, 2016).

There are, however, some criticisms of these new *NGSS* science standards. Zoller (2011) argued we limit curiosity and creativity in primary schooling with such a focused emphasis as *NGSS* has on applied science and technology without incorporating critical thinking. He found that lower order cognitive skills are emphasized in the use of the *NGSS* and that creative thinking and higher order cognitive skills were not happening. Zoller and Robottom (2012) both advocated for an exploration of social and environmental contexts in science education. Social and environmental responsibility is not directly addressed in the elementary grades in the *NGSS*.

The *NGSS* do address ecological change in elementary school in the third-grade standards by suggesting that changes in habitats affect the animals living there (NGSS, n.d.b). Such changes in a habitat are not directly attributed to humans, nor are changes in human environmental behavior addressed in the standard 3-LS4-4. I quote the science practice to accompany this standard below. Note, the *NGSS*, as evidenced in this quote, set an assessment boundary, suggesting teachers are not to address certain topics or related socioscientific issues while teaching this standard (e.g. the greenhouse effect or climate change).

> Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change . . . [Clarification Statement: Examples of environmental changes could include changes in land characteristics, water distribution, temperature, food, and other organisms.] [*Assessment Boundary: Assessment is limited to a single environmental change. Assessment does not include the greenhouse effect or climate change.*] (NGSS, n.d.b, para. 3)

Perhaps the writers of *NGSS* assumed that teachers might have misconceptions about the greenhouse effect and global warming, or not know enough to understand the big ideas in science behind these topics as Roth (2014) found, and so it would be better to avoid the topics. Or, perhaps the writers of *NGSS* thought that introducing the enormity of the issues of global warming and the greenhouse effect to young children might scare them so much that they would ignore the issues rather than address them, creating ‘ecophobia’ (Sobel, 1996).

Elementary school children are capable of abstract thinking (Roth, 2014), so perhaps they are able to understand complex topics and possible solutions if educated about topics like global warming. The aforementioned third grade *NGSS* standard limits the teacher professionally, especially if he or she could capably introduce the issue of anthropogenic environmental change as a threat to an ecosystem with appropriate pedagogy.

The Current Situation

2015. The No Child Left Behind (NCLB) act expired, and was renewed in 2015 in a slightly different form. The act is now called the Every Student Succeeds Act (ESSA, 2015). With this new national mandate, there is still an emphasis on 21st Century Schools and grant funding available for STEM and computer-focused initiatives, as well as for

Environmental Education initiatives, in order to offer children a well-rounded education, improve conditions for student learning, and improve the use of technology to promote digital literacy of all students (ESSA, 2015). 21st Century Schools, as mentioned in ESSA, is a widely used term with many different definitions. As defined by Cator (Education Week Teacher PD Sourcebook, 2010), what 21st Century Schools meant was that schools teach for success in this century.

> Success in the 21st Century requires knowing how to learn. Students today will likely have several careers in their lifetime. They must develop strong critical thinking and interpersonal communication skills in order to be successful in an increasingly fluid, interconnected, and complex world. (p. 32)

This vision does not match current teaching trends in elementary schools as identified by Roth (2014).

Reform efforts such as NCLB initiatives to raise standardized test scores for all students by 2014, or public and private policy initiatives to increase the STEM workforce in our society through education did not meet expected outcomes in the past, even though there was pressure on teachers and students to meet expected outcomes (Cabe Trundle, 2015; Alber-Morgan, Sawyer, & Miller, 2015; NSF, 2012b; Schoen & Fusarelli, 2008). There is a new initiative in ESSA (2015) that reaches beyond applied science and technology to pursue a greater public understanding of the natural environment. The natural environment is where problems are occurring and this warrants an understanding of the natural environment from the youngest of ages (Tippins, Neuharth-Pritchett, & Mitchell, 2015). The ESSA (2015) may suffer the same fate as prior reform initiatives that were in part a reaction to international test scores in science and mathematics

(Programme for International Student Assessment [PISA]; Organisation for Economic Co-operation and Development, 2012). Except, there is a difference: ESSA. The ESSA (2015) includes funding for another initiative capable of improving formal science education in the U.S., Environmental Education. Also, Environmental Education will not be subject to high-stakes testing under the ESSA.

"The greater the consequences for not attaining testing goals, the more threatening and high pressure the school or district becomes as a work environment" (Schoen & Fusarelli, 2008, p. 192). Perhaps due to the current international atmosphere of testing by PISA and national high-stakes testing programs, there is a marked decrease in student interest in science in many countries (Kelly, 2014). This current decline in student interest in science coincides with a recognized need for children to find science interesting and engaging in order to encourage them to choose a career as a scientist and be a part of a scientifically literate society (Taylor & Jones, 2008). We share an urgent need to address worldwide environmental problems linked to global warming in a socially just manner if we are to sustain our growing world population of billions of people and the biodiversity on Earth that we all need to survive (Wilson, 1988). According to biologist E. O. Wilson, in 1988, there were no political measures in place to address this issue. Other nations surpassed the U.S. in science literacy as evidenced by international measures such as mathematics and science scores PISA testing (Organisation for Economic Co-operation and Development, 2012). National leaders in education prioritized science education reform in the last decade, but the success of these reforms depended upon changes at the classroom level (Milner et al., 2012). Teachers needed pedagogies to use in order to help their students develop socioscientific competencies.

> Science education faces a number of important challenges. First we face a global ecological crisis. While such a crisis cannot be addressed by science education alone, studies of how students learn to use evidence, address socioscientific issues, and develop an understanding of the consequences of their actions can inform our educational institutions about pedagogies that develop such competencies. (Kelly, 2014, p. 367)

Kelly (2014) called for research into how students learn to apply science education to current challenges. He found that we as researchers could better inform educational institutions and their political administrations of effective pedagogical practices that will help students develop needed science competencies. Kelly concluded that education alone will not solve an ecological crisis, but he insinuated that science education could facilitate students learning how to devise new ways of addressing ecological challenges.

Science Education is Not Privileged

Science education at the elementary school level was sidelined in favor of mathematics and reading, and this has been the situation for many years (Chapman et al., 1999). Elementary school teachers cut time from science teaching to increase time for mathematics and reading (Griffith & Scharmann, 2008). Although science took on new importance as science assessment was phased in to comply with NCLB, Milner et al. (2012) found that teachers' beliefs about teaching science were more influenced by their administrators and colleagues than by policy. Milner et al. noted a disconnect between the NCLB and STEM initiatives and what is really happening in the majority of elementary school classrooms.

Milner et al. (2012) noted that until administrators make science learning a priority, a knowledge gap at the elementary level will persist; skills will not be learned; interest in science will not be built; and this knowledge gap may not be filled at higher grade levels. Children tend to choose their career early in life (Koerber, Mayer, Osterhaus, Schwippert, & Sodian, 2015). But, student interest in science was found to wane by the last year of elementary school (Carrier, Tugurian, & Thomson, 2013). Despite the fact elementary school is when we should interest students in science, some elementary school teachers in Milner et al.'s (2012) study were told not to teach science while some teachers complained of not having the materials needed or the time to set up science activities. These teachers expressed that they would welcome outside support and help from museums and other science organizations, but Milner et al. reported these external supports were rare. Another aspect of science education that is rare is fieldwork.

Fieldwork is Missing

Science fieldwork as part of science education, an educational activity that makes use of natural and built environments outdoors (Association for Science Education Outdoor Science Working Group, 2011), was found to be under threat by Dillon et al. (2006) and so much in decline that scientists worried it was headed for extinction (Barker et al., 2002). Teachers may take field trips with their class to natural outdoor areas supported by local educators on site, but they seldom possess the pedagogical tools, knowledge, confidence, or experience to enact such experiences on their own for their students (Tal & Morag, 2009). There is extensive literature examining the many challenges teachers face to providing outdoor learning opportunities for students (Rickinson et al., 2004). In a comprehensive review of the literature, Dillon et al. (2006) found that many fears of the outdoor setting act as barriers to fieldwork. Dillon et al. noted safety concerns and fears of natural hazards, such as the fear of finding snakes, could prevent enjoyment of the outdoor experience for both teachers and students. They found evidence in research that feelings that range from inconvenience or physical discomfort to high disgust sensitivity to organic matter can adversely affect students' willingness to learn outdoors.

Teachers reported many reasons for not doing fieldwork. School curriculum requirements and shortages of time and materials are reasons teachers gave for not taking students outdoors for learning experiences (Dillon et al., 2006). Fieldwork is not required in the U.S. Teachers and students may not be comfortable with fieldwork, and policy and social norms are also discouraging factors (Dillon et al., 2006). Dillon et al. noted that elementary school students were found to be significantly more enthusiastic about outdoor learning than older students, but if students were accustomed to pre-set experiments with a standardized outcome (a more static interpretation of science) then experimental practical ecology outdoors (with the possibility of unpredictable outcomes to inquiries) proved to be a difficult concept.

Future Directions

Building understandings of the non-static nature of science and building confidence in science are important components of science education's future (Fensham, 2015). Fensham found that trust in science is key to interdisciplinary and interorganizational partnerships that are now needed in science to investigate current large-scale problems. Promoting a better understanding of the strengths and limitations of science is one suggestion Fensham made to promote trust. Fensham proposed we should seek to achieve science informed citizenry as a goal of science education. He saw a need for this as a response to deliberate campaigns to undermine citizens' trust in science. A campaign such as one creating a public debate over the anthropogenic causes of climate change where there is not a debate in the scientific community is one such example (Hoffman, 2015). Trust in science by the general public could also further citizen involvement in science, Fensham (2015) noted. Building partnerships and seeking involvement in external supports, such as citizen science programs, may be a future direction for science education (Bonney, Phillips, Balard, & Enck, 2016).

In addition to building understandings and trust in science, another future direction for science education is the inclusion of socioscientific instruction. Zeidler (2014) suggested that including socioscientific issues in science education in a democratic format could engage students because it puts many elements of the nature of science in context and gives students a personal landscape upon which they can explore important scientific questions. According to Zeidler, students can explore socioscientific issues, such as the concerns about the impact of technology on fragile ecosystems, and see that there are conflicting goals, and learn that in order to find an optimal solution we may have to temper idealism with facts—all the while engaging in decision-making with a sense of conscience as a guide, informed by ethics, morals, and awareness of contexts.

In our present era of standards based science, SSI is marginalized (Zeidler, 2014). Zeidler explained a variety of teacher beliefs that affected inclusion of socioscientific issues in science instruction. Zeidler found the teachers' belief in a relationship between ethics and science was vital to the inclusion of socioscientific issues in their instruction. Or, Zeidler pointed out, teachers may see a connection between ethics and science but not well understand how (pedagogically) to include socioscientific issues in science education, and ". . . [t]he marginalization of SSI curricula in most standards-based movements exacerbates these concerns" (Zeidler, 2014, p. 705).

We have examples of how SSI can be incorporated into science instruction. Roth and Lee (2004) studied a group of middle school students who learned science while participating in a community environmental effort to find out more about a local watershed. Students' legitimate participation in community as a part of their science education could be viewed as a starting point for lifelong learning and a bridge between formal schooling and outside community life according to Roth and Lee. Their research shows evidence that conducting scientific study of and informing a community about natural areas as part of school science is one way that teachers can incorporate complex social and environmental issues into science education.

The impending challenge in science education is to address climate change and anthropogenic causes in order for students to be able to use science to address these problems (Kelly, 2014). But, as Zoller (2011) argued, *NGSS* are missing critical social and environmental responsibility components (Zoller, 2011). Additionally, elementary science is not being taught using the outdoors as a platform for learning and therefore students are not exposed to the study of ecology and climate change experientially. Science education is missing a critical fieldwork component (Barker et al., 2002).

Science Education Outdoors

Finding out firsthand what the strengths and limitations of science are by actually doing science in the natural world, doing fieldwork as a part of science education, could foster a better understanding of the nature of science (Slingsby, 2006). There is substantial research on teaching and learning out-of-doors, for both fieldwork and outdoors educational visits (field trips), that supports these learning experiences for children because they add value to their daily classroom experiences (Dillon et al., 2006). Barker et al. (2002) suggested that fieldwork be a required part of teaching biology and noted “fieldwork fills a number of worthwhile objectives in an incidental way” (p. 4). Dillon et al. (2006) suggested that it is important to offer a variety of components in fieldwork—for example offering a balance of exciting fieldwork and indoor preparation and follow up work clearly linked to the outdoor work.

Barker et al. (2002) recognized that fieldwork provided students with excellent opportunities to work as teams. Unfortunately, we lack any widespread program that facilitates basic ecological understandings that are learned from the natural world (Van Matre, 1990). A unified national initiative requiring formal science instruction in the outdoors may not be easy to achieve in the U.S., but similar initiatives are already required in other places, such as in the UK (Rickinson et al., 2004).

A Brief History

As Slingsby (2006) noted, science education began outdoors as experiential. This was recognized in Rousseau's (1844/1762) philosophy bestowing importance on learning in the natural world in the Enlightenment era. In response to agricultural depression in the late 19th century, elementary school science lessons for Nature Study were distributed to teachers by Cornell University, and Comstock (1939) later compiled them into a handbook of Nature Study, which remains a valuable teaching tool today (Carter & Simmons, 2010). As Carter and Simmons noted, influenced by the Enlightenment and Nature Study, Outdoor Education and Conservation Education grew to be defined as separate disciplines. Outdoor Education grew in parallel with science education since the early 1800s and though it has many definitions, it is focused on experiences, takes place outdoors, and promotes a relationship between people and the natural world (Priest, 1986; Van Matre, 1990). Conservation Education "helps people of all ages understand and appreciate our country's natural resources—and learn how to conserve these resources for future generations" (U.S. Department of Agriculture Forest Service, n.d.). Recognizing some well-tested lesson plans in the 1920s, the Department of the Interior Bureau of Education published a book of outdoor lesson plans for children derived from schoolteachers' experience (Fox, 1927). Through state and national parks, and other government and university initiatives, Conservation Education also grew in parallel with science education. Forestry (the science of caring for forests) was born in the early 20th century at Cornell University as a reaction to the large-scale losses of woodlands in the 19th and early 20th centuries (Rutkow, 2012). Traditionally, it was through direct contact with the natural world that science was taught in the U.S. (De Boer, 1991), and there is a call from both scientists and educators to revert to incorporating the outdoors into formal science education today through fieldwork, as an integral part of science education (Slingsby, 2006; Wals et al., 2014). With the historical decline in Nature Study and the current decline in fieldwork, science education outdoors is in peril just when it is needed (Barker et al., 2002).

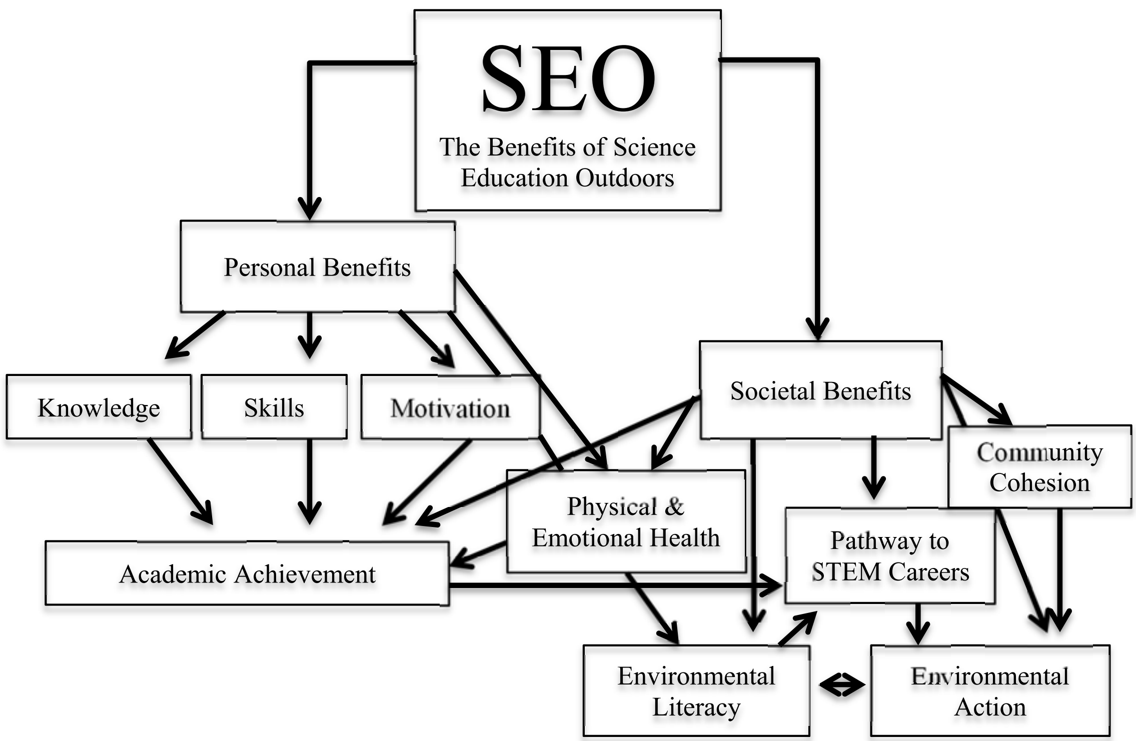
The Current Situation

The U.S. faces the greatest natural challenge yet, an escalating global environmental crisis due to human induced climate change, but lacks a coordinated policy response despite a scientific consensus of the phenomenon (Hoffman, 2015; Oreskes, 2004; Wilson, 1988). Fieldwork could be a critical part of an educational policy response that sets a goal of helping citizens learn to value the environment and understand the science behind it (Barker et al., 2002). In the Achieve Inc. (2013) Next Generation Science Standards (NGSS, n.d.c) there was no mention of 'fieldwork' in the elementary grades, and I found but a scant mention of the word 'outdoors' elsewhere.

Benefits of Learning Outdoors

The many recognized benefits to learning outdoors could be grouped into two major categories: (a) individual benefits, and (b) societal benefits (see Figure 5). Individual benefits include: knowledge; skills; motivation; physical and emotional health; and environmental literacy. Societal benefits include: physical and emotional health; environmental literacy; pathways for STEM careers; community cohesion; and environmental action.

As shown in Figure 5, cognitive, physical, and emotional learning are integrated (Ballantyne, Anderson, & Packer (2010). These benefits can result in academic achievement (Dillon & Dickie, 2012). Academic achievement derived from outdoor science learning can lead to STEM careers for both mainstream and marginalized students (Brown & Lent, 2016).



Note. STEM represents Science, Technology, Engineering and Mathematics.

Figure 5. The Benefits of Science Education Outdoors (SEO).

To explain the relationships between the benefits of learning outdoors, I show (see Figure 5) that when children develop an understanding of the natural world at a young age, it can help promote environmental literacy (Chawla & Cushing, 2007). Environmental literacy in turn encourages environmental stewardship (environmental action) in adulthood (Chawla & Cushing, 2007; Palmberg & Kuru, 2000). I describe these benefits of science education outdoors, supported by empirical evidence, in the following sections of this chapter.

Knowledge. In a review of the literature on outdoor learning, Rickinson et al. (2004) found several studies that reported cognitive gains for students who worked in school gardens or on school farms. Based upon an extensive literature review by Dymet (2004), Rickinson et al. argued that natural environments help students develop cognitive skills related to critical thinking, creative inquiry problem solving, and creative development when learning outdoors on the school grounds. Eick (2012) found that third grade public school students whose teacher used Nature Study to meet both science and Language Arts curricular requirements successfully met the annual yearly progress goals, AYP, in reading.

Skills. Rickinson et al. (2004) found evidence that outdoor learning activities on the school grounds and community projects had a positive effect on students' social skills and motor skills. Miller (2007) noted extensive evidence of improved relationship skills, and improved visual-spatial skills for children engaged in outdoor activities. Slingsby (2006) described the visual-spatial skills that children develop while engaged in fieldwork: observing closely enough to see details and patterns; looking at objects and ideas from different perspectives; learning about pathways and movement through space; developing an understanding of relationships of scale; experiencing what area and volume are; and being able to estimate distance. In addition, he noted that fieldwork helped students develop skills in using instruments with precision.

In a study of pre-school and kindergarten classes conducted by Miller (2007), children developed important skills when engaged in outdoor activities in the school garden and greenhouse. Students learned to observe closely, seeing shapes, patterns, and details. When they went back into the classroom to learn they had an easier time understanding concepts that they had already internalized through hands-on experiences in nature. Knowledge and skills are benefits that can lead to academic achievement, and they are enhanced by increased student motivation to learn, another benefit of science education outdoors.

Motivation. Dillon and Dickie (2012) found that learning experiences in nature increased students' motivation to study science. There were many reasons for this in the literature. Miller (2007) noted that outdoor experiences provide motivation for students to communicate in their own way and on their own time schedule, whereas inside the classroom when teachers make those decisions (e.g., quiet work time, lecture time), students lose interest in communicating their knowledge. Rickinson et al., (2004) noted that outdoor learning activities such as working in a garden promoted motivation to exercise and eat healthy foods.

Teachers in Maynard et al.'s (2013) study noticed increased on-task engagement and enjoyment for their students who were engaged in outdoor learning. Maynard et al. found that motivation to learn on one's own is an important benefit of play-based learning outdoors. They found that the more outdoor places child-initiated activity took place, the more learning that took place. Child-initiated learning in the outdoors environment revealed motivation in students in Maynard et al.'s (2013) study who were considered to be ‘underachieving’ students by their teachers inside the classroom. This phenomenon prompted the teachers to question their classifications (for example underachieving or high achieving) of students. This outdoors space was found by Maynard et al. to be a place in which the children could reconstruct their relationships with their teachers and show themselves as “strong, competent children rather than underachieving pupils” (p. 223). There are, in addition to the aforementioned benefits to outdoors learning, considerable health benefits.

Physical and emotional health. There is ample evidence that time spent in nature has both physical and psychological benefits (North American Association of Environmental Educators [NAAEE], 2016) and a variety of uses of the school grounds were associated with health improvements (Rickinson et al., 2004). Yet, children are going outdoors less over time (Cleland, Timperio, Salmon, Hume, Baur, & Crawford, 2010). Rickinson et al. (2004) found evidence in research that students learning in the outdoors experienced short-term physical fitness gains; they were absent fewer days from school than comparable peers at schools surrounded by tall buildings, and that students working outdoors in school gardens improved their eating habits. There is a large body of research that shows that childhood environmental experiences and contact with nature promote physical and mental health and a sense of well-being in children (Hacking, Scott, & Lee, 2010).

Miller (2007) noted that emotional development happens outdoors for students in a way that could not happen in the classroom. Miller pointed out that this is especially important for special needs children who may not have the skills to communicate what they know because the outdoors provides an area where children can communicate what they know in a different way from the way they might do so in a traditional classroom. With teacher support, Miller found, the outdoors can also become a safe place to express positive emotions, and a place to learn to process and manage negative emotions.

Taylor and Kuo (2011) found that for Attention Deficit/Hyperactivity Disorder (ADHD), a condition diagnosed in children more commonly than any other behavioral disorder, behavior can be improved by regular exposure and play in outdoor settings and offered benefits including but not limited to physical activity, heath, cognitive functioning, and academic achievement. Taylor and Kuo found that children benefit from daily exposure to green spaces, and that this could be a potential treatment for ADHD and ADD.

The outdoors also plays a positive role in social development and learning, promoting teamwork and new friendships, according to a literature review by Rickinson et al. (2004). Passy (2014) learned that the pedagogy used in the garden was inclusive and sought to help all students develop emotionally, socially, and academically. Gardens became a “wonderful space” (p. 34) according to Passy that contributed to students’ social development. Passy noted that promoting using the garden for teaching and learning outdoors was critical. “At a time when funding for such projects is increasingly scarce, this may be difficult—but, given the wider political and financial environment, is of critical importance for children’s social, emotional, and academic development” (p. 37).

Academic achievement. Dillon and Dickie (2012) reported that students perform better in reading, mathematics, science and social studies when learning in nature. When fieldwork is part of the learning experience, students have higher test scores on standardized tests (Dillon et al., 2006). In Rickinson et al.'s (2004) noted that participation in school gardening enhanced academic performance. The school grounds settings were not the focus of a great deal of empirical studies in the past, but the State Education and Environmental Roundtable (SEER) (2016), a program for integrating the environment as an integrating context for learning in California, found that school grounds green initiatives positively influenced academic achievements. The SEER 2005 report on student achievement confirmed that students scored higher on standardized tests than students who did not go out into the schoolyard to take part in the greening initiatives. Klemmer, Waliczek, and Zajicek (2005) also noted increased scores on science achievement tests for children engaged in learning in the garden as compared to children without the same experience. Academic achievement is needed in order to enter the pathway to STEM careers.

Pathway to Science (STEM) Careers. Hiller and Kitsantas (2015) found that citizen science in particular was a significant pathway to STEM careers. They noted that interaction with field experts helped students develop science skills, metacognition, academic achievement, and led to STEM career paths. They further noted that there is evidence in research that natural contexts for science learning not only promote high levels of student interest, they also teach students through first hand experiences the behaviors and habits of scientists. However, not all students involved in citizen science will become scientists, but students could benefit from scientific and environmental literacy gained through the outdoor learning experience.

Environmental literacy. Environmentally literate citizens, according to the NAAEE (2011) are environmentally competent, knowledgeable about what they need to do to keep the global environment healthy and sustain its resources, and have the necessary dispositions to do so. The NAAEE developed a framework for assessing environmental literacy that they released in 2011, as an optional component of the international PISA survey of 15 year olds,

The NAAEE (2011) framework for assessment of environmental literacy includes: competencies (e.g., the ability to ask questions, analyze, investigate, use evidence, and evaluate environmental problems and plans to remedy them); knowledge (e.g., knowledge of physical/ecological and social systems, issues and strategies for resolution); and dispositions (e.g., positive sensitivity to the environment, attitudes/worldview in favor of the environment, a sensation of personal responsibility to reduce negative impacts on the environment, and self-efficacy and motivation to act in favor of the environment).

In order to engage people and communities in finding solutions to biodiversity loss and climate change, experiential and integrated lessons outdoors are an integral part of Environmental Education according to the NAAEE (2016). Lieflander, Frölich, Bogner, and Schultz (2013) found that Environmental Education is a critical tool for young children (under the age of 11 years old) who connected more to what they learned outdoors in natural settings than older students did. Lieflander et al. suggested that

Environmental Education in a schoolyard would not have the same positive effects as a program in a natural setting with woodlands and streams, however they also found that experiencing nature outdoors for several days had a stronger learning impact than shorter or one-day programs.

Community cohesion. Working together outdoors aids in community cohesion according to Maller et al. (2006), and this can be viewed as another societal benefit of engaging children in fieldwork. Community cohesion is the dissolving of prejudices about race and economic status (Maller et al.). Community cohesion according to Amortegui (2014) seeks to build common objectives in a tolerant multi-cultural community with high degrees of social interaction and civic engagement, and promotes a willingness to help others. As Amortegui described community cohesion, it was difficult to implement, however Dillon and Dickie (2012) found evidence in qualitative research that community cohesion was one of the many benefits of learning in nature.

A literature review by Evergreen (2000) found that teachers benefited from participating in school grounds projects. Teachers made new curriculum connections and increased their morale and enthusiasm for teaching. Evergreen found that school grounds projects gave teachers new reasons to go outside. He noted that going outdoors increased their engagement in teaching and students' enthusiasm for learning and that it reduced discipline problems and classroom management problems.

Eick (2012) noted the importance of childhood experiences facilitated by significant adults, and suggested that schoolteachers can play this role by fostering knowledge about environmental issues and connecting children to larger community-based projects. Lower income children with low academic achievement reasonably have fewer opportunities for outdoor recreation (Liefländer, Fröhlich, Bogner, and Schultz, 2013). The accessibility of the schoolyard to all schoolchildren is equitable and affordable. Many children have lost access to outdoor play environments because of parents' fears, and this means that school grounds and school gardens are among the few outdoor spaces that are still accessible to children (Malone, 2007). Such access allows children of all economic statuses to participate in outdoor learning. Such learning can be facilitated by the schoolteacher (Wals et al., 2014). According to Malone (2007), learning ecological concepts is enhanced by prior experiences in nature, and if children lack those experiences they are at a disadvantage in learning those concepts.

Environmental action. The act of participating in scientific investigation into the global effects of biodiversity loss and climate change by collecting data in the schoolyard for scientists to use (i.e. citizen science) could be considered a form of environmental action. However, Tseverni (2011) found that top-down science instruction for environmental action projects in Greece was not effective in generating students' critical thinking or student interest in learning. Tseverni recommended an environmental action model where students take on an issue of importance to them in their community and teachers put more emphasis on student-led investigation and action, and less emphasis on obtaining science knowledge.

Summary of benefits. Science Education Outdoors (SEO) is a form of learning science that is part of and preceded the institution of formal Environmental Education (e.g., out-of-doors scientific investigations as part of Nature Study, Conservation

Education, Outdoor Education, fieldwork, or citizen science). In response to a natural world in danger (e.g., deforestation, pollution, global warming, climate change, defaunation, and environmental degradation) we enact responses in science and Environmental Education that are philosophical, political and educational in nature. These responses pull us again and again towards the first-hand study of our natural environment, where these crises are occurring.

Holbrook and Rannikmae (2009) defined scientific literacy as retaining an appreciation for the nature of science, scientific knowledge, attitudes, and social values. Science education plays an important part in the underlying concepts of Environmental Education and can boost environmental awareness (Littledyke, 2008). Meaningful science literacy can be supported by environmental literacy through science and Environmental Education outdoors in a natural setting.

Science education and Environmental Education were found to lead to environmental literacy and environmental action (Chawla & Cushing, 2007). The two fields of science education and Environmental Education can benefit each other (Tal & Abramovitch, 2012). When combined they offer many benefits to children (Dillon & Dickie, 2012). For individuals, science education outdoors with Environmental Education offers knowledge, skills, motivation, health and environmental literacy. For society they offer the benefits of public health, environmental literacy, community cohesion and environmental action. Children's knowledge, skills, motivation, health, and environmental literacy support science academic achievement, which Hiller and Kitsantas (2015) suggested, can in turn lead to STEM careers that are needed in our society now and in the future. If science education outdoors and Environmental Education use citizen science, this form of education addresses the current ecological crisis as defined by Kelly (2014).

Environmental Education

Environmental Education and Science Education can benefit each other, but Environmental Education is not a required part of formal education in most states in the U.S. As defined in Chapter I, Environmental Education is a learning process that increases people's knowledge and awareness about the environment and associated challenges, develops the necessary skills and expertise to address the challenges, and fosters attitudes, motivations, and commitments to make informed decisions and take responsible action. (UNESCO, 1978, p. 2).

Environmental Education is not as widespread in the U.S. as it is in other areas of the world. Many states do not include environmental literacy as part of formal education or graduation requirements from high school. While ESSA (2015) potentially provides the opportunity for funding Environmental Education efforts, this funding is competitive with and available to support a wide range of initiatives. In contrast, European countries not only require Environmental Education as an integral part of students' required course of study, but envision that it should play a role in promoting sustainable practices as well (Dopico & Garcia-Vazquez, 2011).

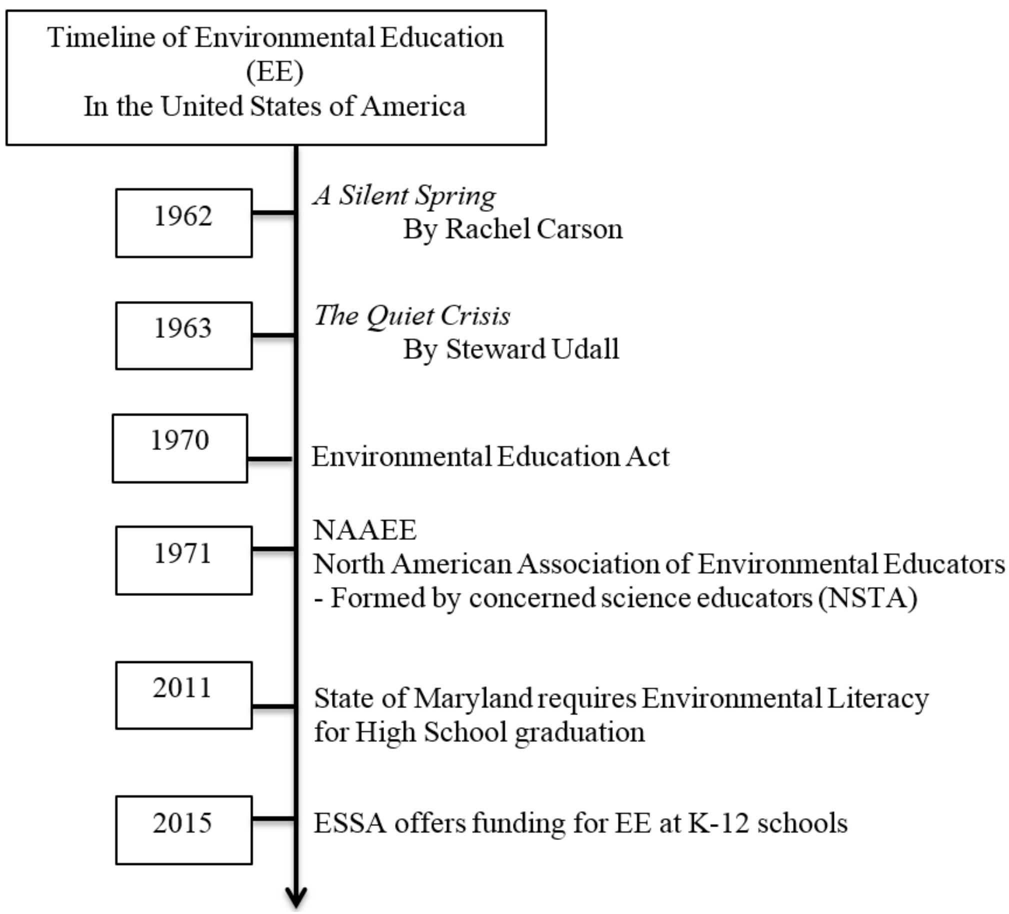
A Brief History

Carson. Environmental Education in the U.S. began in great part as a response to environmental pollution and pesticide dangers well publicized by authors such as Rachel

Carson in her book, *Silent Spring* (1962). What was once seen as limitless nature too large and grand for a mere human being to have an effect upon, had slowly grown to be seen as nature affected by atomic fallout and industry—and something that was limited (United Nations Secretary-General's High-level Panel on Global Sustainability, 2013). Rachel Carson inspired a generation to take heed in her book. She brought to light the damages being done to our environment by pesticides. As a biologist, she included science in her perspective, and scientific evidence in her prose. She described interrelationships in nature, from the poisoning of a caddis fly in a stream, with step-by-step detail, to the silence at the stream—until there were no more Robins. She wrote, "They are matters of record, observable, part of the visible world around us. They reflect the web of life—or death-that scientists know as ecology" (p. 189).

In this brief description of ecology Carson expressed the simplicity of scientific fieldwork. It is recording observations of the world around us, and it is simple enough for a child to do. Perhaps the simplicity of listening at the same time each day for a certain bird call seems simpler than science is thought to be, but it can be 'doing science' for a child if the observations are recorded in a systematic fashion, and linked to science theory. Rachel Carson sounded the alarm for the American public, and we became aware of a deteriorating environment, as well as the causes of that deterioration (Carter & Simmons, 2010). The scientific revolution that brought us advances and economic development also brought us environmental degradation.

Udall. Another book published at about the same the time, Steward Udall's *The Quiet Crisis* (1963), reminded the American public of what had been lost, and what could be lost due to environmental threats. This book and *Silent Spring* (Carson, 1962) helped promote a decade of important environmental legislation from Congress. Prompted in part by a study conducted by the National Science Teacher Association (NSTA) that found a need for environmental education curriculum development; legislation was soon passed to fill a gaping hole in knowledge about the relationship of the human race to the environment. The Environmental Education Act became federal law in 1970 (see Figure 6).



Note: ESSA (Every Student Succeeds Act, 2015); EE (Environmental Education); NSTA (National Science Teachers Association)

Figure 6. Timeline of Environmental Education (EE) in the U.S.

Soon after that, concerned educators formed an association, the North American Association for Environmental Educators (NAAEE) with the purpose of developing environmental educational materials. Environmental Education is a multi-disciplinary field, which is informed by science and other subjects. Environmental Education also draws from earlier versions of science education outdoors, for example Nature Study, Outdoor Education, and Conservation Education (Carter & Simmons, 2010).

Environmental Education in Response to Crisis

The environmental crises highlighted in Udall's and Carson's books opened the doors for environmental legislation and public response. E.O. Wilson (1984) found that genetically we as humans respond to nature and patterns in nature positively but, as Richard Louv (2005) noted, children are now suffering from a nature 'deficiency.' Therefore, we face a new type of crisis because, despite the benefits, children are not experiencing the natural world. Rickinson et al. (2004) pointed out children benefit from experiencing the laws of nature and the natural world first hand. The outdoors acts as a platform for learning in Environmental Education, but it is under-utilized in formal education, despite the positive responses nature generates.

The multidisciplinary aspect of Environmental Education is useful to many elementary school teachers in meeting some science curricular demands, as well as other subjects' curricular demands (Carter & Simmons, 2010). In some ways, as Carter and Simmons described it, Environmental Education is hard to define. As they noted it is rooted in a wide range of source disciplines—science (especially environmental science), mathematics, Language Arts, social science, politics and philosophy are part of what constitutes Environmental Education. As they described it, ". . . environmental science is the engine of data collection and knowledge creation, while EE [Environmental Education] is the vehicle for dissemination and application of that knowledge with environmental literacy as the ultimate goal" (p. 12).

Environmental Education, largely based upon outdoor instruction, does encompass some science instruction (Carter & Simmons, 2010), but national science curriculum does not encompass the outdoors or fieldwork at all in the U.S. (Achieve, Inc., 2013). Now, with the looming crisis of the side effects of human induced climate change and natural resource loss (United Nations Secretary-General's High-level Panel on Global Sustainability, 2013), there is no unified global political response requiring Environmental Education for all children.

Children in the U.S. are not going outdoors to learn and explore, as they were once able to do (Louv, 2005), and no federal legislation mandates taking students outdoors to learn as part of formal education. Environmental Education (http://www.naaee.net/) guidelines can be aligned with *NGSS* and thusly integrated, but this is not required. Environmental Education and fieldwork are a required part of school curriculum at the state level in a few areas of the US, as in the case of the state of Maryland, where one of the requirements for high school graduation is environmental literacy (Lyons, 2011; MSBE, 2014). Environmental Education fosters the hope that students will be knowledgeable, willing, and prepared to find new ways to conserve the natural world for future generations. History has shown education to be a consistent response to crisis.

Future Directions

Environmental Education helps individuals and communities develop skills and understandings of the ecological challenges we face globally (NAAEE, n.d.). NAAEE has a vision that includes a sustainable future for all. They focus on education to motivate environmental and social responsibility in individuals and institution's choices/decisions. Members of NAAEE facilitate Citizen Science programs. They are educators committed to the use of best practices in education to promote environmental literacy. They hope to connect more and more people with nature and fieldwork and promote life-long stewardship values.

Citizen Science

Citizen science can be defined simply as "citizens doing science" (Tomasek, 2006, p. 37). As the EXPLORE grant application defined it, ". . . citizen science engages non-professionals of all ages and backgrounds in the process of observing and reporting data to be interpreted and utilized by professional scientists, specifically biologists and natural resource professionals." In fields of science where immense quantities of observations known as 'big data sets' (Gauvin, 2015) are required from across varied habitats and geographic locations over long periods of time, citizen science enlists the public to help gather data (Bonney et al., 2009).

Traditionally in citizen science volunteers gather data for use in scientific research designed by scientists (Tomasek, 2006) and more recently, in some cases, volunteers gather data for research designed by citizens (Clark, 2016) including research designed by high school students (Bodor, 2015). Some degree of collaboration between practicing scientists and the public is something most citizen science programs have in common (Gauvin, 2015). Tomasek (2006) did not include short-term scientific studies, one-time field trips to scientific study sites, or incidences where scientists worked with students as a part of after-school or summer programs in her definition of citizen science.

Data Collection for Citizen Science

Citizen science, when coupled with formal education, is much more than a process whereby scientific research is conducted (Bonney et al., 2009); much more than the volunteers' process of observing, collecting, and reporting data (Hiller & Kitsantas, 2015). It is both science fieldwork and a learning experience. Brewer (2002) suggested scientists should train the data collectors. Yet the processes involved in data collection can be effective learning experiences for students according to Hiller and Katsantas (2015), if teachers include time for students to understand the science behind the study and time to think of their own questions. The act of data collection can serve to help students generate questions (Tomasek, 2006). Tomasek described students' participation in eBird as a "question engine . . . an activity that engages students in making observations and inferences as a precursor to generating research questions" (p. 206).

Student investigation was found to be a key feature of effective use of citizen science for education in schoolyards by Trautmann, Shirk, Fee, and Krasny (2012) but something hard for teachers to achieve. As described by Penuel and Means (2004), a study of Global Learning and Observations to Benefit the Environment (GLOBE, an international science and education program, www.globe.gov) teachers showed that when they were supported in developing student investigations the students were more likely to collect and report data regularly and reliably. Implicitly the ideology of citizen science data collection in the schoolyard also includes an emphasis on learning about the local environment and the health of the community beyond the school walls (Britton & Tippins, 2015). The fieldwork processes, with all of their inherent challenges to collecting quality data (Tomasek, 2006), benefit both the students as science and environmental learning experiences and professional scientists as a source of valuable data that can be applied to real world problems.

Utilization of Citizen Science Data

The number of scientific reports and peer-reviewed academic articles resulting from citizen science data in the past two decades has greatly expanded (Bonney et al., 2014). With protocols and oversight in place, Bonney et al. noted that volunteers have collected expert quality data on a scale unattainable by individual researchers. They reported that eBird data has been used in at least 90 book chapters and peer reviewed articles on varied subjects such as ornithology, ecology, and climate change. An effective citizen science program, such as eBird, requires a dedicated staff to manage project development, online presence, data collection, analysis, and make sure results are accessible to both scientists and the public (Bonney et al., 2009). Sustaining the costs of managing these research programs to yield both science and education outcomes long-term is, as Bonney et al. (2009) described it—a challenge. The current culture of citizen science supports open access to both data as well as results (Bonney et al., 2009). The use of online reporting of citizen science databases is relatively new, and does take time and money to oversee, but amateur scientists have contributed greatly to our present body of knowledge in science for most of our recorded history and it is not a new phenomenon (Bonney et al., 2014).

Brief History

Citizen science is a term that has been around for decades (Fazio & Karrow, 2015). It is growing with outreach efforts on both the World Wide Web and through all levels of education (see Figure 7).

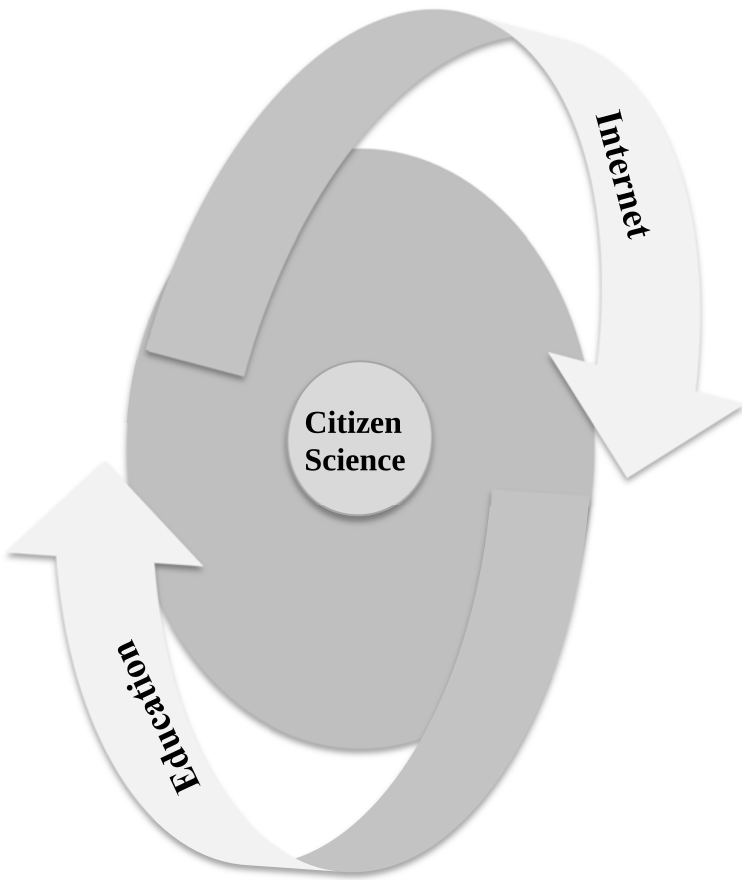


Figure 7. Citizen Science Growth and Outreach.

As part of a recent initiative by the White House, Rush Holt (2015), the Chief Executive Officer (CEO) of the American Association for the Advancement of Science

(AAAS), spoke of the history and goals of citizen science. The AAAS was founded in 1848, by scientists who abolished disciplinary societies in favor of a society to advance science (a new word at the time). The first president was William Redfield who observed the cyclonic nature of storms and enlisted hundreds of people along the seaboard to note which way the wind blew and record the barometric pressure. Holt highlighted the significance of Redfield's contributions to science as a citizen.

> We now know, from every evening's weathercast, that storms do circulate. And this citizen science activity established modern meteorology. Redfield was not a trained scientist; he was a steamship owner who had steamboats up and down the rivers, the Hudson River and so forth, in the early part of the 19th century. But he knew he could think like a scientist. And he could engage others to think like scientists. That's the goal of AAAS. To see that society at large integrates science into the society, into the culture, into the policy. (para. 4)

Holt cited many recent scientific studies that were advanced with the help of citizen science, and spoke of a recent article in a new open access journal reporting a citizen science project utilizing smart phone technology to measure earthquakes in 'real time' (making data available immediately to both the public and to scientists)—in fact so timely that it can be used to give warnings of earthquakes because radio waves travel faster than seismic waves. Coupled with advances in technology many new possibilities have opened up for citizen science.

Future Directions

The extraordinary range of possibilities for the use of citizen science are unfolding rapidly, and Holt (2015) felt public participation in science could help to correct misunderstandings of science in our society. Citizen science gives a democratic public access and opportunity to both produce and evaluate science. Holt explained, "Science is accessible to all. It is essential that everyone practice this, at least to some extent, for the sake of our society and our policies" (para. 13). Citizen science accessible via the World-Wide Web acts to increase knowledge like never before and carries us forward towards a global contribution to science (Dickinson & Bonney, 2012). This will only happen as long as people have access to computers and the global network. Citizen science is an instructional tool that can inspire and motivate students through participation in authentic science fieldwork (Trautmann et al., 2012). It is also a framework for increasing awareness of local environmental issues (Tomasek, 2006). Through schools in the U.S. we can offer web access to citizen science for all students, even those who may not have Internet at home or on their phones/technological devices.

Fazio and Karrow (2015) saw school citizen science as collaboration between at those schools and those conducting scientific studies. Through crowdfunding, the general public collaborates by offering their direct financial support of scientific research (Clark, 2016; Holdren, 2015).

There are three main types of citizen science programs online: (a) biology and conservation ecology, the largest, (b) geographic research, and (c) social sciences and epidemiology (Kullenberg & Kasperowski, 2016). Because data can be collected from large geographical areas over time scientists can track defaunation (the reduction in fauna populations), endangered species, environmental degradation, and climate change. These data may be of interest to the general public. This involvement, as Fazio and Karrow (2015) describe it, promotes critical scientific thinking. Citizen Science also enhances science education by providing a forum for presenting results (Trautmann et al., 2012). Recent efforts to further disseminate information about why and how to participate in citizen science include the following:

1. The White House citizen science initiatives as the subject of a recent forum (Holdren, 2015),
2. The recent formation of the Citizen Science Association (CSA) in 2015, that will hold a conference in Raleigh, North Carolina in 2017 (CSA, n.d.),
3. Websites such as www.citizensciencecenter.com,
4. Publications such as *Citizen Science Handbook* by the New York State Adirondack Park Agency and Stoneybrook University of New York (SUNY) (Beguin et al., 2013), and
5. The recent publication of a citizen science lesson book, *Citizen science: 15 lessons that bring biology to life, 6-12,* by the National Science Teachers Association (NSTA) (Trautmann, Fee, Tomasek, & Bergey, 2013).

Citizen science can help the fields of science and Environmental Education converge (Wals et al., 2014). To enact a synergy of citizen science outdoors, Environmental Education and school science, such as the convergence Wals et al. discussed, requires specific pedagogies for teaching outdoors that are not generally part of teacher education (Tal & Morag, 2009). I discuss the lack of teacher preparedness to teach science, or teach science outdoors, at the elementary school level and the types of pedagogies that are recommended to remedy this situation in the next section.

Teachers

Unfortunately, research in elementary science education shows a dearth of well-trained teachers who can effectively educate young children in the subject of science (Appleton, 2007; Duschl, Schweingruber, & Shouse, 2007; Roth, 2014; Shamos, 1995). I describe what we know about elementary school teachers with respect to teaching science and existing training and preparation to teach science. I argue for the kinds of science teaching that are needed. I further describe how teachers can prepare for successful science teaching outdoors in order to provide the benefits of science education outdoors to students.

What We Know

Teachers are critically important to student achievement.

> The effects of good teachers on student achievement have been well documented . . . but the specific teacher characteristics that contribute to student success are less clear . . . Some studies have cast doubt on whether commonly measured indicators, such as teachers' licensure scores or the selectivity of their undergraduate institutions are related to teaching effectiveness. (NSF, 2012a, p. 1-22)

There is a general consensus in the literature that elementary school teachers are not prepared to teach science because they have limited training in science fields, and/or lack science content knowledge and science pedagogical knowledge (Milner, 2015; Roth, 2014). The quality and quantity of science education that occurs at the elementary school level is affected by time taken away from science to prepare for tests. In addition to high-stakes testing preparation for mathematics and literacy, and associated anxiety, Appleton (2007) recognized that teachers in elementary schools have some common avoidance strategies for teaching science. These avoidance strategies include keeping to higher comfort level topics, often biology; stressing process over concepts; going ‘by the book’; not engaging in discussion; and avoiding difficult to work with materials. Tal and Morag (2009) found that teachers do not have training to implement fieldwork.

Although Appleton (2007) looked at research on teacher practices, research about elementary school teachers focuses more often on teachers’ lack of knowledge and insufficient training to teach science than on actual teaching practices (Roth, 2014). As Roth pointed out, very little instructional time is left for science as English, Language Arts, and mathematics are tested at lower grades, and therefore these other subjects are privileged. Roth found gaps in elementary school teachers’ knowledge about how to teach science to students with diverse needs. She also found that the science taught is most often low quality, focusing on passive learning, or facilitating an activity just for the sake of doing an activity. Roth noted that the most common fault with low-quality lessons was a lack of student engagement with important science content or scientific practices. There may be a few excellent teachers, she argued, but overall science instruction is not of high quality.

In an era of lingering NCLB measures in North Carolina, students’ standardized test scores are used as a measure of teacher effectiveness (Department of Public Instruction, n.d.), and science was recently added to the subjects in fifth grade affected by high-stakes testing (NSF, 2008). Using students’ standardized STEM test score statistics as evidence, Milner (2015) found a need for improved teaching. “Statistics from the ‘National Math and Science Initiative’ suggest that fresh approaches to STEM education are necessary in order to address the disconnection in [teacher] workforce development" (p. 54). Milner highlighted research that showed STEM teaching was more effective when teachers formed collaborative teaching communities. Promoting more complex scientific reasoning facilitated through enacting inquiry is an example of a fresh approach from Roth (2014) that Milner (2015) may have been referring to, but traditional pre-set lessons where students put more importance on thinking about the answer a teacher wants than thinking for themselves are the norm at the elementary school level, according to Roth (2014). Chapman et al. (1999) found that fresh approaches were something few teachers in North Carolina were willing to risk in high stakes testing environments if they felt their students' end of year standardized test scores would dip as a result.

Yet, national assessments show that more elementary school students are proficient in science than older students. Scaled scores on the National Assessment of Educational Progress (NAEP) in 2009 show more fourth graders performed at or above the proficiency level in science than either eighth graders or twelfth graders (National Assessment of Educational Progress, n.d.; National Center for Education Statistics, 2011; National Science Foundation, 2012a). Not only do students lose interest in science in upper elementary school, as Carrier et al. (2013) noted, but students lose proficiency in science as they age (National Assessment of Educational Progress, n.d.). Thirty-four percent of fourth-graders scored at or above the proficiency level in NAEP testing in 2009 according to the National Center for Education Statistics (NCES, 2011), which is not an acceptable proficiency rate for a society in need of widespread scientific literacy

(Bonney et al., 2009; Bybee, 2012). Teachers are critical to student achievement and attention has shifted to the need for effective teachers (Cochran-Smith & Lytle, 2009).

Roth found that many teacher development programs were framework-driven, and she identified types of frameworks for teacher training: (a) science as argumentation, (b) science as inquiry, and (c) science to encourage critical thinking. Roth also identified a gap between what exists in terms of teacher preparation today, and what is needed. The training model of professional development is one that Roth (2014) alluded to as a ‘model for inquiry framework’ (description follows). In a comprehensive review of studies done on professional development in the U.S. from 2003 to 2004, 92% of teachers reported participating in workshops, conferences, or other training sessions over the previous 12 months (Wei et al., 2009).

One alarming aspect of the findings Wei et al. (2009) reported was that many fewer teachers participated in other forms of professional development, such as university courses related to teaching (36%), or observational visits to other schools (22%), and this percentage of teachers enacting visits to other schools represented a sharp drop from the past (34% of teachers reported visits to other schools in data from 2000 to 2004, while reports of participating in other forms of teacher professional development stayed at stable percentages over time). In general, I found nearly all teachers participated in the training model of workshops and conferences.

Some teachers rated these content focused training model professional development workshop experiences higher than others. “Teachers in elementary schools rated their content-focused professional development significantly more highly than teachers in secondary schools" (Wei et al., 2009, p. 42). Marilyn Tallerico (2014) described the training model as lecturing or large-group direct instruction. Professional development training model workshops did not reach expected STEM teaching outcomes in the past (Milner, 2015); and that form of professional development is the most common, despite a growing consensus that the most effective forms of professional development are those that (a) are most closely related to teaching practices, (b) are intensive, (c) are sustained over time, (d) are integrated with local school reform needs, and (e) actively engage teachers in collaborative professional communities (Wei et al., 2009).

What We Need

In preparing elementary school teachers to teach science, there is no one existing professional development program that can cover all that a teacher needs to learn (Roth 2014). Tal and Morag (2009) suggested fieldwork be included in preservice teacher training. Carter and Simmons (2010) suggested that Environmental Education should be included in teacher education courses. Tal (2010) found preservice teachers' scores on a knowledge and environmental awareness test increased substantially after a college Environmental Education course. Environmental Education encompasses science instruction as described by Carter and Simmons (2010) and includes socioscientific issues as described by the NAAEE (2016). Tal (2010) suggested that even further Environmental Education was needed for preservice teachers beyond one college course in order to continue what she worded was the "transformation process" (p. 263).

We could use elementary teachers' preferences for teaching biology that Appleton (2007) identified to our advantage by training preservice and in-service teachers to conduct biology fieldwork. The *NGSS* in the U.S. for elementary grades do not currently require outdoors teaching, or directly address anthropogenic causes of environmental degradation as exemplified in the aforementioned third-grade standard for Earth and Human Activity (NGSS, 2016a). There is work to do in developing support for effective use of the outdoors for science teaching as Slingsby (2006) suggested, for enacting Environmental Education and citizen science in the schoolyard as Wals et al. (2014) suggested, and in training teachers to teach outdoors as Tal and Morag (2009) suggested.

Despite the well-accepted benefits to outdoor learning and advantages to fieldwork recognized by Barker et al. (2002), neither existing teacher education nor professional development for in-service teachers provides teachers with sufficient pedagogical knowledge and experience to feel comfortable teaching outdoors (Tal & Morag, 2009). The lack of teacher preparedness to teach elementary school science could benefit from teacher learning through professional development (Roth, 2014).

What We Can Do

Cochran-Smith and Lytle's (2009) Professional Learning Communities (PLC) model of professional development, which was informed by empirical and theoretical literature, would be appropriate for teachers who want to learn more about teaching science outdoors. They based their model upon the idea of teachers taking a stance of inquiry about their own practice. What we can do is promote Cochran-Smith & Lytle's model of teacher self-directed learning as a form of teacher professional development. I discuss this model of professional development in detail and the benefits and limitations of the model.

This model meets the challenge today in teacher professional development of practitioners being able to be the *drivers* of needed change in a system that recognizes their importance and role in enacting change, but does not allow them to initiate it on a large scale (Cochran-Smith & Lytle, 2009). Highley expressed this sentiment: ". . . it is imperative for teacher leadership to take hold now. As educators, we need to find ways to demonstrate that we are indeed experts who deserve decision-making powers" (Berry et al., 2011, p. 214). A professional learning community with the idea of teachers taking on their own professional development is a currently popular and widely recommended sociocultural approach to teacher learning in professional development (Lieberman & Miller, 2014).

Professional Learning Communities (PLCs). Lieberman and Miller (2014) described PLCs as formed or clumped around three big ideas: reflective practice (Schön, 1983); communities of practice (DuFour & Eaker, 1998); and inquiry as stance (Cochran & Lytle, 2009). Schön's (1983) idea was that a professional has a "reflective conversation with a unique and uncertain situation" (p. 130). He described how reflective practice is part of the role of a professional. Reflection is key to a PLC's structure and to teacher self-directed learning.

Through restructuring a situation in reflection, or conducting *reflection-in-action*, Schön explained, a professional researches his or her own practice. He pointed out there are unique situations the practitioner may encounter which do not lend themselves to learned theories or techniques learned in training, so practitioners need to construct theories and methods of their own. The structures, according to Schön, of this reflection-in-action are: (a) a practitioner is presented with a unique problem or case to solve, (b) the practitioner must contract an understanding of the situation, (c) the practitioner must conduct an inquiry and look at varied solutions to the problem, and, finally, (d) the practitioner must respond to this complexity artfully using prior knowledge and experience to create a solution. Schön (1983) noted that “the idea of reflective practice leads to a vision of professionals as agents of society’s reflective conversation with its situation, agents who engage in cooperative inquiry within a framework of institutional contention” (p. 353) and he recommended professionals engage in reciprocal (with each other) reflection-in-action.

DuFour and Eaker (1998) suggested a collective process was important in professional development opportunities to inspire the dispirited to seek professional development with passion and persistence. They equated a professional learning community of teachers to a ‘voyage,’ and warned that educators need to be prepared for occasional ill winds along the way. The members of a professional learning community will stay the course and address problems as they arise, addressing them, not as a checklist from a factory, but as a true community continually searching for better ways of enacting education. They described the main characteristics of these learning communities as:

1. Having a common mission and vision,
2. Sharing values and a commitment to guiding principles,

3. Using collective inquiry as an engine of growth,
4. Being open to new possibilities and constant improvement,
5. Working as collaborative teams able to learn from each other, and
6. Turning vision into reality with a willingness to experiment and assessing the results of these purposeful acts

They argued that while an energized individual can sustain improvements for a while, it takes a community to sustain improvements over the long haul.

Description of PLC: Inquiry as stance idea. The practitioner inquiry that Cochran-Smith and Lytle (2009) described is not simply teacher as researcher but is a generative framework with far reaching goals of transforming “teaching, learning, leadership, and schooling in these new times” (p. 153). They point out five themes or trends in the idea of inquiry as stance that have emerged through their study of practitioner research as a professional learning community for professional development: (a) equity, engagement and agency, (b) developing conceptual frameworks, (c) inventing and re-inventing communities of inquiry, (d) shaping school reform and educational policy, and (e) re-forming research and practice in universities. These five themes emerged according to Cochran-Smith and Lytle even in an era of student assessment generated evaluations of teachers in many areas of the U.S. due to the NCLB federal legislation.

Cochran-Smith and Lytle (2009) indicated that there are many new academic assumptions about teachers as professionals, such as the assumption that they continuously theorize as part of their practice. Teachers as researchers are also valuable partners in the construction of contextualized knowledge about teaching and learning, according to Cochran-Smith and Lytle, but education policy lags behind these currently accepted assumptions. In their view, it is through inquiry that teachers problematize their own knowledge and practice as well as others' knowledge and practice, connecting theory to research as professionals, aided through journaling and reflection. But as Cochran-Smith and Lytle noted, policymakers use assumptions about teachers made decades ago that have since been rejected by scholars and practitioners. We know much today about how teachers learn that can be incorporated into a PLC.

Definition/theory of teacher learning in PLC/Inquiry as stance. The idea of learning in community in a PLC is in line with the sociocultural theories (Vygotsky, 1978) of human learning, and underpins adult learning theory. Learning and change for adults is currently theorized to be *self-directed*, and best done when learning is experiential, reflective, and discussed with others in community (Rohlwing & Spelman, 2014). Adult learning theory is one of the theoretical underpinnings of professional learning communities. Knowles (1980), who described how adults learn and need their own pedagogy, or 'adragogy,' and Mezirow (1985), who established self-direction as central to adult learning and transformation, gave us a foundation for current adult learning theory. Knowles and Mezirow's theorizing and the idea of self-directed learning as contextualized and sociocultural was a base for further development of adult learning theory by Merriam, Caffarella, and Baumgartner (2012).

Rohlwing and Spelman (2014) described that adult learning theory recognizes that adults bring a variety of life experiences to learning and approach their learning task differently because in any given group of adults, the members of the group are at different stages of their development. It is recognized that "to develop professionally, teachers should be provided opportunities to reflect on their instruction and to examine various methods of instruction" (Martin, Kragler, Quatroche, & Bauserman, 2014, p. xxii).

The use of adult learning theory in the design of learning experiences for teachers can offer a wealth of information to guide professional development designers. As Rohlwing and Spelman (2014) concluded, the fact that participants come from and are in unique contexts in professional development communities needs to be taken into consideration. Another point these authors made was that the providers of professional development should honor each participant by respecting each participant's point of view. It is important to know where the learners are in their life-long learning journey so that teachers may, if constructing a bridge to a new skill or practice, make sure the bridge is well anchored on both sides. Rohlwing and Spelman pointed out that teachers need dialogue, not a debate, to find agreement, and they need to share to find common ground before attempting to bridge over to new concepts. Adults need to experience learning, take part in reflective activities, and participate in embedded dialogue in any given professional development program.

Adult learning and change, even for an active teacher-learner in the classroom, can be slow to materialize. In a nine-year-long case study of a science teacher who was engaged in action research in her classroom, it was not until the end of the study that she was able to move from the exclusive use of closed problems to the beginnings of incorporating socioscientific issues into her instruction (Vázquez-Bernal, Mellado, Jiménez-Pérez, & Leñero, 2011). The important findings from this case study were that "Continued learning in practice with the community of her fellow teachers with the emotional support they provided and a solid knowledge of the content were revealed as essential for her professional development" (Vázquez-Bernal et al., 2011, p. 337). Vázquez-Bernal et al. found that for this science teacher to grow, she needed many of the components of a PLC.

Limitations/constraints of PLC: Inquiry stance idea. Teacher research with a critical stance may be difficult to implement on a large scale, but it may be the best way we know of to implement change on a grand scale. Besides the limitation of case studies being small and not generalizable, this method of professional development cannot be widely instituted in schools unless teachers are given time on the job to reflect, study, research, meet with colleagues, and write up their reflections. This form of inquiry cannot be sustained long term for a teacher, or implemented on a large scale with many teachers, considering the current time demands that teachers have in schools. Important questions would be "Who facilitates this?"; "How can such an organization of collaborative teachers survive without a leader, or facilitator, or university professor to guide the teachers through the process, at least at the beginning?"; and "Could Environmental Educators facilitate this for teachers?"

Teaching Outdoors PLC: Elementary science and Environmental Education. A PLC dedicated to teaching science outdoors in conjunction with environmental educators or that includes members who are environmental educators could be a way to improve science education. The initiative to include the use of the natural world as a platform for elementary school science teaching is often left to the teacher in the individual classroom, as Milner et al. (2012) found; teachers may choose to incorporate Environmental Education in science teaching, or use existing lesson plans outdoors that research shows benefit students in many ways (Rickinson et al., 2004). Science education outdoors at the elementary school level, when coupled with Environmental Education and participatory science projects (citizen science), could help learners explore larger socioscientific issues, issues that need to be included in science education (Wals et al., 2014).

Teaching outdoors in a way that actively engages students and corresponds with school learning is complex for an elementary school teacher on a field trip. Additionally, if there is an onsite environmental educator leading activities (which is typically the case for school fieldtrips), then this requires negotiation of control of the experience. Tal, Alon, and Morag (2014) stressed in their findings from a recent study of 62 field trips for students in Grades 4–8 that good collaboration between the field trip guide and the teacher is key to a high quality outdoor learning experience for students. Students actively engaged in learning were also a sign of excellence in the field trips they observed. This outdoor learning opportunity often only happens on field trips.

Effective science education outdoors is not limited to ecological field trips or Nature Study. The outdoors can be used to teach many subjects and many sciences other than biology. Working in the outdoors can introduce students to scientific practices that are useful in all science disciplines (Slingsby, 2006). Some U.S. elementary school teachers are trained in Environmental Education (48 North Carolina teachers have earned state certification [Lisa Tolley, personal communication, July 21, 2014]) and Environmental Education includes science in the curriculum and outdoor lessons, but Environmental Education curriculum is not required in all states or districts. To obtain certification as an Environmental Educator in North Carolina, 50 hours of structured outdoor experiences are required in order to introduce the adult learners to outdoor skills and experiences (NC Environmental Education, 2014).

Environmental Education curriculum is included in the social studies curriculum in North Carolina (Sarah Yelton, personal communication, January 17, 2015), but social studies is marginalized along with science due to emphasis on testing in mathematics and reading. Voluntary Environmental Education certification is not often rewarded with salary recognition; it is not rewarded in North Carolina. Despite the fact that there is no financial reward, there are teachers who choose to become certified. In North Carolina teacher initiative is one way that science is taught outdoors at the elementary school level in public schools. A teacher does not have to negotiate teaching outdoors with an environmental educator if he or she is one.

It is also due to a teacher's initiative that NSTA published one of very few new books for teachers on teaching science outdoors, *Outdoor Science: A Practical Guide* (Rich, 2010). But barriers to teaching outdoors remain for most teachers, such as safety concerns, teachers' lack of confidence to teach outdoors, curricular requirements they feel they cannot complete outdoors, and lack of institutional support. Our research community has long been aware that there are wider changes in the educational system that are required in order to prepare teachers to offer outdoor learning experiences to their students (Milner, 2015); improvements in existing pedagogy are necessary in order to achieve needed student learning goals (Rickinson et al., 2004). These changes have not yet been made in the U.S. on a large scale. The multidisciplinary aspect of Environmental Education we have in place is underfunded (albeit newly eligible for funding in ESSA [2015]), but could be useful to many elementary school teachers.

What would a professional development plan for teaching science and Environmental Education outdoors informed by the PLC look like? This PLC model of professional development would be a self-study over time of teaching science and Environmental Education in the schoolyard, as was suggested by Wals et al. (2014). Research shows that time outdoors is beneficial to student learning in many ways (Dillon, 2014; Rickinson et al., 2004). Cochran-Smith and Lytle (2009) suggested self-reflection and theorizing one's own practices as beneficial to teachers in community, as evidenced in inquiry as stance case studies. Optimal pedagogy recommended in recent literature includes (a) being prepared to address biodiversity (Wilson, 1988), (b) facilitating engaging, accessible science with Environmental Education (NAAEE, 2016), (c) fostering cultural connections and cultural relevancy in class with a holistic view of science (Brayboy & Maughan, 2009), (d) guiding students to think critically about environmental issues (Preston, 2011), and (e) utilizing transformative learning approaches for a better understanding of teaching ecocultural sustainability (Glasser, 2007). For a view of the structure of this type of professional development (see Figure 8).

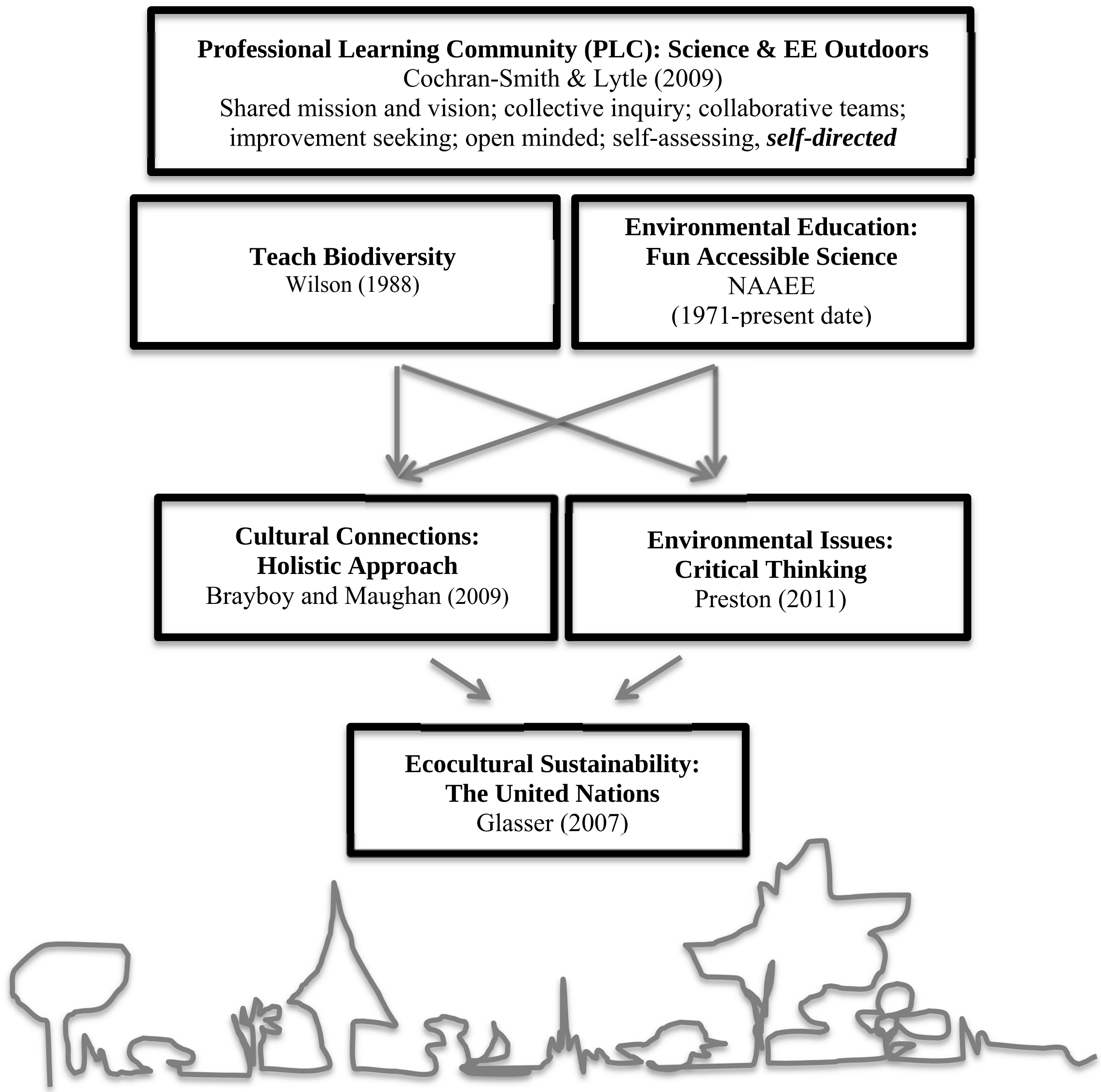


Figure 8. Learning Community for Science Education Outdoors.

By engaging in inquiry not only into what are the most recently recommended pedagogies for elementary school science outdoors but inquiry into their own practices of implementation of these pedagogies, teachers could share stories of how they improved their own science teaching. Research from such teachers could be helpful to other teachers who find similarities in their situations. In order to realize such an ambitious plan for professional development informed by the PLC model, teachers could set up PLC's and seek knowledgeable partners in the endeavor. Partnerships with professors, scientists, researchers, educators, environmental educators, partner organizations, or school district administrators could offer much to the group, in person, or in an online community with peers far away.

Long-time members of the PLC could eventually take on mentor roles. A best-case scenario would be that through membership in the group, with so many experts in the group, a teacher might be able to be coached, or to explore, without having to take a university course in teacher research. Teachers staying in the group long term could be more effective at research (moving from the periphery to the center, as described by Lave and Wenger [1991] in their learning community). By staying in the group they could improve their own professional development because of the time extension spent on learning (Wei et al., 2009). Staying in the group would be a great way to help this form of personal professional development prosper and thrive, and to spread the benefits as recognized by Wals et al. (2014) of teaching citizen science outdoors. This would fit well with the notion of participatory appropriation put forth by Rogoff (1995), an idea that people, through their participation in activity, transform their understandings of activities.

Summary of Literature Review

Now, with the looming crisis of the effects of human-induced climate change and natural resource losses (United Nations secretary-General's high-level panel on Global sustainability, 2013), we need to join with other nations and take a more holistic approach to teaching science and use the outdoors as a platform for science learning as suggested by Wals et al. (2014). We can shift this task from parents to the public schools, because children are not going outdoors to learn and explore as they once did (Cleland et al., 2010; Louv, 2005). If we are to encourage environmental action, Chawla and Cushing (2007) found that children benefit from a mentor to show them the natural world. We therefore need to find a way for teachers to be prepared and feel comfortable teaching the formal science curriculum and Environmental Education in the outdoors, as Tal and Morag (2007) suggested, with the hope that these teachers' students will become knowledgeable, willing, and prepared to find new ways to conserve the natural world for future generations, as Kelly (2014) suggested.

The interesting point of reviewing the history of science education in the U.S. is that in essence there always was and is now a movement to get 'back to nature.' The emphasis in science education went from Nature Study to technology to engineering, and the current ecological pushback is exploring, disseminating, and funding citizen science studies critical to the scientific study of the environment (Bonney et al., 2016). Environmental Education grew out of science education to exist in response to crisis in a more holistic manner (Carter & Simmons, 2010). An Environmental Education initiative is gaining momentum along with citizen science online, and this democratization of science among those who have access to the World Wide Web could transform how we teach science from the bottom up as suggested by Plakitsi (2013), starting with the teacher as suggested by Milner et al. (2012). History has shown education to be a consistent response to ecological crisis, and research supports teachers enacting citizen science education outdoors as a logical next step. In the next chapter, I describe the methodology I used to research the meanings teachers make of learning to enact citizen science projects outdoors as part of Project EXPLORE.

CHAPTER III

METHODOLOGY

> . . . look for well bounded communities of practice or functional systems, . . . collaborative subjects of learning. (Engeström, 2001, p. 140)

The Experiences Promoting Learning Outdoors for Research and Education (EXPLORE) program sought to provide Environmental Education and citizen science education to area schools. To participate, individual teachers applied and explained which of the citizen science programs would be implemented at their school. If accepted, the Arboretum educator(s) visited the school and modeled program components. Classroom teachers hosted the Arboretum educator(s), read about the program and prepared lessons on different topics, collected data in the field with their students, helped students to analyze the data, sent the data to a citizen science website, and presented information about their participation in EXPLORE to the general public. Because the program was multi-step, I did not expect uniform interpretation or implementation of EXPLORE. Instead, I expected a variety of outcomes because teachers had a variety of reasons for applying to the program based upon their individual teaching and learning experiences (see Chapter IV for information from teacher applications). Moreover, each teacher's school's expectations for science instruction or participation in the EXPLORE program were also expected to influence outcomes. Due to the expected variance in teachers' meanings, I used sociocultural theory as a theoretical framework.

Sociocultural Theory

In keeping with Vygotsky's (1978) socio-historical theory of learning, each individual brings his or her personal cultural history to an activity. Sociocultural theories of learning were derived from Vygotsky's work in the early 20th century and they allowed me to understand how the teacher interpreted the interplay between personal practices at the microsystem level and instructional goals from the larger macrosystem context (Brandt & Carlone, 2014). In the integration of EXPLORE into schools' curricula, the individual teacher becomes the critical link between activity enacted at the classroom level and the program's systemized instructional goals (Milner, et al., 2012). As a result, it is critical to understand the meanings individual teachers ascribe to their involvement in the program. Sociocultural theory allowed me to take a stance, which highlighted the teacher and the many social and cultural factors affecting the individual pedagogical choices that she made while engaging in the adoption of this particular program. Sociocultural theory also allowed me to look at how teachers' individual interpretations of learning to enact citizen science projects in the schoolyard became internalized and externalized as they utilized teaching tools and implemented the program components that varied from school to school. Activity theory, a sociocultural theory, allowed me to look closely at teachers' meanings.

Cultural-historical Activity Theory (CHAT)

No teacher is truly alone in the classroom. He or she is part of a social network, a community, with established normative practices. This network has certain divisions of labor, or embedded power sharing practices, and these elements are constantly interacting with each other and changing based upon past history and future expectations for engaging in activity. The Arboretum and each school in this study were viewed as having established programs with established instructional goals. Just because a school or program had specific goals, however, did not mean these goals were going to be met or met in any uniform way. It would be naïve to assume that a system-wide educational program would be adopted in the same way at each school or in every classroom. Therefore, because I felt it was critical to better understand individual teachers' experiences and how they learned to implement system-wide activity, I used activity theory because of its focus on the interrelated elements of a system.

Cultural-historical activity theory (CHAT) evolved over time, from Vygotsky's (1978) theory building work in the 1920's, to a multi-faceted research analytical tool used today in many different ways. The core principle of CHAT is derived from Vygotsky's (1978) view of learning—humans mediate their learning through the use of artifacts for a purpose (or object). These artifacts come from the environment, or context, in which the learner lives. Using the CHAT framework for data analysis allowed me to focus not only on the teachers' meanings of the activity of collaborative learning (teachers were collaborating with the Arboretum on the citizen science programs and in some cases with colleagues), but to systematically pull apart and examine the interconnected elements of the activity. Based upon Engeström (1999), the CHAT activity system triangle diagram (see Figure 9) includes the elements of subject, artifacts, tools, object, rules, community, division of labor, as well as cultural history (including tensions), and outcomes (such as expansive learning). I will describe each of the elements in the triangle as they relate to the activity.

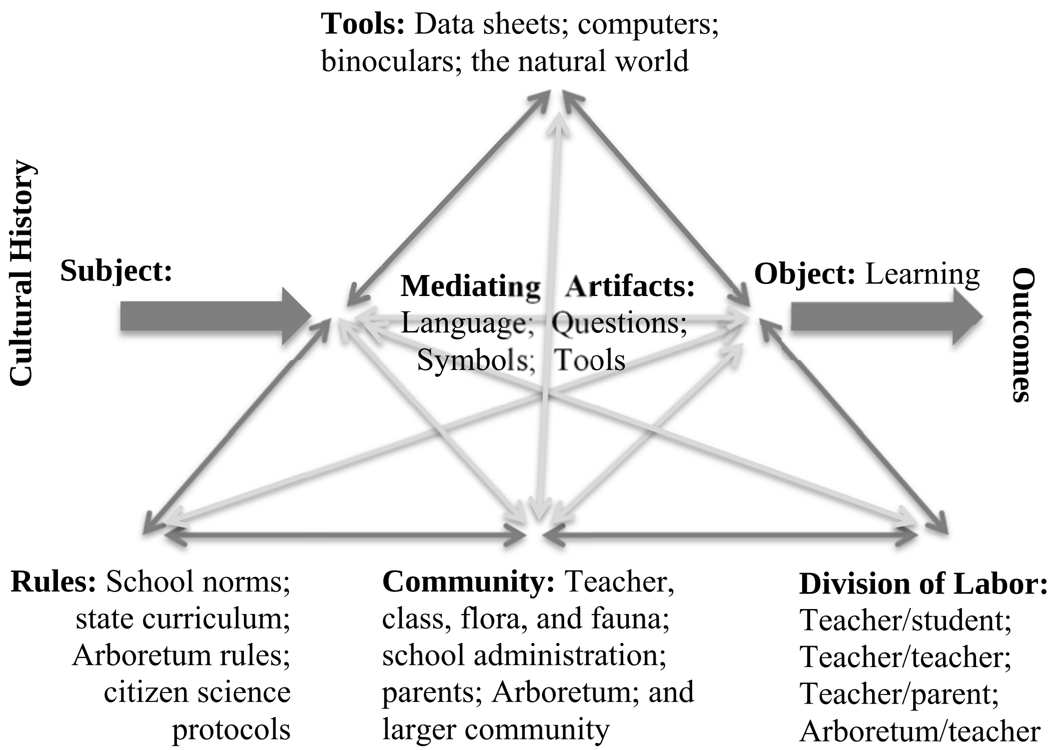


Figure 9. The EXPLORE Teacher Activity System Triangle.

Subject

Each primary participant was the subject of a smaller school-based bounded activity system. These smaller activity systems, when combined, both composed and were in partnership with the larger activity system of EXPLORE. Each teacher brings his or her individual cultural history to an activity. This individual cultural history included childhood experiences in the natural world and prior educational experiences. Data were gathered that were informative about the subjects and their cultural histories. For example, if a teacher noted that she spent time in the garden as a child, she brought this experience to the outdoor classroom with her as part of her cultural history.

Artifacts

Mediating artifacts for learning in the smaller activity systems included the use of language, symbols, and tools. Language as a mediating artifact can be discussion (teacher-teacher or teacher-student), lecture, or questions to provoke thinking. Symbols can be signs, words, or drawings. Teachers may have had prior knowledge of scientific practices to share with students or other teachers while outdoors through the use of language (e.g. by the questions they asked). While outdoors with the class, a teacher could ask a student if a bird he or she spotted had been verified by the other teacher. In this way a teacher could use a question to mediate data collection protocols that required students to verify data with an adult. Tools are discussed next as they are included separately in CHAT triangle diagrams (Engeström, 2001) as a mediating artifact.

Tools

Tools for the smaller activity systems included curriculum, media, books, mental tools, such as prior knowledge, or physical tools, such as computers, binoculars, a field guide, a meter stick, or an iPad. Teachers could also use bird nests, dead trees, fallen leaves, or animal footprints as teaching tools from the natural world. Depending upon teachers' and students' familiarity with these tools they could or could not be used effectively. Small children have a tendency to play with binoculars, look through them backwards, or spend time untying or re-tying the strap when birding. Effective use of the binoculars by a teacher could encourage students to follow his or her example.

Object

An object, in the smaller activity systems in this study, was a purpose or meaning for the activity. A teacher had instructional goals or purposes for implementing a citizen science project outdoors. The purpose (object) could be overarching teaching objectives, or perhaps a special and unique meaning for the activity and experiences. A teacher's object (purpose) for the activity could be for students to learn more about the natural world, or to learn the scientific method.

Rules

Rules or guidelines governed the various activities in the smaller activity systems of EXPLORE. The context in which the activity took place involved classroom rules, school rules, school district policies, state curricula, national policies, educational assessments, Arboretum rules, citizen science program rules, and cultural norms. For example, teachers needed to take the class outdoors in order to meet the requirements for participation in EXPLORE to collect data weekly in the schoolyard. Some teachers might have been restricted by school rules about the time of day and how often they were allowed to teach science, and so these EXPLORE teachers would have had to either restrict their outdoor activity to those times, or ask for permission from the principal to use other times of the day or week for fieldwork.

Division of Labor

The relationships between different people in the smaller activity systems and the roles or tasks teachers assumed while teaching constituted the division of labor. The teacher could take on different roles; he could act as a director, a lecturer, or a facilitator.

She could delegate the outdoor science lesson to a teacher assistant, an intern, or a student teacher. I sought to understand the hierarchy of power in the activity system. I was curious to find out who had the power (the teacher or the students) to decide how, when, what, and where to record data for citizen science projects. The role of the principal could also be important. Was the principal a leader; was the principal supportive of the teacher; or, did the principal hand power over to the teacher to take initiatives? The negotiation of this power sharing is important to consider when looking at the interrelated elements of an activity system.

Community

The socially and geographically bounded place where the activity occurred included the school community, flora and fauna, parents, the Arboretum EXPLORE community, the local city or town, the state, a national community of citizen scientists, and a connection to a global community of teachers, learners and scientists. As the study commenced, each of these communities and the relationships among them were expected to evolve. For example, supporting colleagues could play a role in organizing and recruiting teachers to apply to participate in Project EXPLORE.

Interrelated Elements of CHAT

The activity systems in EXPLORE, encompassing these aforementioned elements, were complex. Many often-subtle influences upon learning from different dimensions could be teased apart by looking at these elements and how they were interrelated. The analytic lens of CHAT focused on the teacher group (larger activity system of EXPLORE) as well as the individual teacher (smaller activity system), and all the teacher brought to the activity from her personal and cultural history, as the subject of study. CHAT helped me, as a researcher, to take note when the teacher was taking on one or more roles in the power structure of the activity. EXPLORE teachers worked in the school and larger community (a larger community contains institutional and societal rules and norms a teacher may or may not have adhered to), which affected the way they taught. The teacher used the natural world as one of many artifacts (such as language, symbols, or tools) to mediate the process of learning for her students.

For each participant, I dove deeply into what I interpreted were the most relevant relationships between elements of CHAT. For example, for one teacher the relationship between subject and division of labor could be important. A relationship between a teachers' belief in democracy in the classroom and the power sharing she exhibited when students decided which citizen science program to do by a majority vote (division of labor) could be relevant elements to a teacher's meaning-making. Rather than making the decision of which citizen science program to implement by herself a teacher could share this power with the students and this could be a focus of my description of that teacher's activity system. In this way the CHAT framework for analysis is versatile and was adapted in order to highlight particular outstanding interrelated elements in each smaller activity system for each teacher subject.

Principles of the Activity System

In addition to analyzing the implementation of EXPLORE by examining elements and relationships between the elements of the system, another perspective is to look at these interrelations through the principles of an activity system. There are five defining principles of an activity system (Engeström, 2001). The activity system is (a) artifact mediated and object oriented, (b) a community of multiple voices, (c) a system that developed over time, (d) a system of contradictions (tensions) as sources of change, and (e) able to undergo systemic expansive transformations. A matrix in the Data Analysis section of this chapter shows how the principles of activity theory are used in data analysis. These five principles help to summarize activity theory and were used in this study to analyze outcomes of expansive learning.

Expansive Learning

Expansive learning, as defined by Engeström (2001) is learning that is not always pre-defined or intended. Engeström described it as learning as new forms of learning are literally being created. There is no teacher in expansive learning, according to Engeström. Therefore, as Engeström explained it, expansive learning is when people learn new forms of activity. Expansive learning, in all its complexity, was revealed by teasing apart the effects and influences of all of these aforementioned elements and principles upon the activity system(s).

I used the principles of CHAT to look at what and how expansive learning took place. This allowed me to take into account the immediate surroundings for learning, as well as the implicit institutional and cultural-historical influences on learning. To better understand the interrelated complex processes and dynamics in an activity system of learning to implement citizen science projects outdoors, I used the methodology of a qualitative descriptive case study, as described by Merriam (1988).

Case Study Methodology

I used Merriam's (1988) qualitative case study methodology to better understand teachers' meanings by interacting with and viewing the social processes of learning and all of the interrelated elements of a bounded activity system as described by Engeström (2001). Denzin and Lincoln (2011) suggested case study is a form of qualitative research in alignment with interpretivist views. If we accept Paul's (2005) interpretivist view, a researcher would need to interact with participants and their world in order to understand how meanings are performed and negotiated in everyday contexts. Merriam (1988) described education as a social process. Both the study of a social process and interaction with participants to better understand their meaning making could be best accomplished with qualitative case study methodology.

Qualitative researchers usually study one phenomenon, one setting, one system, or a small number of individuals, often using purposeful sampling, and rarely make claims about external generalizability, beyond the case of their research (Maxwell, 2013). According to Maxwell, the value of a qualitative study actually depends upon its lack of generalizability in the larger population, in order to illuminate an extreme case or ideal type. Concrete case knowledge can be more valuable than a vain search for predictive theories or universally generalizable factors of cause and effect (Denzin & Lincoln, 2011). Case study can be defined as an intense analysis of an individual unit (such as a person or a community), stressing developmental factors and their relationship to their environment (Flyvbjerg, 2011).

Although the subjective nature of qualitative case study research can give rise to a criticism of bias on the part of the researcher, according to Flyvbjerg (2011), this critique is a misunderstanding. He largely based his research on case study on a long history of the use of case study methodology in the field of political science. Case study, according to Flyvbjerg, contains no greater bias towards verification of researchers' preconceived notions than any other method of inquiry. Experienced case researchers find that case study has its own rigor (Flyvbjerg). Flyvbjerg noted that case study is different from quantitative research, certainly, but still robust—it can focus on real life, and researchers' preconceived views can be tested in relation to the phenomena of study. Researchers who conducted in-depth case studies typically found that their preconceived views were wrong and the case material compelled them to revise their hypothesis on one essential point or another (Flyvbjerg). Flyvbjerg argued that subjectivity and bias towards verification apply to all methods of research, not just case study. "There are no objective observations, only observations socially situated in the worlds of—and between—the observer and the observed" (Denzin & Lincoln, 2000, p. 21).

Merriam (1988) found there is no general consensus on what 'case study' is. Often, as Merriam described it, a case study involves fieldwork, is a form of ethnography, and is considered a type of qualitative research. Yin (1994) defined case study as empirical inquiry, encompassing contemporary real life phenomena in context, and described it as so situated that it cannot be separated from the context. Merriam (1988) explained how case study tries to pinpoint the unit of study (e.g., person, social unit, and/or place) and seeks a holistic description of what is being studied. The "single most defining characteristic . . . lies in delimiting the object of study, the case" (p. 27). Merriam described how case studies focus on a particular phenomenon; are bounded by a specific integrated system; include rich, thick descriptions; and illuminate the reader's understanding with a holistic view of the situation. The case study researcher "aims to uncover the interaction of significant factors characteristic of the phenomenon" (p. 29).

Qualitative case study plays an important role in advancing a field's knowledge and is especially useful for studying innovations in education according to Merriam (1988). As Merriam described qualitative case study, the researcher does not test a specific hypothesis, but rather seeks discovery, insights, and interpretations while uncovering factors or interactions characteristic of the phenomenon. As such, qualitative case study includes as many variables as possible in order to best describe this phenomenon. In a sense, the researcher, according to Merriam, seeks insights into how what is observed got to be the way it is, and should examine the specific, but illuminate the general. According to Merriam, this type of research may or may not be influenced by the author's bias, and should seek to illustrate the complexities of the phenomenon from multiple points of view. Moreover, case study does not require or claim specific methods for data collection (Merriam, 1988).

Case studies, according to Merriam (1988), can be classified by their described intent. "A descriptive case study in education is one that presents a detailed account of the phenomenon under study—a historical case study that chronicles a sequence of events" (p. 38). In the field of education, often a unit such as a 'classroom' or a 'student' bound a qualitative case study's phenomenon. In this study, the EXPLORE activity system is the larger bounded unit of study, and the teachers are each viewed as learners in smaller activity systems (see Figure 9).

Focusing on smaller activity systems within and in partnership with the larger activity system allowed me to more deeply understand Project EXPLORE and the meanings teachers made of learning to implement outdoor citizen science projects. Meanings teachers gave to the events and their experiences in EXPLORE, were viewed as a "dynamic interplay between individuals and their society" (Merriam & Heuer, 1996, p. 246). Qualitative case study methodology is in alignment with Vygotsky's (1978) sociocultural perspective of learning undergirding CHAT.

Project EXPLORE Program

This qualitative descriptive case study was bounded by the Project EXPLORE integrated system. EXPLORE was partially funded by the Arboretum and a grant from GlaxoSmithKline. The annual schedule for Project EXPLORE as described in the grant document was from October through May. Arboretum educators selected participants whom they recognized as outstanding teachers from the pool of applicants after a review of essays on application forms. School site training was completed, and Arboretum pre-surveys focusing on attitudes towards science and Environmental Education were administered by EXPLORE teachers to their students during October and November. From December through April teachers were instructed to collect citizen science data weekly outdoors with their class(es). In April, teachers shared their class citizen science research data at the Mountain Science Expo at the Arboretum. In May, Project EXPLORE teachers administered the Arboretum's Project EXPLORE Student Post

Survey that focused on attitudes and program evaluation. Some questions on the Post Survey were the same as questions on the Project EXPLORE Student Pre Survey (e.g. Do you like learning about science?) and some were evaluative in nature asking students how their participation in Project EXPLORE may have changed their attitudes (e.g. After doing this project are you more likely to: (a) take another science class, (b) do a citizen science project at home, (c) learn more about plants and/or animals, and/or (d) none of the above).

The objectives of Project EXPLORE, as explained in the grant application are varied: to promote citizen science; to provide quality hands-on science experiences for youth; to extend the Arboretum's programming; to provide free programming to an underserved population; and to fulfill the need to offer Environmental Education to children. The Arboretum claimed EXPLORE might boost student test scores at local schools, partly based upon research showing the academic benefits of regular Environmental Education outdoor learning experiences.

Funded by a GlaxoSmithKline Foundation grant and private donations, the Arboretum's Project EXPLORE offers teachers training in how to conduct one of three citizen science projects with their class on their own school campus. Many characteristics of EXPLORE, such as the length of the program and the intensive instruction in context, are highly recommended by recent findings in teacher professional development research (Wei et al, 2009).

The most effective professional development programs for teachers are closely related to teaching practices, intensive in nature, sustained over time, integrated with local school reform, and actively engage teachers in collaborative professional communities (Wei et al, 2009). EXPLORE offered an innovative program of on-site professional development for area schoolteachers with long-term follow-up. It included personalized on-site support from Arboretum educators.

The Arboretum education staff (including state-certified environmental educators) prepared teaching materials, offered a $100 stipend in the academic year 2014-2015 to help teachers buy materials, and loaned teachers equipment such as binoculars. The teachers were requested to take their classes outdoors once a week for 15 minutes to observe and collect data for their selected citizen science project. Data were to be uploaded to specified citizen science databases. As participants in Project EXPLORE, teachers could choose eBird, Project Squirrel, Nature's Notebook or another program of choice.

The eBird program is an online checklist of bird observations and has revolutionized the way the birding community reports and accesses data about birds. The goal of the eBird program is to maximize accessibility and usefulness of observations made by both recreational and professional birdwatchers. It is one of the largest and fastest growing biodiversity data resources in existence (eBird, 2015). Initiated in 2002 over 3.1 million bird observations in North America were recorded on eBird by 2012. The Cornell Lab of Ornithology, the Audubon Society, the National Science Foundation (NSF) and Leon Levy Foundation are sponsors of eBird.

Anyone can become a citizen scientist and report sightings of squirrels from anywhere, anytime with the Project Squirrel online citizen science program. The Project

Squirrel online citizen science program recommends submitting at least one observation per site per season, but allows as many observations as the observer would like to make. The website has been active since 1997. The University of Illinois Chicago and the Peggy Notebaert Nature Museum (The Museum of the Chicago Academy of Sciences) sponsor this citizen science program.

Nature's Notebook is a part of the National Phenology Network (npn) citizen science program with a website for posting observations. The purpose of this project is to track seasonal changes in plants and animals. Participants can choose to observe, for example, a tree and record key seasonal changes such as flowering, leaf color change, loss of leaves, and the budding of leaves. Scientists, land managers, and policy decision makers use these data for their research, and for making decisions about land use and policy. The sponsors of npn are The University of Arizona, the University of Wisconsin Milwaukee, The Wildlife Society, The National Park Service, National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), Oak Ridge National Laboratory, and the United States Geological Survey (USGS).

All three of these programs host websites, which offer an opportunity for citizens to upload data. Teachers decided which of the three programs they felt best suited their class and grade level curriculum and specified which program they were going to do in their application to Project EXPLORE. Each program has slightly different ways of collecting data for upload to the website. Navigating those options can be complicated, and the Arboretum provided information, data sheets and field guides, and an initial informational session at teachers' schools in the fall to facilitate successful participation in the projects.

Participating teachers, according to the grant application, were expected to (a) apply to the Arboretum to participate in the EXPLORE program; (b) participate in on-school site training at their own school and conduct a pre-survey of their students (see Appendix H); (c) collect data weekly for the citizen science project; (d) report students' academic progress to Project EXPLORE; (e) present citizen science research at the Mountain Science Expo April 11, 2015, (f) administer a survey of students (see Appendix I); and complete teacher evaluations of the EXPLORE program (see Appendix J).

Given the program's structure and my research interests and in order to be able to look at varied dimensions of activity as theorized by Engeström (2001) the methods I used for gathering data for this qualitative descriptive case study were varied (Merriam, 1988). As noted on Table 1, I employed multiple methods of data collection (e.g., questionnaire, interviews, observations, and review of artifacts), with special emphasis on gathering data from teachers in their own words (teacher voice). My observations sought evidence of teachers acting on the meanings they expressed in their interviews and essays.

Table 1

EXPLORE Qualitative Descriptive Case Study Methods of Data Collection

EXPLORE Methods of Data Collection	Where
Questionnaires	Teachers completed a written questionnaire in the classroom
Interviews	
Initial semi-structured interviews	Held in the classrooms/school offices
Short open-ended interviews after observations and/or self-recorded reflection after outdoors lesson	In classrooms and/or outdoors
Final semi-structured interviews	The Mountain Science Expo 2015
Observations	
Observations of teaching	Held outdoors and in the classroom, with and without educators from the Arboretum present; included classes taught by Arboretum educators
Observations of posters/presentations	The Mountain Science Expo 2015
Observations of teachers' group discussion and CHAT diagrams completed by primary participants	Working in small groups at The Mountain Science Expo 2015
Observations at special events such as school-wide programs or parent teacher association meetings with teachers and/or children performing; meals out	School classrooms, auditoriums, gymnasiums, or cafeterias; nearby fast-food restaurant
Observations of school board meetings	School districts' central office buildings

Table 1

(Cont.)

EXPLORE Methods of Data Collection	What
Review of artifacts	
Classroom artifacts	Classroom materials such as teacher lessons, teacher generated worksheets; posters in the classrooms
School artifacts	In halls and gathering places: school handouts; hall bulletin boards; student artwork; student project library exhibits; school board meeting handouts
Arboretum artifacts	Arboretum GlaxoSmithKline grant document; surveys and results; teaching materials (including lesson plans); worksheets/educator-made data collection sheets; teacher applications to participate in EXPLORE; teacher/student public posters at Expo; excel spreadsheet of demographic data from Project EXPLORE participants; email correspondence from primary participants to the educators; hall displays at the Arboretum
Online artifacts	Arboretum website; school websites; school philosophy/mission statements; schools' 'report card' science test scores online; data uploaded to citizen science websites; email correspondence from participants to the researcher

Study Participants

Primary participants ($N = 13$) in this study were middle class females, and all but two of them self-identified as White. I use pseudonyms for participants in this study. All primary participants had experience teaching; the average was 12 years in the classroom, and most had between 7 and 13 years of experience (see Figure 10). Only two teachers had less than seven years of experience teaching in the classroom. The median number of years in the classroom for primary participants was 13.5 years. Participants are further described in Chapter IV.

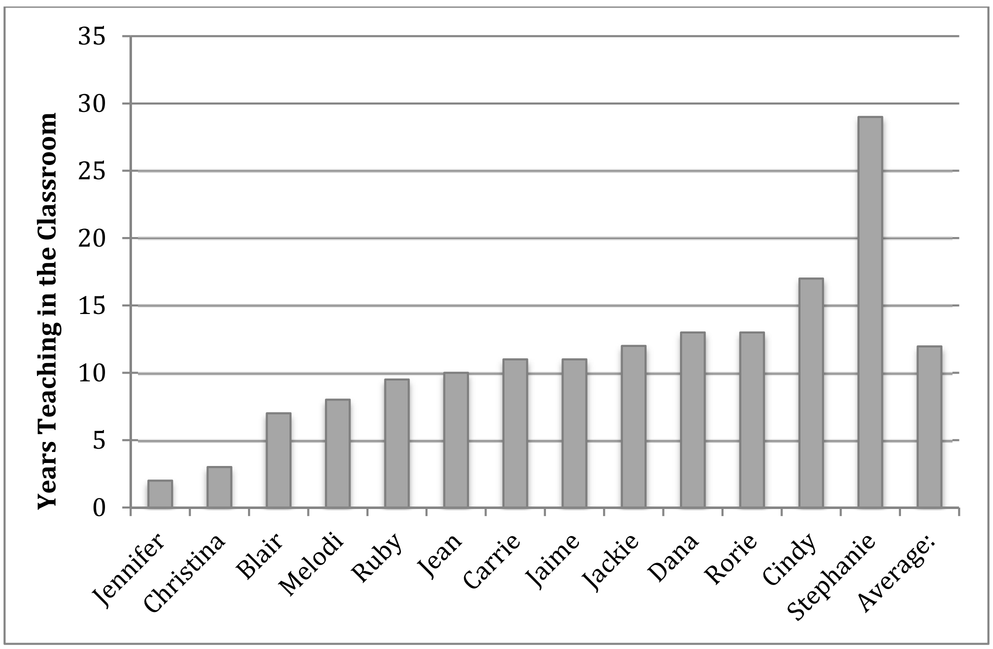


Figure 10. EXPLORE 2015 Primary Participants' Years of Teaching Experience.

Supporting participants in this study were community members in the EXPLORE activity system and included school principals, librarians, garden teachers, Academically Intellectual and Gifted (AIG) teachers, student teachers, interns, parents, district science coordinators and Arboretum environmental educators.

Study Design

I used a research study design that included multiple to collect teachers' reflections. This study design allowed me to participate in and observe the social processes of education, and gave me the ability to analyze data in alignment with sociocultural theory. Research procedures included initial interviews, questionnaires, and observations with Arboretum educators at the primary participants' schools. Additional interviews, observations and review of artifacts for some participants and Arboretum educators also occurred at the schools. Using supporting participants' insights, questionnaire data from the primary participants, initial interview data, and pre-established criteria described in detail in the Study Participants section of Chapter IV, I purposefully selected four teachers as focal participants. Between February and May 2015, I observed the focal participants teach various times both with and without the Arboretum educators, conducted short interviews after some observations, asked teachers to record their reflections on small hand-held digital recording devices, and reviewed pertinent artifacts (i.e., teacher applications; instructional materials; presentations for Mountain Science Expo on April 11, 2015; survey data collected by the Arboretum; information from the Arboretum and school websites).

Transcriptions of primary and supporting participants' recorded interviews were completed through an online transcription service (Rev.com). I transcribed my handwritten field notes for focal participants were into Microsoft Word after data collection. Analysis of data was constant and ongoing. Application essays, interview transcripts, and questionnaire short answers and descriptors (demographics from questionnaires) were uploaded to Dedoose.com online and coded. With the help of doctoral student colleagues, I established codes for themes, connections, relationships, and outstanding elements. Field notes and supporting participant interviews were also uploaded to Dedoose.com and used to support insights gained from data coded on Dedoose.com.

The data sources in this study included interviews, observations and artifact data. A list of the data sources is shown in Table 2. Excerpts from transcripts of interviews and teachers' essays were coded on Dedoose.com. I used the interrelated elements of CHAT (subject, artifacts/tools, rules, community, division of labor, object), expansive learning, tension, and cultural history as my initial codes for excerpts. I assigned sub-codes to emergent themes in the data analysis. I charted outstanding elements for each of the focal participants on activity triangle diagrams (CHAT Charts), and included them in findings in Chapter IV. I triangulated these findings with data from other sources, such as field notes, supporting participant interviews, and artifacts. After my completion of data analysis, I made inferences from the findings.

Table 2

EXPLORE Research Study Data Sources

1. Teacher (primary participants) Questionnaire (see Appendix D)—demographics uploaded to Dedoose.com
2. Teacher Initial and Final Interviews—(see Appendix D; Appendix G) digitally recorded interviews, transcribed and uploaded to Dedoose.com
3. Teacher Essays from EXPLORE Applications—transcribed and uploaded to Dedoose.com from application forms to EXPLORE

Table 2

(Cont.)

4. Teacher Email Correspondence—with Arboretum educators and researcher
5. Teacher Self-recorded Reflections—after teaching outdoors—digitally recorded, transcribed, and uploaded to Dedoose.com
6. Researcher Observation Field Notes—handwritten observations of teachers teaching outdoors and in class, including maps of classrooms and the outdoor environments at each school, and observations from the presentations at the Expo—transcribed and uploaded to Dedoose.com for the four focal participants
7. Researcher Observation/Field Notes of Arboretum Educators' Visits—visits to all 13 participants' classrooms—generally Arboretum educators gave a one-hour presentation at schools twice a year and I observed the second Arboretum presentation/lesson in each participating teacher's classroom in the spring (teachers were not always present)
8. Arboretum Educators' Presentations—digitally recorded lessons taught by Arboretum educators at all 13 participants' schools
9. Recorded Conversations—digital recordings of conversations with Arboretum educators
10. Interviews with Supporting Participants (see Appendix E)—Arboretum educators, principals, colleagues, student teachers, district administrators, digitally recorded, transcribed, and uploaded to Dedoose.com
11. Mountain Science Expo 2015 observations—field notes, photos and digital recordings
12. Teacher posters of activity system triangle elements—drawn and labeled activity system triangles composed by primary participants (n = 8) at the Mountain Science Expo 2015
13. Online website information about Arboretum and schools (e.g., science standardized test scores, student demographics, and school enrollment numbers)
14. Researcher Journal—personal reflections upon myself as a researcher and descriptions of how I situated myself in the context of the study

Stages

This qualitative descriptive case study of EXPLORE had three overlapping stages. The first stage was the design of the study. The second stage was both data collection and data analysis (research procedures). The third stage was making inferences from the results of data analysis (see Table 3).

Table 3

EXPLORE Research Study Design Sequence

Stages	1. Design	2a. Data Collection	2b. Data Analysis	3. Inferences
Methods—Qualitative Interview & Observation; ***Methodology—Descriptive Case Study;*** ***Theory—Sociocultural informed by Cultural-historical activity theory;*** ***World view—Interpretivist***	Design study calendar; design interview, observation, and review of artifacts protocols; design data analysis protocols; design upload to Dedoose; a priori CHAT coding themes	i. Demographic questionnaire and initial interviews; observations; and review of artifacts (*N* = 13); ii. Focal (*n* = 4) observations & interviews; self-recordings of reflections; iii. Posters @ Expo (*N* = 13); CHAT diagrams and final interviews (n=8)	Transcriptions of field notes, & interviews (Rev.com); coding data for themes or outstanding CHAT elements (Dedoose.com); expansive learning matrix using CHAT principles; CHAT charts for four focal participants	Compiling results, determining connections, interrelations of elements, conflicts, and relationships between components, developing understandings, and making inferences.

Note: This table was adapted from Castro et al., (2010), and customized for this study.

In the design stage, I chose descriptive case study methodology in alignment with the sociocultural theory used in this study. The questionnaire, interviews, teachers' recordings of their own reflections on their teaching, conversations with students, and other details of the context in which they taught, and field observations allowed me to study the multiple dimensions of CHAT theory. I used information about school locations for the primary participants ($N = 13$) to map out an initial interview schedule. When I visited each site, often with the Arboretum educators, I observed outdoor lessons.

The first phase of data collection with primary participants was a questionnaire (Appendix D). The purpose of the questionnaire was to gather demographic information from the primary participants (e.g., grade teaching 2014-2015, years of teaching experience, number of students taught per year, and type of school), as well as to gather information about each teacher's childhood and cultural history—especially with respect to experiences in nature and knowledge of the natural world. Extensive research in Environmental Education shows exposure to nature in childhood can affect environmental knowledge, behavior and attitudinal outcomes (Chawla & Cushing, 2007). More recent research also suggests that a positive relationship with nature is necessary to support actions needed to counter environmental crisis (Liefländer et al., 2013).

In the data collection and analysis stage, in conjunction with administering the initial questionnaires and conducting interviews, I observed all of the Arboretum educators' spring visits to all primary participants' classrooms ($N = 13$). I recorded the Arboretum educators' presentations and took field notes during these observations. Using pre-established criteria (see Study Participants section in Chapter IV), I purposefully selected focal participants ($n = 4$). I conducted from four to six field observations of focal teachers, as well as one to two short post-observation open-ended interviews on site with most primary participants. Four of the 13 primary participants recorded self-reflections on their implementation of the Project EXPLORE citizen science projects; two of the teachers who recorded self-reflections were focal participants.

With the help of faculty and colleagues, I observed the Mountain Science Expo 2015 event on April 11th as teachers and students presented their citizen science research to the larger community by sharing posters, displays, and by speaking with the public who passed by to view their posters and displays. We audio recorded the public presentations by students and wrote field notes. Faculty and colleagues helped me conduct final interviews during the same day with all of the primary participants at the Mountain Science Expo 2015 (n = 8). All four of the focal teachers attended the Expo and participated in final interviews. For the research procedures stage of this study, the data collection procedures are listed in Table 4. I listed these procedures in the approximate order they occurred.

Table 4

EXPLORE Research Study Data Collection Procedures

1. Solicited five school districts for support of this research study; sent recruiting emails to potential primary participants (N = 13)
2. Gave a short open-ended interview and initial questionnaire (see Appendix D) to each of the primary participants (N = 13)
3. Selected focal participants (n = 4) as described in the Study Participants section in Chapter IV
4. Observed, recorded and compiled field notes for Arboretum educators' spring visits to primary participants' classrooms, and transcribed field notes for focal teachers
5. For all four focal teachers:
    a. Reviewed pertinent artifacts specific to focal teachers e.g., lessons, teacher designed materials, presentations for Mountain Science Expo 2015, and other artifacts such as teacher application forms and emails (if any) to Researcher and the Arboretum.
    b. Observed and compiled field notes of science lessons outdoors/indoors with the class (the observations included preparation and/or follow up in the classroom, for a range of four to six observations on site per focal teacher)

Table 4

(Cont.)

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   c. Conducted/recorded short open-ended interviews with focal teachers (when possible) after observations (or teachers audio recorded a short reflection after teaching outdoors if the teaching outdoors was not observed by me)
   d. Observed presentations at Mountain Science Expo 2015, including observation of primary participants' and their students' verbal presentations and posters on exhibit
   e. Conducted/recorded final short semi-structured open-ended interviews (see Appendix G) for all four focal participants, along with four other primary participants who also attended the Mountain Science Expo 2015
6. Reviewed pertinent artifacts (EXPLORE teacher applications, EXPLORE instructional materials and questionnaires, data collected by the Arboretum from Project EXPLORE including student surveys, teacher evaluations, the Arboretum and school websites; posters at the Mountain Science Expo 2015)
7. Sent recruiting emails and conducted short semi-structured open-ended interviews with supporting participants (key informants) in school communities, and observed community and school events and meetings and took handwritten field notes
8. Sent transcriptions by email of interviews to primary participants and supporting participants for member checking
9. Asked primary participants to download reports of citizen science data they had contributed to citizen science websites, and to share the report with me

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Field Observations

In field observations, the following questions: How and in what ways did teachers learn to implement citizen science projects outdoors as they engaged in (a) Professional development? (b) Lesson planning process? (c) Teaching practice? and (d) Data collection? (See Table 5). A 'how' dimension of expansive learning was established in a data analysis matrix developed by Engeström (2001) (see Data Analysis section). In the most common forms of teacher professional development (Wei et al., 2009), teachers learn from instructors' modeling (in EXPLORE the environmental educators modeled practices for taking students outdoors to collect citizen science data). Another way teachers learn is by doing, such as in the process of planning a lesson, or the instructional practice of teaching a lesson (Lieberman & Miller, 2014); and as described by Ivey and Johnston (2015) in their study of a classroom setting using the CHAT theoretical framework, teachers learn by engaging in a new activity. In the case of EXPLORE, primary participants were collecting research data as citizen scientists, which was a new activity for them. These a priori questions pertaining to professional development, lesson planning, teaching practices, and data collection in expansive learning were based upon what we know from academic research about teacher professional development and teacher learning (Wei et al., 2009).

Table 5

EXPLORE Observation of Expansive Learning: How Do Teachers Learn?

Professional Development?	How and in what ways did teachers learn to implement citizen science programs outdoors from Project EXPLORE professional development activities (e.g., The Arboretum training sessions/visits, materials provided by The Arboretum, and communication with Arboretum educators)?
Lesson Planning Process?	How and in what ways did teachers learn to implement citizen science projects outdoors as they themselves engaged in the activity of lesson planning (lessons including indoor preparation for teaching outdoors, outdoor activity, and follow up in the classroom)?
Teaching Practice?	How and in what ways did teachers learn to implement citizen science projects outdoors as they themselves engaged in the activity of teaching or engaged in the supervision of teaching by other adults?
Data Collection?	How and in what ways did teachers learn to implement citizen science projects outdoors as they participated in citizen science activities with their students (such as collecting and verifying data, and uploading data to citizen science websites)?

I aligned field observation data gathered in this study with the research questions and I addressed these a priori questions in field observations. These observations tied to a priori questions, in order to be valid empirical evidence of teachers' meaning-making, needed to align with the meanings of learning to enact citizen science projects outdoors expressed by teachers in reflection (e.g., interviews or essays). I further describe validity in this study in the next section of this chapter.

Validity

To increase the validity of this research, I clarified my point of view, experience, and methods. I used member checking with transcripts of interviews. Each interview transcript was sent by email to the interviewees. Interviewees were offered an opportunity to check the transcripts to assure they represented themselves in the interview as they had intended to represent themselves. Participants had an opportunity to clarify, add information, and to correct errors in the transcription of the recording. I used varied methods of collecting data [questionnaire, interviews, interviews with key informants (supporting participants), observations, self-reflection recordings, and review of artifacts] for triangulation in order to increase the validity of the study.

Triangulation

Triangulation in this study was mainly a process of corroborating evidence from different data sources and different methods of data collection to help support interpretations of participants' meanings (Creswell, 2012). As shown in a crosswalk (see Table 6) different methods of data collection were used to answer each research question.

Table 6

EXPLORE Research Question to Analysis Crosswalk for Case Study

Research Questions	Questionnaire	Interviews	Observation & Self-Reflections	Document Review	Method of Analysis
1) What is the nature of The Arboretum's Project EXPLORE professional development for public elementary school teachers when viewed as an activity system? 1a) How and in what ways is there expansive learning in this activity system? 1b) What are points of contradiction in this activity system? 1c) How does this activity system transform or change over time?	Teacher history; demographics; childhood & adult experiences in nature; first experience with EXPLORE	Initial, post observations, focus group, and final interviews	Observe teacher & Arboretum educators at onsite visits; observe Mountain Science Expo 2015 poster presentations	EXPLORE grant doc., application essay, emails, lessons, Mountain Science Expo 2015 class posters, and other artifacts	1) Code for themes, connections, contradictions, and outstanding elements; use CHAT framework to identify elements and for expansive learning matrix of 5 principles for CHAT asking 4 questions about learning for each principle.
2) What meanings do public elementary school teachers who are participants in Project EXPLORE make of learning to teach citizen science outdoors in practice?			Observe class indoors and outdoors in EXPLORE activity	Lesson plans, data sheets, or class posters at the Mountain Science Expo 2015	2) A priori code for *how* teachers learn (matrix); observations as evidence of teachers' meanings
3) What meanings do public elementary school teachers who are participants in Project EXPLORE make of learning to teach citizen science outdoors in reflection?	Qualitative short answers	Initial, post observations, focus group, and final interviews	Teacher records self-reflections after teaching outdoors	Emails to researcher or EXPLORE; Application essays; short answer essay	3) Code for themes, connections, contradictions, CHAT elements & expansive learn matrix

The process of triangulation is done in qualitative data analysis by using different kinds of data sources. Varied methods of data collection allowed me to corroborate some evidence from varied data sources in order to better validate descriptions, connections, and relationships between elements, and the emerging themes during analysis of the case study data. While, in interpretive qualitative research, one person's meaning does not need to be validated by corroboration with meanings attributed by others, triangulation still enhances some information, such as dates, names of people, details about events in the past, or shared histories.

Data Coding Protocol

Data coding was guided by the research questions for this study. My first research question focused on the nature of the Arboretum's Project EXPLORE professional development for public elementary school teachers when viewed as an activity system (Engeström, 1999; 2001). This question led to three sub questions (a) How and in what ways is there expansive learning in this activity system? (b) What are points of contention in this activity system? and (c) How does this activity system transform or change over time? My subsequent research questions focused on the meanings public elementary school teachers who were participants in Project EXPLORE during the school year 2014–2015 made of learning to conduct a citizen science project outdoors in reflection and in practice.

Two doctoral student colleagues, Lacey Huffling and Mary Ash, specializing in science education who assisted me with observations and final interviews (n = 8) along with Dr. Catherine Matthews at the Arboretum Expo, helped me establish a protocol for coding data. I explained the theoretical framework for this study and preliminary findings from EXPLORE questionnaires to my colleagues before the Expo. Their prior knowledge of the research study was helpful in our later discussion about how to begin a preliminary exploratory analysis of the data (Creswell, 2012) and how to proceed from there. I then trained a colleague, Daniela Amortegui, to assist me in coding data according to the protocol I had established with help from Lacey and Mary.

Preliminary Exploratory Coding

As my two doctoral student colleagues and I discussed how best to proceed with coding, we agreed that we would first need to analyze teacher interviews, essays from their application forms, and recorded reflections, and then use those coded data to help code the observation field notes and interviews of supporting participants. My doctoral student colleagues and I would then search for representation of the teachers' meanings in practices. My doctoral student colleagues and I realized we would have to first code teachers' meanings from their reflections before coding observations in field notes or supporting participant interviews. After that, my doctoral student colleagues and I decided the analysis of the data for the EXPLORE system overall could be done as a synthesis of coded data from reflections and observations of all 13 primary participants. In essence, I would be coding research question 3 first, then research question 2, then research question 1 (see Table 6). We decided to use the Research Alignment Instrument (Appendix D) I developed as a guide for initial coding of the themes (Creswell, 2012) or domains (Spradley, 1980) of cultural history, activity system overall, subject, object, artifacts/tools (combined), rules, community, division of labor, and outcomes. As an exploratory analysis exercise the three of us, two doctoral student colleagues and I, each coded a copy of the same initial interview transcript alone. When we completed coding domains on the same interview transcript, we compared our codes, paragraph by paragraph. We agreed on all codes (100% of my approximately 20 coded quotes), and discussed at length any additional coding domains that the other two doctoral students identified that I did not identify in our preliminary analysis. We reached consensus on codes through this discussion.

Coding Discussion

After our sample preliminary exploratory analysis of the data, we discussed how we coded excerpts and why we each coded excerpts the way that we did. For example, my colleagues both coded the Arboretum educator as a 'tool.' They believed that if the primary participant considered bringing in an outside expert as a teaching tool, then that stated intention should be coded as 'using a pedagogical tool.' I did not code the Arboretum educator as a tool. My colleagues' decisions broadened my understanding of a pedagogical tool in the activity system to include bringing in experts to present information to the students. Our discussion helped me expand and deepen my view of the meanings teachers made overall because my colleagues found more phrases to attach to domain codes than I had. The exercise helped me to see more coding opportunities in the transcripts than I had first realized.

Coder Training

I later used our beginning exercise to train a work colleague (she has a MA in International Education) in my established coding protocols. She was well versed in the

CHAT theoretical framework and coding as described by Spradley (1980). I first explained the coding domains to be used and we coded the first paragraph of the interview transcript together. When she finished coding the rest of the transcript on her own, we compared her results with the first three coded copies of the same transcript and found most codes were the same across coders. We discussed any items that were not coded in the same way, and specifically clarified the coding of ‘outcome’ as broader than the outcome of a lesson. Because her specialty is in social science (i.e., international education with a focus on marginalized communities and critical theories), rather than science education, she was able to identify and code for science language used by the interviewee that my doctoral colleagues in science education and I had taken for granted and not coded as science language (perhaps because it was familiar language commonly used by us). She further helped me code all of the EXPLORE data using this protocol. We both coded all EXPLORE data on Dedoose.com to double-check each other and continued to use our established inter-rater reliability. I made the final decisions on the coding of all data. The CHAT theoretical framework informed data coding and my analysis of teacher meanings.

Data Analysis

People have a natural inclination to make meaning of their own lives and lived experiences (Krauss, 2005). The meanings teachers may attribute to learning as participants in EXPLORE were their interpretations of reality. Meanings included aspects of culture and norms; their definitions of the situation; their typifications; their ideology; their beliefs or worldview; and their perspective (Lofland & Lofland, 1995). In data analysis I sought to interpret and understand their experiences in order to better describe and explain their meanings.

Data gathered in the questionnaire and initial follow up interview included personal cultural history (e.g., experience teaching outdoors, years in EXPLORE, years teaching, and education), demographic information (e.g., gender, income, age, education), a description of the school community (e.g., income, school location), as well as reflections on learning to conduct citizen science projects with their students outdoors as a participant in EXPLORE. These data were analyzed for frequency counts of coded excerpts ($N = 13$). All field notes from observations and field notes from my review of artifacts were transcribed and used to corroborate themes found in coding of essays and interviews (Maxwell, 2013). Using the CHAT framework as a lens for analysis, I grouped data by (a) themes, connections, contradictions, or outstanding elements; (b) CHAT elements (subject, artifact, object, rules, tools, division of labor, and community), expansive learning, and tensions, looking for interrelationships; and (c) a matrix (see Table 7) of dimensions of expansive learning as it related to the five principles. As noted by Engeström (2001), the five principles of an activity system are: (a) the activity system is the unit of analysis, (b) the activity system is multi-voiced, (c) the activity system has historicity, (d) the activity system has contradictions, and (e) the activity system has expansive cycles. These five principles were a part of data analysis. The activity system was the unit of analysis, and multi-voicedness, historicity, contradictions, and expansive cycles of the activity system were also considered as part of data analysis.

Table 7

Matrix for the Analysis of Expansive Learning

Analysis of Expansive Learning	Activity system as a unit of analysis	Multi-Voiced	Historicity	Contradictions	Expansive Cycles
Who are learning?					
Why do they learn?					
What do they learn?					
How do they learn?					

Note. This matrix is from Engeström (2001, p. 138).

Themes were identified and frequency counts were calculated for the themes of expansive learning and tensions. Outstanding outcomes were highlighted, and inferences were made from the findings in the final stage of research. Activity theory is "above all, a framework for understanding transformations in collective practices and organizations" (Engeström et al., 2002). In this study I used CHAT to examine teachers' meanings to determine themes of expansive learning in the collaborative group of Project EXPLORE as well as for each one of the focal participants. Outstanding themes were listed on an activity system triangle for each focal teacher based upon Engeström's (2001) diagram, and these are included in results in Chapter IV.

Summary of the Methodology

This study consisted of a qualitative descriptive case study of Project EXPLORE, with 13 primary participants, of which four were purposefully selected as focal participants. The methods for data collection were a short questionnaire and a follow up open-ended interview of all primary participants, as well as interviews of supporting participants and observation of teachers' classes with the Arboretum educators. In addition to the completion of the questionnaire and initial interview, I observed focal teachers (n = 4) four to six times as they and their students conducted citizen science projects outdoors. I observed as teachers prepared students to go outdoors, and I observed follow up after fieldwork in the classroom. Focal teachers further participated in both short open-ended interviews after some observations, and final interviews. Four additional primary participants also participated in final interviews, which were conducted at the Mountain Science Expo 2015. I also reviewed artifacts that teachers used in teaching.

I observed and hand wrote field notes during Arboretum educators' visits to school sites, during lessons in the schoolyard at school sites, as teachers prepared students to go outdoors, and during follow up after fieldwork in the classroom, as well as while observing students' and teachers' presentations at the Mountain Science Expo April 11, 2015 at the Arboretum.

On April 11th, we (faculty, science education doctoral colleagues, and I) made observations of informal presentations by focal teachers who stood with their students or by themselves or sat and watched their students who shared information with the public at the Mountain Science Expo 2015. Following and during our observations, we conducted and recorded final interviews with the 8 primary participants who attended the Expo.

Data analysis was done continuously throughout the data collection period from February through May 2015, and afterwards until February of 2016. The final stage of this research study was compiling results, and using a CHAT framework to code themes in data sources in teachers' own words, determine connections, identify contradictions (tensions), describe relationships between significant factors, develop understandings, and make inferences.

To assure validity of the research, member checking was conducted on all transcripts of interviews. This study used triangulation of data collection methods, collecting data from 14 different sources. Coding of the data was done with the assistance of other peer researchers to triangulate codes. This qualitative descriptive case study methodology and these methods (questionnaire, interviews, observations, and review of artifacts) are in line with a sociocultural theory as informed by activity theory. In this light, this qualitative descriptive case study of a group of teachers is seen as bounded by a unit, the larger activity system, Project EXPLORE. The smaller activity systems of primary participants ($N = 13$) are seen as embedded in and interacting with EXPLORE. In Chapter IV, I present my findings from this research.

CHAPTER IV

RESULTS AND DISCUSSION

> People and organizations are all the time learning something that is not stable, not even defined or understood ahead of time. (Engeström, 2001, p. 137)

Cultural-historical activity theory (CHAT) offered a useful framework for data analysis of this descriptive case study of Experiences Promoting Learning Outdoors for Research and Education (EXPLORE). CHAT enabled me to highlight certain important aspects (e.g. elementary school teachers' meanings and practices) and outcomes (e.g. expansive learning) of the implementation of citizen science projects that existing research seldom recognized or emphasized. This study's data analysis consistently revealed evidence of teachers' expansive learning. The 13 experienced teachers participating in this study designed and mastered new ways of expanding upon science education, science education outdoors, Environmental Education, and citizen science for educational use at the elementary school level.

In this chapter, I present the results of my study. The results are organized by research question. The research questions for my study were:

RQ #1: What is the nature of the Arboretum's Project EXPLORE professional development for public elementary school teachers when viewed as an activity system?

RQ #1a: How and in what ways is there expansive learning in this activity system?

RQ #1b: What are points of contradiction in this activity system?

RQ #1c: How does this activity system transform or change over time?

RQ #2: What meanings do public elementary school teachers who are participants in Project EXPLORE make of learning to conduct a citizen science project outdoors in practice?

RQ #3: What meanings do public elementary school teachers who are participants in Project EXPLORE make of learning to conduct a citizen science project outdoors in reflection?

To answer to my first research question, I begin with a description of the EXPLORE activity system elements using CHAT as a lens. Then, I look closer at the element of community. I first describe the grade K-5 EXPLORE student community, using data the Arboretum gathered from pre and post surveys in 2014-2015. I then introduce the teacher community in the larger activity system of EXPLORE and describe how they formed professional learning communities (PLC's) using preliminary data from questionnaires and interviews for all thirteen primary participants. This introduction of the teacher community offers background information about primary participants' activity systems as part of the CHAT framework for data analysis, as well as insights into the students in their classes.

Then, to answer my research question 1a, I go on to describe outcomes in the larger activity system of EXPLORE, specifically the themes of expansive learning (designing and mastering new ways of doing things) that occurred. I point out contradictions (tensions in the structure of the activity system[s] that have accumulated over time) to answer research question 1b, and describe transformations or changes over time in EXPLORE to answer research question 1c.

I answer my second research question by describing how my observations were used to triangulate teachers' meanings of how they learned to conduct a citizen science project outdoors. I address my third research question by describing four important themes of expansive learning (discussion, inclusion, integration, and collaboration) that focal teachers reflected upon with respect to learning to conduct a citizen science project outdoors. I highlight one of these themes of expansive learning in detail for each one of the focal participants in a vignette. Finally, I follow the four focal teachers' vignettes with a discussion of findings and inferences.

EXPLORE Activity System Overall: RQ #1

I viewed Project EXPLORE as a large activity system composed of an Arboretum in partnership with various teachers who were subjects in their own smaller activity systems. Teachers chose to apply to participate in Project EXPLORE. Teachers selected as participants agreed to host two presentations by environmental educators from the Arboretum. The Arboretum educators offered on-site in-context teacher training and follow-up support. EXPLORE teachers were provided with professional consultation and material support for at least one school year. They received e-support (online help that would have otherwise required a visit or phone call with an Arboretum educator) for up to two years. EXPLORE teachers could choose any citizen science program, but since the

Arboretum adapted materials for K-12 science education for three programs, each primary participant in this study chose one of those three. Nine primary participants chose eBird, two chose Project Squirrel, and two chose Nature's Notebook 2014–2015.

The CHAT elements of the large activity system in this study were specifically identified as follows:

1. *Subject* was the group of teachers and arboretum educators who participated in EXPLORE;
2. *Rules* were set by the Arboretum, national/state/district/school curricula, Environmental Education curricula, cultural norms, and citizen science programs;
3. *Community* included the natural wildlife, the Arboretum, the entirety of participating school systems including students, teachers, administrators, parents, scientists, and myself as a researcher;
4. *Division of labor* described how teaching/learning/science tasks were shared across teachers' activity systems (such as collaboration to address tasks by two or more teachers at the same school) and within systems (such as tasks that teachers shared with parents, assistant teachers and student teachers or interns in their own classroom);
5. *Tools/artifacts* were online resources offered by citizen science programs, materials designed and shared by the Arboretum, materials designed and utilized by the teachers, and physical items such as binoculars, data collection

sheets, computers, and even the ribbons marking the study trees for Nature's Notebook;

6. *Object* (purpose), shared between the Arboretum and schools was teacher learning (learning to implement citizen science programs in the schoolyard) and student science learning benefiting students' engagement in learning in some way; and
7. *Outcomes* were knowledge and expansive learning for both teachers and their students.

The Arboretum collected data from students through pre and post surveys to ascertain attitudes and to evaluate the effects of the program. Highlights from these data are presented in the next section.

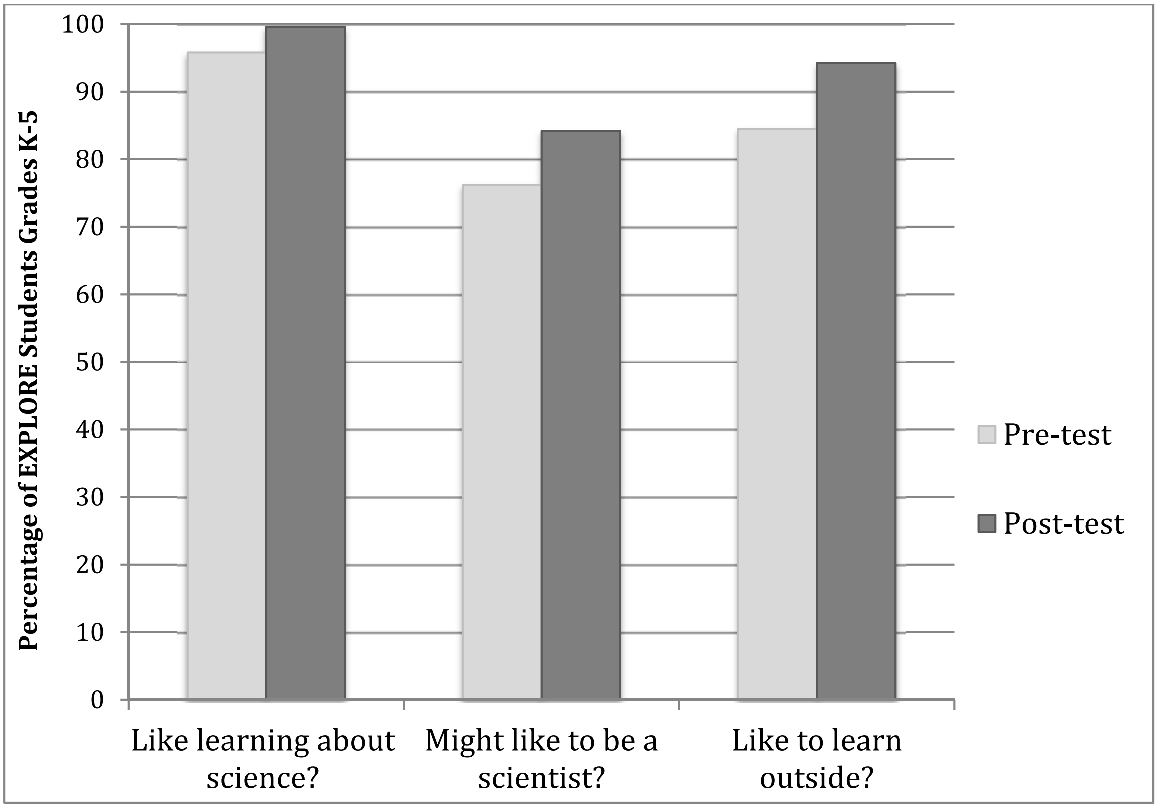
Arboretum EXPLORE Student Surveys

The Arboretum asked EXPLORE teachers to administer surveys to their students in the fall of 2014 and in the spring of 2015. A total of 259 elementary school students (grades 1, 2, 3 and 4) took the post-survey. All of the student respondents were first time participants in EXPLORE, with the exception of 6 students in Stephanie's special education K-2 classroom who had participated in eBird in both the current (2014-2015) and previous (2013-2014) years. 78% were students of primary participants in this study, and 22% of respondents were at charter and private elementary schools whose teachers were participants in EXPLORE, but not participants in this study.

On the post-surveys administered in May of 2015, students responded favorably when asked if EXPLORE had (a) increased their understandings of what scientists do

(95.3%), (b) increased their interest in nature (93.8%), and (c) increased their interest in science (92.3%). A large majority of student participants felt this project increased their understandings and interest in science and nature.

The Arboretum found that by comparing 2014-2015 pre and post survey results, there was evidence that children experienced a positive shift in attitude towards science and outdoor learning (see Figure 11). In general, students were overwhelmingly interested in science and being a scientist, and showed an almost 10% increase in their favorable attitudes towards outdoor learning after participating in citizen science programs with their teachers as part of Project EXPLORE. The 2014-2015 results showed that there was a 9.7% increase in elementary school students' favorable attitudes towards learning outside (from 84.5% to 94.2%). On the pre-survey 76.2% of the students replied that they might want to be a scientist, and 84.2% replied the same on the post-survey, representing an increase of 8% after participation in EXPLORE. The 2014-2015 pre and post surveys also showed EXPLORE K-5 students' attitudes towards learning about science increased favorably (from 95.8% to 99.6%, an increase of 3.8%). There was high interest in learning about science on both the pre and post surveys, in contrast to a general trend of declining interest in science (Kelly, 2014).



Note. Pre-tests (*n* = 336) and Post-tests (*n* = 259) were designed by the Arboretum for K-12 students, administered by EXPLORE teachers, and results were reported to me by The North Carolina Arboretum.

Figure 11. EXPLORE Pre-Post Survey 2014–2015 Results Grades K-5.

Study Participants

Data from questionnaires, interviews, essays on application forms, and artifacts gave me extensive information about each individual teacher in this study, and I use these data to describe the public elementary school classroom teacher primary participants (N=13) in this section and the next section of this chapter. This study's primary participants were all experienced teachers who had an average of 12 years in the classroom. All but two of the teachers had at least seven years of teaching experience in the classroom, and the two with less than seven years in the classroom were both pursuing Environmental Education certification in North Carolina.

All primary participants reported a good deal or extensive experience in the outdoors as children, and most reported experience outdoors as adults. On the questionnaire, using a 1–4 Likert-type scale (1-very little experience in nature; 2-some experience in nature; 3-a good deal of experience in nature; and 4-extensive experience in nature), all of the primary participants reported having some, a good deal, or extensive experience and knowledge of the natural world (see Figure 12). From this measure, Jennifer had one of the highest scores; she scored as one of the most knowledgeable of the outdoors in the group of primary participants. This may have been because she had 17 years of experience working in Environmental Education before teaching in the classroom. In this study, the teachers who chose to engage in Environmental Education and citizen science in partnership with the Arboretum as part of elementary science education had past experiences in nature and knowledge of the natural world.

Most primary participants mentioned they had prior experience teaching outdoors; however, none had enacted citizen science programs in the schoolyard before participating in EXPLORE. Over half of the participating public elementary school teachers in this study identified their schools as rural. Surprisingly, teachers reported that their students had less experience in the outdoors if they were in rural areas than students in suburban and urban schools (EXPLORE 2015 Questionnaire, 2015).

All the schools in this study where these teachers taught were public Title I schools. The Title I nomenclature denotes a high concentration of low-income students enrolled at the schools. All five school districts where the primary participants taught agreed to participate in this study. All 13 of the public elementary school teachers who participated in EXPLORE 2014–2015 also agreed to participate in this study, and were willing to be focal participants if selected.

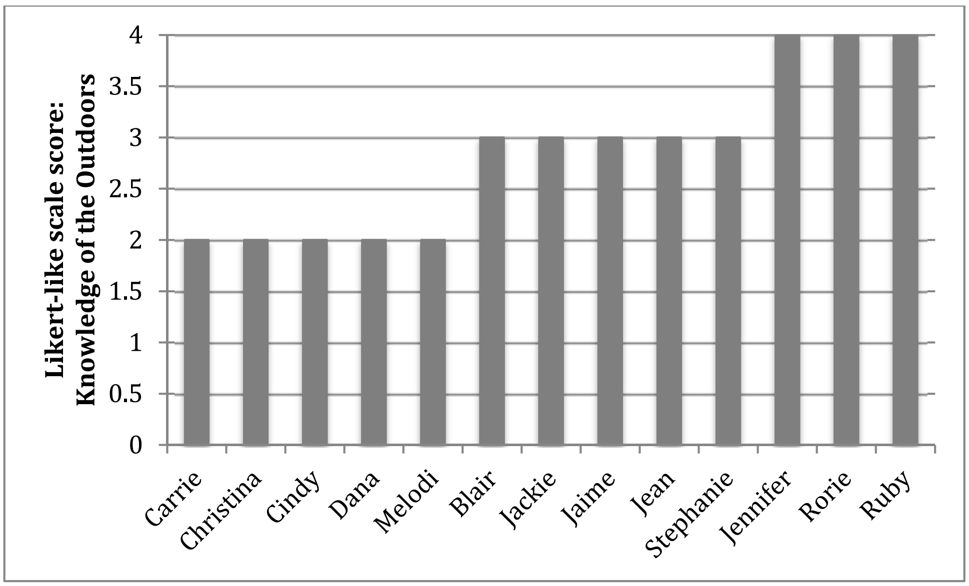


Figure 12. EXPLORE 2015 Questionnaire: Primary Participants' Knowledge of the Outdoors.

I purposefully selected focal participants from among the 13 primary participants. In my purposeful selection of focal participants (*n* = 4), I sought a broad representation of teachers, schools, grade levels and so on as described below; my selection was also dependent upon the availability and accessibility of primary participants. I chose focal participants who were teachers in typical elementary school classrooms (this excluded the one elementary K-2 special education classroom which had a total of six students). From the remaining typical classrooms, which included first, third and fourth-grade classes, I chose focal teachers from each grade level (two in first grade, one in third, and one in fourth). Project EXPLORE had only existed for one year before this study, so I chose both first-year and second-year EXPLORE participants (one first-year focal participant, and three second-year focal participants). I purposefully chose at least one focal teacher participating in each one of the three types of citizen science projects (eBird, Project Squirrel, and Nature's Notebook). I therefore chose two eBird teachers (both taught first grade), one focal teacher who implemented Project Squirrel, and one focal teacher who implemented Nature's Notebook. I chose focal participants at schools with (a) only one EXPLORE teacher, (b) two same grade level EXPLORE teachers who worked collaboratively, and (c) three same grade level EXPLORE teachers who worked collaboratively where one acted as a mentor. I chose focal participants at two suburban schools, one rural school, and one urban school.

I used information from the initial questionnaires and interviews, as well as interviews of supporting participants (e.g., Arboretum educators), to help choose focal teachers. Accessibility was also important in my choice of focal teachers. I could only choose focal participants with whom multiple observations could be arranged. For example, because Jackie's school had a different spring break from all of the other public elementary EXPLORE schools, she was the most accessible Nature's Notebook participant. I had a whole week of possible times to choose from to observe her and her class while all of the other schools in the study were on vacation. I also used information gathered from interviews with supporting participants (key informants).

Supporting participants (16) were Arboretum educators, school administrators, and other key informants including parent volunteers, school librarians, district science coordinators, collaborating teachers who taught other subjects, interns, and student teachers. These supporting participants helped me better understand the focal teachers' meaning making of their experiences in Project EXPLORE. I interviewed all 16 supporting participants, all of whom agreed to participate in the study. The semi-structured interview protocol included questions about the community as well as questions about specific teachers who participated in EXPLORE (see Appendix E).

In addition to data collected from the primary and supporting participants in this study, I collected data via other venues. I gained insights by attending school board meetings; a meeting of a teacher with a district science coordinator; a parent teacher association meeting/program; school programs, shows, and events; student club meetings; a gardening class; a library class; outdoor recess with teachers and students; lunch with the students and teachers in school lunchrooms; and informal meals with teachers and teacher teams outside of school.

Descriptions of the 13 Primary Participants and Their Schools

A total of 28 teachers, including some charter and private elementary school teachers, some middle school teachers, and high school teachers, participated in Project EXPLORE in 2014–2015. However, my study was limited to the 13 public elementary school teachers, eight of whom were second-year participants in EXPLORE, and five of whom were first-year EXPLORE participants. These primary participants taught at eight different schools in five different school districts in the Appalachian Mountains area (see

Table 8). Focal teachers are indicated on Table 8 by an asterisk and their names are printed in bold text. Data were gathered from school locations from February through May. The schedule of data collection dates (via questionnaires, interviews, and observations) and the number of observations at each site are listed in Table 9.

The names of public elementary schools (pseudonyms), the primary participant teacher(s) at each school, the grades they taught 2014–2015, and the citizen science project in which they were engaged are included in descriptions in alphabetical order by school names, after Table 9. These descriptions of primary participants were written using data gathered from questionnaires, initial interviews, and review of artifacts. In describing classroom contexts, I used my observation field notes and classroom maps to inform my descriptions of classrooms and schoolyards.

Table 8

EXPLORE Research Study Descriptions of Primary Teacher Participants

Teacher First Name	Gender/ Years in EXPLORE/ Cohort Status	Race	Title I Location	Grade Level 2014–15	Years Teaching Experience	EXPLORE Citizen Science Program	Students in Class	Education Degree Level Earned	Elementary School	County/ School District	Additional Information
						Returning Participants 2014–2015					
Cindy	F/Y2 w/Y1	White	Rural	3	17	eBird	20	Graduate	Fraser Fir Elementary	Williamson	Wildlife Rehabilitation License; eBird mentor
Dana	F/Y2 alone	White	Suburban	1	13	eBird; & NN 1st yr	23	Undergraduate	Buckeye Valley Elementary	Vickers	Biology/ Ecology fieldwork experience
Stephanie	F/Y2 alone	White	Rural	K-2	29	eBird	6	Graduate	Betulu River Elementary	Williamson	Special Education specialty; to retire 2015
***Jackie**	F/Y2 alone	White	Rural	3	12	NN	25	Undergraduate	Brushy Mtn. Elementary	Stiles	Graduate work done in 2015; NC EE Certif.
Jennifer	F/Y2 w/Y2	Hispanic	Urban	1	2	eBird	20	Undergraduate	Willow Elementary	Reidsboro	17 years of experience in EE; fifth gr. first yr.
***Rorie**	F/Y2 w/Y2	Other	Urban	1	13	eBird	19	Undergraduate	Willow Elementary	Reidsboro	Wants to do graduate work w/STEAM
Jaime	F/Y2 w/Y1&Y2	White	Rural	1	11	eBird	17	Graduate	Magnolia Elementary	Duncan	Social Studies specialty; Carrie her mentor
***Carrie**	F/Y2 w/Y1&Y2	White	Rural	1	11	eBird	20	Undergraduate	Magnolia Elementary	Duncan	Specialized in lower grades; eBird mentor
						New Participants 2014–2015					
Christina	F/ Y1 w/Y2	White	Rural	3	3	eBird	18	Undergraduate	Fraser Fir Elementary	Williamson	State EE Certification near completion
Melodi	F/Y1 w/Y2&Y2	White	Rural	1	8	eBird	16	Undergraduate	Magnolia Elementary	Duncan	Grew up and lives on a farm; EE in college
Jean	F/Y1 alone	White	Suburban	4	10	NN	24	Graduate	Mount Maple Elementary	Vickers	Communications major; democratic class votes
***Blair**	F/ Y1 w/Y1	White	Suburban	4	7	Project Squirrel	27	Graduate	Tulip Tree Elementary	Vickers	AIG/ at grade level class; mountain biker
Ruby	F/Y1 w/Y1	White	Suburban	4	9.5	Project Squirrel	27	Graduate	Tulip Tree Elementary	Vickers	Psychology and Early Childhood specialty

Note: ***Denotes focal teacher; Y2 denotes Returning (second year) EXPLORE participant; Y1 denotes New (first year) EXPLORE participant; NN denotes Nature's Notebook; NC denotes North Carolina; EE denotes Environmental Education; STEAM denotes Science, Technology, Engineering, Arts, and Mathematics; AIG denotes Academically or Intellectually Gifted. Teacher, school, and school district names are pseudonyms.

Table 9

EXPLORE Data Collection Dates

Name of Primary Participant	Questionnaire	Initial Interview	Arboretum Spring Visit Observation	**Field Observations	Expo: Final Interview
Returning Participants Spring 2015					
Cindy	3/24/15	3/24/15	2/23/15	2	4/11/15
Dana	3/2/15	3/2/15	3/23/15	1	4/11/15
Stephanie	3/10/15	3/10/15	3/3/15	1	
Jackie	3/25/15	3/31/15	*3/17/15	4	4/11/15
Rorie	3/5/15	3/5/15	*3/11/15	6	4/11/15
Jennifer	4/9/15	3/5/15	*3/11/15	4	
Jaime	3/26/15	3/12/15	3/16/15	1	
Carrie	3/13/15	3/14/15	3/16/15	4	4/11/15
New Participants Spring 2015					
Christina	3/18/15	3/18/15	2/23/15	1	4/11/15
Melodi	3/12/15	4/9/15	3/16/15	3	
Jean	3/9/15	3/9/15	3/4/15	2	4/11/15
Ruby	3/6/15	3/6/15	3/3/15	6	
Blair	3/6/15	3/6/15	3/3/15	6	4/11/15

Note. *Teacher was absent; ** Dates before 4/11/15.

Betulu River Elementary—Stephanie. Betulu River Elementary School, a rural school where Stephanie taught, was modern brick building with a gabled roof over a long walkway from the parking lot to the front door of the school. The school had a natural area at the rear of the building where there were many tall trees and a paved nature trail winding along a small creek bed on a slight downward sloping hill. Near the back doorway, adjacent to Stephanie's room, was a garden and chicken coop her students tended. Stephanie was a second year EXPLORE participant and had implemented eBird with her students both years (2013–2015). Her students usually remained with her for two years or more as she taught grades K–2 in an intensive intervention (special education) classroom. Stephanie had 29 years teaching experience and had taught in every elementary school grade level as well as at the middle school level. Her graduate degree was in Education, with a specialty in Severe Disabilities. She had an assistant teacher and an intern helping in her classroom of six students. She reported going outdoors once or twice a week with her class, more often in fall and spring than in winter. She had various bird feeders held by suction cups on her window glass, allowing her students to observe birds alighting there.

I did not observe Stephanie teaching alone, but when I observed her during the Arboretum spring visit, she went out with the Arboretum educator, Madie, and was very active in teaching outdoors. On our search for what birds needed in a habitat, she constantly asked her students questions and pointed out birds and nests as we walked through the outdoor natural area at her school.

Brushy Mountains Elementary—Jackie (Jackie was a focal participant). Brushy Mountains Elementary School where Jackie worked was the farthest from the Arboretum of the eight schools in this study, located in a rural area of the Appalachian Mountains. It was an older brick building, physically in the worst condition of all the schools in this study. Brushy Mountains offered both free breakfast and free lunch to all students because the school had such a high concentration of low-income students. The school was clean, but worn. The interior architecture had no frills, with straight lines painted on the floors of the narrow halls to guide students as they were walking in line from one place to another. Yet the boldly colored artwork hung in the halls was cheerful.

The school grounds had an adjacent large wooded natural area. Jackie's students chose trees to study for their Nature's Notebook project and marked these trees with ribbons tied to branches.

Jackie had 12 years of experience teaching, and had taught second through 12th grades. Her undergraduate major was English, and she completed her graduate degree in the summer of 2015, specializing in Instructional Design. Most of the time Jackie taught her class of 25 students alone, but she did have a student intern working with her on certain days. She had her North Carolina Environmental Education certification and I observed she seemed to feel confident when teaching outdoors.

Buckeye Valley Elementary—Dana. The entryway to Buckeye Valley Elementary School where Dana worked was a National Wildlife Federation (NWF)-certified wildlife habitat area. Dana told me it was planted to attract birds. There was evidence of the success of this endeavor. The beams under the open gabled roof over the entry walkway were stained with white bird droppings. This was but a small blemish on an otherwise immaculate suburban school. Dana had participated in Project EXPLORE for two years (2013–2015). The first year she implemented Nature's Notebook (a tree phenology project). The second year she implemented eBird. Dana had 13 years of elementary school teaching experience, had taught all grades (K-5), and was currently a first-grade teacher. Her undergraduate major was Biology and she had extensive experience in field ecology. She had an assistant teacher and a student teacher helping her with eBird in her classroom community of 23 students. Dana went outdoors for lessons regularly, but not at scheduled times, so I was unable to be available to observe her teach outdoors on her own. However, she recorded reflections for this study after teaching citizen science lessons outdoors on a small handheld digital recording device.

At the Mountain Science Expo 2015, she shared an elaborate exhibit, a poster documenting students' eBird data collection and their impressions of their participation in eBird citizen science, accompanied by student-made bird models in handmade nests. These bird and bird nest models were evidence of cross-curricular teacher teamwork as her students made them in art class. Dana's class poster won one of the top prizes at the Expo, and the reward was a pizza party for her whole class paid for by the Arboretum.

Fraser Fir Elementary—Cindy and Christina. Fraser Fir Elementary School, where Cindy and Christina worked, was a relatively new building in a rural area. Fraser Fir Elementary school district included some of the poorest neighborhoods in the larger school district. When the school opened in 2008, Cindy told me, it did not have a playground or textbooks so she and her husband built a nature trail in the woodlands on the large school property. Cindy used the nature trail as a play area and as a teaching tool. The trail began with a small wooden plank bridge and archway that Cindy and her husband built over a shallow drainage ditch at the edge of the dense tree growth bordering the mowed field behind her classroom. I was able to observe Cindy teaching outdoors on her nature trail. She went with a walkie-talkie, stopped in the middle of the hike in an area with wooden slat benches for students to rest and observe, and appeared quite confident to me in teaching outdoors.

Cindy participated in eBird for two years (2013–2015), and was also active at her school. She was one of the teachers in charge of organizing a large annual event for the community to showcase a leadership initiative program, based upon the book *7 Habits of Highly Effective People* (Covey, 1989). During the school year (2014–2015), in addition to participating in eBird, Cindy ran a tulip citizen science project as part of the Journey North Test Gardens, an Annenberg Learner citizen science project (http://www.learner.org/jnorth/tm/tulips/AboutSpring.html) to record bloom dates with her class in the schoolyard garden. The initial tulip planting was supported by a partnership with a nearby public botanical garden.

Cindy had her graduate degree in Elementary Education, taught third grade 2014-2015, had 17 years of experience teaching, and had taught every elementary grade (K-5) except fourth grade, as well as computer lab and special education. Cindy obtained a wildlife rehabilitation license in order to bring small mammals she rehabilitates, such as baby squirrels, to school to share with her students. Her colleague, Christina, had three years of experience teaching third grade, and worked closely with Cindy as a grade level team member. Christina was close to completing requirements for her North Carolina Environmental Education certification. This was something she pursued on her own initiative after exposure to Environmental Education in her graduate elementary education program.

Cindy acted as a mentor for Christina who was a first year participant (2014–2015) in EXPLORE. I observed them both take their classes of 20 and 18 students, respectively, out to the ‘curriculum garden’ at the end of the school day on a sunny afternoon. This was a garden Cindy built. Neither one had classroom assistants.

Magnolia Elementary—Carrie, Jaime, and Melodi (Carrie was a focal participant). Magnolia Elementary School, where Carrie, Jaime, and Melodi worked, was in a rural area of the Appalachian Mountains about an hour north of the Arboretum. There was a ring of small birdhouses on poles in the large mowed grassy center of the circular drive for the car pick-up line in front of the modern new school building. There were many bluebirds flying around the birdhouses each time I arrived at the school. The school had large open spaces in the interior entry and eBird teachers had large glass pane windows taking up half a classroom wall with bird feeders just outside in plain view.

Carrie was a second-year participant in eBird and acted as a mentor to the other two first-grade teachers on her grade level team. Not only did she act as a mentor, she even took other first-grade classes out with her class of 20 students, or asked her classroom assistant to take other first-grade classes out to bird watch, as her assistant had also become proficient at leading eBird observations. She majored in Elementary Education at the undergraduate level, and had been teaching for 11 years. She had experience teaching both first and second grade. Teachers from the first-grade team at Magnolia who participated in eBird with Carrie were Jaime (a second-year participant in EXPLORE 2013–2015, with 11 years of experience teaching and a graduate degree in Social Studies, K-6) and Melodi (a first-year participant in EXPLORE 2014–2015, with eight years of experience teaching Kindergarten and first grade, and a degree in Elementary Education). Both Jaime and Melodi looked to Carrie for guidance and support in implementing eBird.

Mount Maple Elementary—Jean. At Jean's school, Mount Maple Elementary School, the athletic field and playgrounds were in front of the school building. Jean would have liked to do eBird, but her students voted for the trees, and she liked to run her classroom democratically, so Nature's Notebook it was! Her school was in a suburban area; an apartment complex and a factory were adjacent to the school grounds. This was Jean's first year in Project EXPLORE (2014–2015), and she, like Stephanie and Dana, was the only teacher at her school officially participating in EXPLORE. She had 10 years teaching experience, taught fourth grade 2014-2015, and had experience teaching second grade as well. She had a graduate degree and majored in Communications. She did not have a classroom assistant, student intern, or student teacher for her class of 24 students. She taught on her own and had a tall director's chair in the room with her name on it. I was able to observe her take her class out on her own, near the end of the school day. It was a beautiful warm, sunny, spring day. Her class went out at a time when only older students, fourth graders, (her school only went through fourth grade), were allowed out. The trees her students chose to study and marked with ribbons for Nature's Notebook were located in front of the school where other students were playing.

A teacher approached one of Jean's students who held a clipboard with a data sheet on it. She asked him what they were doing. Jean was a short distance away visiting small groups of three to four students gathered at their study trees. She visited groups one by one to take pictures and check their data recordings. The boy told the other teacher that they were collecting data for scientists, communicating to her his recognition of the purpose of his citizen science task.

Tulip Tree Elementary—Blair and Ruby (Blair was a focal participant). Tulip Tree Elementary School where Blair and Ruby worked had an outer periphery of classrooms clustered around open common areas called pods. Each pod was named for a local landmark with historical significance. These pods all surrounded a central hub where the offices, media center, auditorium and gymnasium were located. A visitor had to walk a good distance to the central hub from the parking lot in order to enter the school. The walk passed an overgrown wooded area where I saw squirrels each time I visited. These naturally overgrown areas on two adjacent sides of the school building were heavily wooded and offered a surprisingly large natural area for a suburban school.

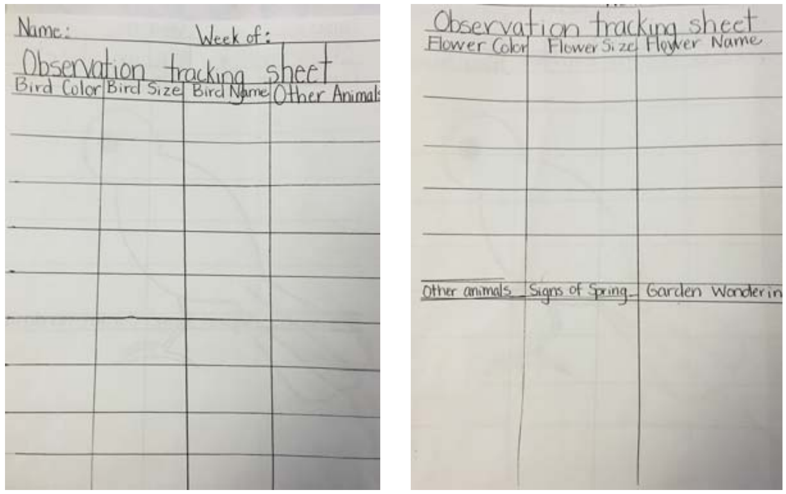
Both Blair and Ruby were first year participants in EXPLORE in 2014–2015. Blair said she picked Project Squirrel because she thought it would be the easiest citizen science project out of the three suggested by the Arboretum to do with her class. Blair and Ruby taught fourth grade and each had 27 students in their classes. In Blair's class 17 students were classified as AIG (Academically or Intellectually Gifted) and all other students were at or above reading level for their grade. Ruby heard about Project EXPLORE from Blair; they worked closely together on a fourth-grade team and their classrooms were next door to each other. In addition to collecting data on squirrel observations, they decided to conduct a study of squirrels' feeding habits over four consecutive days. Blair's class used dried ears of corn on shallow cardboard boxes to attract squirrels and Ruby's class used sunflower seeds in bowls of playground sand.

Blair had seven years of experience teaching, had taught fifth grade as well as fourth, and had her graduate degree in Elementary Education (grades K-6). Ruby had nine and a half years of experience teaching fourth grade, and had her graduate degree in Psychology and Early Childhood Education. An assistant teacher helped both Blair and Ruby in the mornings by taking students outdoors early each of the four days of the Project Squirrel feeding preference experiments. Parent volunteers took students outdoors in the afternoons of the four days of the experiments.

Willow Elementary—Rorie and Jennifer (Rorie was a focal participant). Willow Elementary School, where Rorie and Jennifer worked, had lively colored larger than life artwork on the front of the school building facing out for all to see. The rich soil was being leveled to the left of the main entrance for a new outdoor learning area with a circular gathering spot in the center. According to the artist's rendering posted on an easel just inside the front entrance of the school, the area would one day be filled with trees and shrubbery. Just above the front entrance of the school, on the second floor, was a row of large glass pane windows from the media center where students could bird watch in rainy or snowy weather. To the right of the school building was a large athletic field, an active greenhouse with parents coming in and out with toddlers, and a lush green garden, as well as a playground structure under tall trees in the far back corner. On the opposite end of the mowed grassy athletic field was a wooded area where a short trodden path with a gradual downhill slope rambled under tall trees in a naturally overgrown tiny forest. Groups of Robins were pecking for worms all over the field whenever it was empty of students. A large clear plastic cylindrical bird feeder hung from a tree on the edge of the parking lot. On sunny days, holes bored in benches along the driveway held extremely large colorful umbrellas. Students could sit in the shade while waiting to be picked up by car. The principal was often ‘working’ the car line and greeted parents by name as he helped load students into their cars. This was an urban Title I school that was well connected to the larger community.

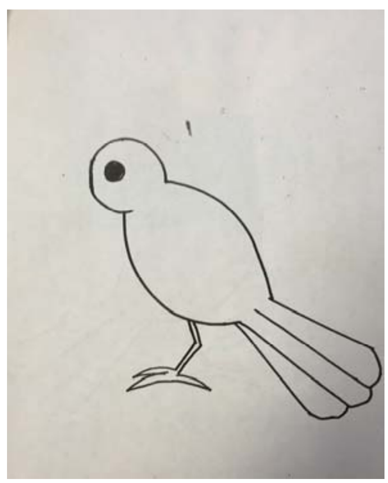
Rorie and Jennifer were both on the first-grade team at Willow Elementary (2014–2015) and had both implemented eBird for two consecutive years. Rorie was the teacher who identified her race as ‘Other.’ She and Jennifer (the teacher who identified her race as Hispanic) had classes of 19 and 20 students, respectively. They were eager to tell me when I first met them of all they did with science. There was a school-wide focus on science at Willow Elementary. Rorie took me to see the binoculars in the Media Center, stored in a plastic bin on a low shelf with copies of a data collection worksheet she had adapted for her students (see Figure 13); and a simple bird outline template she made and copied for them. Her students could draw/color the birds they saw with crayons. Students had to observe the bird’s colors in order to draw it on their own (see Figure 14). The template was not complete (it was missing a beak), so some of the drawing had to be completed freehand. These data collection worksheets and direct observation bird templates were an innovation for the activity designed by Rorie.

Rorie had been teaching for 13 years, was teaching first grade in 2014–2015, and had taught prekindergarten at a Montessori school, as well as Kindergarten, second, third, and a K-2 class. She majored in Elementary Education. Rorie expressed she would like to complete her Master’s Degree and specialize in STEAM (Science, Technology, Engineering, Art, and Math).



Note. Data collection included flora and fauna in addition to bird species.

Figure 13. Rorie's Classroom Data Collection Sheet (2-sided).



Note. Students drew the beak.

Figure 14. Rorie's Classroom Bird Template.

Jennifer taught fifth grade in 2013–2014, and had been teaching for two years. She had 17 years of experience in Environmental Education administration before becoming a classroom teacher. Her undergraduate major was Environmental Policy with a minor in Economics. Jennifer completed a teaching licensure program beyond her BS, and had taken some graduate level classes as well. She was working towards her state Environmental Education certification. Jennifer and Rorie's community of practice as defined by Lave and Wenger (1991) is described in a vignette in more detail later in this chapter.

EXPLORE Communities of Practice

An advantage of EXPLORE was that communities of practice (Lave & Wenger, 1991) formed where teachers in the program were mentored or assisted by other teachers. Teachers' supportive communities, by sharing responsibilities and tasks, strengthened teachers' abilities to offer their students the many benefits of learning outdoors. Four teacher participants were the sole EXPLORE participants at their school and spoke of their classrooms as a community and included, if they had one, their assistant teacher and their student teacher or intern in their description of their activity system. In fact, an uncalculated benefit of the EXPLORE program was that assistant teachers, student teachers and interns (preservice teachers volunteering as part of their university coursework) working with EXPLORE teachers learned to enact citizen science programs in the schoolyard and some led outdoor data collection fieldwork activities for their class.

Expansive Learning: RQ #1a

I found that for the 13 teachers in this study, the most prominent outcome reflected upon in primary participant interviews and essays was expansive learning. I coded teacher reflections from applications and interviews for the CHAT elements of (a) subject, (b) tools/artifacts, (c) rules, (d) community, (e) division of labor, and (f) object(s); I also coded (g) cultural history, (h) tensions, and (i) outcomes. These nine codes were all a priori codes. As I examined these data for emergent themes (e.g., discussion, inclusion, integration, and collaboration) they were also coded. These codes were evidenced within an individual teachers' activity system, and/or across activity systems within the larger EXPLORE activity system (Engeström, 2001). These themes also appeared within and across data sources. Teacher reflections were often evidenced in teacher practices I observed, and triangulated by supporting participants' interviews.

It is important to note that primary participants learned to implement citizen science projects in their own schoolyards, a new experience for all of them. Each of the 13 participating teachers transformed the activity, Project EXPLORE, in some way, going above and beyond the requirements and therefore designing an expanded educational experience for their elementary school students. From the composite of teacher voices the most prevalent outcome that emerged via reflections in interviews and essays was expansive learning because these experienced teachers all designed and mastered new ways of doing things (Engeström, 2001).

Through an analysis of frequency counts on Dedoose.com of coded excerpts, I found that more primary participants spoke of expanded thinking (all 13) and did so more frequently (60 excerpts out of 293) than any other theme of expansive learning (see Table 10). Frequency counts for just the four focal teachers showed that the most frequent theme of expansive learning for the focal teacher sub-group was engaging science, and the second highest frequent theme of expansive learning for the sub-group of focal participants was expanded thinking (see Table 11).

Table 10

EXPLORE Frequency Counts of Excerpts from Interviews and Application Essays by Trends

Trends	**Number of Participants**	**Number of Excerpts**
Outcomes		
Expansive Learning, Knowledge, Student Excitement	**13**	**408**
Expansive Learning (RQ #1a)	13	293
Expanded Thinking	13	60
Engaging Science	10	57
Integration	10	52
Skills	11	45
Collaboration	8	34
Discussions	8	26
Inclusion	8	19
Knowledge	12	66
Student Excitement	10	49
Contradictions/Tensions (RQ #1b)	**13**	**171**
Mandated v. Teacher Choice of Time Use	11	34
Indoor v. Outdoor Behavior	11	30
Time Scheduling vs. Unpredictability of Nature	13	29
Excitement v. Containment	7	29
Non-normative Practices vs. Normative Practices	7	24
Community Customs vs. Time in Nature	6	15
Online Citizen Science vs. Technology Limitations	5	10

Note. These frequency counts are for excerpts from transcripts of interviews and application essays for all primary participants (N = 13). Dedoose.com was used as an online tool for qualitative data analysis. RQ denotes Research Question.

Table 11

Focal Frequency Counts of Excerpts from Interviews and Application Essays by Trends

Trends	Number of Participants	Number of Excerpts
Outcomes		
Expansive Learning, Knowledge, Student Excitement	**4**	**223**
Expansive Learning (RQ #1a)	4	168
Engaging Science	4	46
Expanded Thinking	4	33
Skills	4	22
Integration	4	22
Discussions	4	18
Collaboration	4	16
Inclusion	3	11
Knowledge	4	38
Student Excitement	4	17
Contradictions/Tensions (RQ #1b)		**67**
Non-normative Practices vs. Normative Practices	4	16
Mandated vs. Teacher Choice of Time Use	4	13
Time Scheduling vs. Unpredictability of Nature	3	12
Indoor vs. Outdoor Behavior	4	9
Community Customs vs. Time in Nature	4	9
Excitement vs. Containment	3	4
Online Citizen Science vs. Technology Limitations	1	4

Note. These frequency counts are for excerpts from transcripts of interviews and application essays for focal participants (n = 4). Dedoose.com was used as an online tool for qualitative data analysis. RQ denotes Research Question.

Expanded thinking is a theme that represents teachers' perspective of either their students' expanded thinking or their own expanded thinking. Teachers often described notions of expanded thinking of their students as thinking outside the box, independent thinking, developing critical thinking skills, asking questions and having more detailed discussions, and integrating the project with other subjects like arts and engineering.

Teachers demonstrated their own expansive thinking by detailing future plans to expand Project EXPLORE, integrating the project into all subjects, making it a school-wide project, and describing how what they learned broadened their perspectives and changed their pedagogical practices.

Rorie, who worked at a Title I elementary school in a high-poverty, high-crime area, had an exemplary interview excerpt of the theme of expanded thinking. This excerpt was coded for both teacher and student expanded thinking. Rorie expanded her thinking about science education through participation in eBird to include a larger context for student learning, and she saw that her students could think above and beyond what was happening in their nearby urban neighborhood.

> Project EXPLORE, for me, is to take them away from stuff that they are focused on and trying to survive and open up to, "Yes, but let's look at the bird." Like the bird is one of the only animals who has adapted to rise above everything, literally. Wingspans, all the different types of birds in their area, can either tell you what season we are in [or] how [they] pollinate; and they were working in the garden so much too, that it led them to explore other animals like butterflies and bees. (Interview, April 11, 2015)

For many of her students, as Rorie explained it, life was dangerous in the high crime area in which they lived. As she described the experience EXPLORE afforded her students in her interview, I interpreted Rorie's story of her students' focus on the flight of the bird as a metaphor for a freeing experience of the mind for the children. Her first-grade students were able to expand their thinking without leaving their neighborhood from seeing crime on the ground to viewing a bird in the sky, and ponder what that bird meant to the natural world. This was but one example of expanded thinking as a theme of the many reflections teachers had upon expanded learning.

There were other themes of expansive learning that were important to primary participants. Eleven out of 13 primary participants spoke of designing and mastering new skills (refer to Table 10). Ten spoke of innovations in engaging their students in science learning. Teachers also spoke of four other themes of expansive learning that I have chosen to highlight: discussion, inclusion, integration, and collaboration. These themes involve practices that are lacking, yet important, in elementary school education (Roth, 2014).

All four focal participants indicated that expansive learning was the most significant outcome of their EXPLORE experience. In the sub-group of focal teachers expansive learning was the outcome code with the highest frequency count (168 excerpts out of 223) (see Table 11). The four focal teachers (Jackie, Carrie, Blair, and Rorie) and their school-based activity systems were studied in more detail and these teachers' stories exemplify the four aforementioned themes of expansive learning outcomes which were found across and within the 13 primary participants' activity systems.

In the following sections, I describe and define the teachers' expansive learning themes of discussion, inclusion, integration, and collaboration as they were recognized in this study, using evidence from the four focal participants in support of these findings. Later in this chapter, I describe these four themes of expansive learning in greater detail as they pertain to specific focal teachers (one theme per teacher) in answer to the third research question.

The expansive learning theme of discussion. Teachers can give students an awareness of the nature of science by drawing their attention to variations in actual data collected, variations not present in in textbooks or field guides; examining variations is more powerful than examining generalized science data (Hamza & Wickman, 2009). Hamza and Wickman found that as a result of a deeper understanding of the detailed variations in nature, students began to expand their vocabulary and talk the science language. Blair, a focal participant who taught fourth grade, observed this happening in her classroom early on in discussions about Project Squirrel. "They were funny trying to use those words," Blair said, "I can't remember, but one of the words one of the kids was mispronouncing, but they were trying to use these. They like these new words" (Interview, March 6, 2015).

Discussion, talk, or conversation are the words Blair and other focal teachers used to describe discussions they facilitated in their classrooms to accompany their class's EXPLORE activity. Blair described how she made time for discussions she led to accompany Project Squirrel, ". . . we just don't have a lot of time for science. That's unfortunate and sad, but we're having to cut out a reading lesson in order to fit it in and talk about Project Squirrel" (Interview, March 6, 2015). Blair indicated she was sacrificing one subject (reading) to make room for talking about or discussing Project Squirrel and the class's squirrel food preference experiment (science). "We had a quick conversation every day at the end of the day or at the beginning of the next day," she said, "to see how much corn was eaten and why we thought not a bit of the corn was eaten" (Final Interview, April 11).

Discussion was something all four focal participants mentioned. Carrie, a first-grade teacher, noted that before EXPLORE she and her class talked about habitats and an array of animals but with eBird students had more in-depth knowledge of specific bird species' habitats and behaviors. For example, Carrie said that her students liked being able to differentiate between different habitats for different birds and I observed that her students were able to imitate a Crow's behavior, they knew the Crow's call from memory in whole class discussion. Rorie, also a first-grade teacher, led discussion with her students when they came in from whole class eBird fieldwork. She posed some open-ended thought provoking questions, such as "“Why would this bird be big and what is its size going to help them do versus a small bird that's going to be in a tree right near our school?" (Final interview, April 11, 2015). Jackie spoke of how her third-grade students, through their participation in EXPLORE, were more willing over time to discuss things in class that they did not understand about their Nature's Notebook tree phenology study. This is evidence that Jackie allowed students' questions to be part of class discussion.

In Blair's classroom, discussion was inquiry-based (Capps & Crawford, 2013) and she had some preconceived goals for her students' conversations. She had students who were working in small groups outdoors, taking turns to leave corn out in the morning in 'safe' and 'unsafe' spots and retrieve it in the afternoons to collect data on the residual corn, and then report their findings to the whole class.

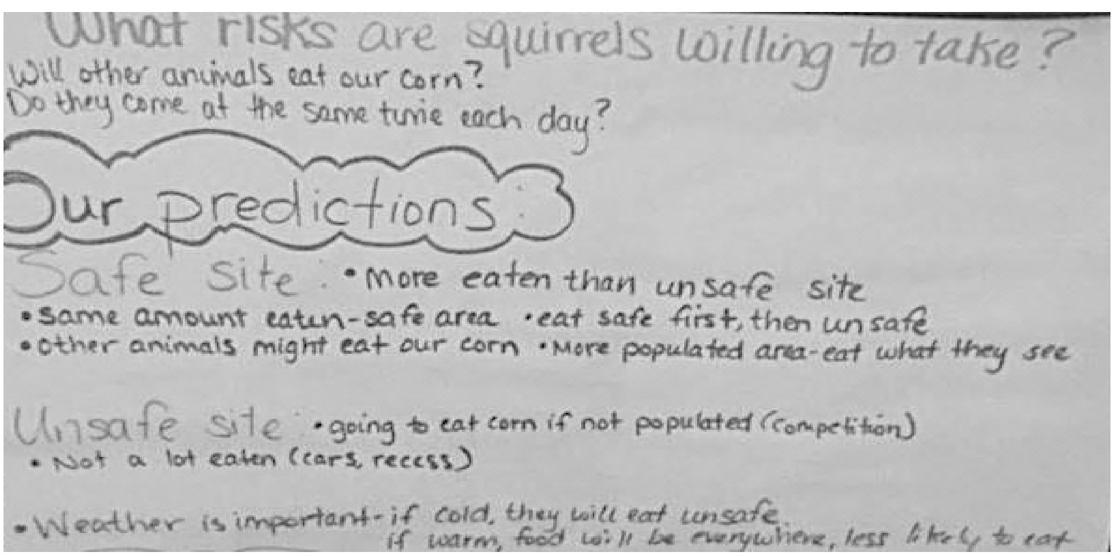
> By studying the change in food amounts we set out, the students will see how the squirrels responded to a change in their environment. If we see that our food amount dwindles significantly, students can draw the conclusion that the squirrels responded well to the extra food source. We could experiment with different

> locations of the food to see if that has any impact on the food left over.
> (Application form for 2014–15)

Before acceptance to Project EXPLORE, Blair read the Project Squirrel materials and saw that the food experiments would meet fourth-grade science and social studies curricular standards (the gray squirrel is the state mammal) as well as introduce her students to the scientific method. She had a preconceived notion in her application that the squirrels would eat the food left out, and she already had an idea that she and her students could conduct further inquiry. This is important to note because this was later reflected in her classroom discussions. Blair's inquiry-based discussion was broad in scope because in her class's discussions not all inquiry was teacher initiated (Capps & Crawford, 2013). She set the tone for discussions by her initial openness to further inquiry, but in later interviews she thought the ideas for further inquiry her students came up with were especially 'cool' and she was excited by their enthusiasm. The experimental data from the schoolyard did not support Blair's original hypotheses that she included in her application, and perhaps because of this she shared her students' curiosity as to why the squirrels didn't eat the corn. Her hypothesis was that squirrels would eat the corn that the class set out, but in actuality almost none of the corn was eaten by squirrels.

However, the students, as well as Blair, were intrigued by why the squirrels would not eat the corn. This led to many interesting discussions in the classroom. After small groups of students presented their data to the whole class during discussion time, the class talked about the findings and the whole class was allowed to contribute to a critique of the results and the experiment. This was evidenced by a poster (an artifact) that Blair made for the class (see Figure 15) and added to each of the four days of the experiments.

Blair exposed contingencies in science by making students' findings the topic of discussion. She used words that researchers Oliveira, Akerson, Colak, Pongsanon, and Genel (2012) identified as "*hedges* (tentative words such as maybe)" (p. 652). The fourth-grade elementary school teacher in a qualitative study done by Oliveira et al. used science education discussion that was mostly hedged; as opposed to a kindergarten teacher they studied who used mostly "*boosters* (expressions of certainty such as 'clearly' and 'obviously')" (p. 652). As in an academic conference, one group of 'scientists' were presenting their findings in Blair's classroom, and the whole class was helping them use the evidence presented and their prior knowledge about squirrels to discuss the causal nature of the findings.



Note. This poster noted initial discussion points from Project Squirrel discussion in Blair's class.

Figure 15. Blair's Classroom Daily Discussion Poster.

Blair's students engaged in inquiry about how they could gather more evidence to help them better understand the squirrels' behavior in their schoolyard. As Blair had not foreseen their findings, nor imagined some of the further inquiries her students were suggesting, she was implicitly communicating to them through her class discussion the nature of science (Oliveira et al., 2012), which is that there exists uncertainty in the outcomes of scientific investigations.

The expansive learning theme of inclusion. Inclusion for EXPLORE participants meant including all students, students with special needs, learning difficulties, English language learners, gifted students, and students who may have otherwise been marginalized from science learning for economic or academic reasons, such as reading ability. Children with special needs are included in *Project 2061*, a program of the American Association for the Advancement of Science (AAAS) promoting science for all, and this presents a challenge for elementary educators in part due to a well-documented lack of teacher science content knowledge—knowledge that could help a teacher successfully teach science to all students, including those with special needs (Alber-Morgan et al., 2015). Alber-Morgan et al. found that a critical component to effective inclusive science instruction for children was providing hands-on inquiry learning opportunities. Biologist Rachel Carson (1999) expressed the idea that feelings are also important for children's science learning. She wrote that it was more important for a child to *feel*—to experience a world of beauty, wonder, and excitement—than to learn science facts that he or she could not readily understand. The *feeling* would pave the way for the child to want to know more.

Focal teachers Blair, Jackie and Rorie spoke of ways they facilitated learning for exceptional, marginalized and struggling students, mastering ways to include them all in the citizen science learning experience with hands-on inquiry outdoors. Blair's class was composed of 17 Academically or Intellectually Gifted (AIG). All 24 of her students scored at or above grade level in reading. "We researched everything that they could find out about the gray squirrel," Blair explained, "just to give us some more background knowledge on that" (Interview, March 6, 2015). In order to meet their advanced learning needs, Blair designed activities related to EXPLORE that would challenge her students and require them to negotiate advanced technology skills (an online research 'web quest' investigation) and presentation skills (presenting data to the class).

As Jackie described her classroom community it was intellectually, racially, and ethnically diverse.

> I had 5 ESL [English as a Second Language] students, 4 AIG, and the rest were low to average. Out of 19 students, 14 were low socioeconomic, with all students at [my school] being on free and reduced lunch. I had five Hispanic, one student from Yemen, and one Black student. The remainder of the students were White. (Email, January 21, 2016)

Jackie's school was located in a high poverty area of the Appalachian Mountains and was notably the oldest school building of all the schools in the study. The bathrooms especially showed the marks of wear and use over time. When I observed Jackie I noticed that her school, Brushy Mountains Elementary School, was in many ways bleak and empty of frills indoors, but had a rich, lively, densely populated natural area outdoors.

As I observed Jackie's class March 25, 2015, I noticed she allowed students to make scientific observations in addition to those required for Nature's Notebook. Jackie asked students to list their observations on the white board when they came back inside. Then she had them present their observations to the whole class. Jackie allowed students to bring specimens into the classroom from fieldwork, such as flowers or lichen. During teacher-led discussion time, Jackie allowed students, in particular one boy who was interested in lichen, to come to the back table where I was sitting to more closely examine the lichen specimens. His preference for tactile learning was allowed both outdoors and inside the classroom.

On April 2, 2015, when I observed Jackie's class, I noticed that she gave the students an open-ended exercise; she wrote on the white board "Research facts about your tree". As students were working on researching facts about trees, Jackie allowed students to also work on different tasks. This allowed for student curiosity through a differentiation of learning tasks. Some students were drawing the life cycle of a tree, some wrote down their feelings about trees in their journals, some wrote poems. A group of four girls were researching information about red maple trees on their desktop computer tablets with attached keyboards. As the girls explained it to me, they were all working together, putting their ideas together. This differentiation, promoted students' curiosity and was evidence of how Jackie allowed her students to research answers to their own questions, thus including all students' questions in the classroom curriculum.

Rorie's first-grade class of 18 students was composed of a wide variety of learning levels and needs (three students were above grade level, three on grade level, and 12 below grade level in reading, writing, and mathematics). Two females, one Israeli and one biracial (white/Asian) were classified as Academically or Intellectually Gifted (AIG) and five males (three Blacks and two Whites) had Individualized Education Programs (IEP) for special learning needs. Rorie said that a major impact of her participation in Project EXPLORE was that it "introduces science in a way to them that makes sense" (Final Interview, April 11, 2015).

Rorie was careful to request her students take one action at a time, making it simpler for all of them, for those with special needs as well as for others, to know exactly what she expected. When outdoors with her class, Rorie had all of her students take responsibility for data collection, and for keeping track of their science folders and recording sheets, as was evidenced in my field notes.

> Then it began to rain, so we went to a covered area. Rorie began to line the children up to go indoors. Another teacher came by, I believe a teacher, an adult woman, White in her 40s, and she asked the children who left their folder over there, or something like that. Rorie told the other adult "I'm going to line them up first". Rorie takes full possession of her teaching and does not like to be interrupted I think. She lined the children up, and then she asked them to look around and see if they were missing anything. She's very good about having each child be responsible for his/her self. She does it step-by-step. She's very organized about that. (Field notes April 6, 2015)

This excerpt from my field notes is evidence of Rorie using age-appropriate instructional methods outdoors for high needs students that are useful to all of her students.

The expansive learning theme of integration. Integration of the disciplines of science and Environmental Education was required as part of the EXPLORE project, but all four focal teachers spoke of integrating citizen science with other subjects (e.g., mathematics, reading, Language Arts, art, technology, engineering, and music) in addition to Environmental Education, often in response to school curricular requirements. For example, Blair said, “Ours [Squirrel Project experiments] are a little bit more complicated. Ours kind of go a little more into the math in my case, having to weigh [the residual corn] in grams, and trying to figure out how much is left over” (Interview, March 6, 2015). Carrie and Rorie both integrated mathematics with their first-grade classes’ citizen science projects by asking students to make bar graphs using data from their eBird observations.

Uçar (2015) concluded from his research on early childhood science education that mathematical concepts are needed to understand scientific concepts. He found that integrating science instruction with other subjects could enrich effective science learning for young children. The integration of different subjects with science while using citizen science in education was documented in prior research (Mayer, 2010). Mayer presented an example of how a fifth-grade teacher who used a phenomenological citizen science program called Project Budburst in her classroom integrated citizen science with other subjects.

> In addition to honing the scientific skills of observation and data gathering, the students are using Project Budburst as a launch pad for exercises in expository writing (they write about their trees and their observations), reading (they research the tree species, the seasonal cycles, and climate change), and technology (as a team they visit the Project Budburst Web site and enter their data). [The teacher] calls this approach “transdisciplinary,” and says her school district has been very supportive of her use of Budburst in the classroom. (p. 174)

As in this example of Project Budburst in the elementary school classroom, Jackie's third-grade students kept science journals of their outdoor observations during the weeks they were collecting data for Nature's Notebook and they used individual tablet computers at their desks to find information to include in written reports about the tree species that their group was observing. They searched freely for relevant information. As I roamed the room on April 2, 2015, I saw some students reading general information about the tree and other students reading about more specific characteristics, such as about the leaves that their tree had. I learned at a school board meeting, April 20, 2015, that computer access and technological literacy for all students was a district-wide initiative in the Stiles school district where Jackie taught. Jackie integrated technology instruction with the tree citizen science project in alignment with her school district's initiatives.

Rorie participated in a STEAM (Science, Technology, Engineering, Arts and Mathematics) project in collaboration with the garden and music teachers at her school. The project focused on planting a rain garden on the school grounds and presenting a musical to celebrate the experience of planting a rain garden. Rorie integrated data collection for the rain garden/musical project with data collection for the eBird citizen science project. While the children in Rorie's class were outdoors they could record data about birds, insects, and plants on the data sheet Rorie designed to both meet the requirements for eBird in EXPLORE and to boost deeper understanding of the ecosystem in preparation for planting a rain garden and singing about it for the integrated STEAM project later in the spring (Field notes from observation and from STEAM presentation

May 21, 2015). The STEAM project was also evidence of team collaboration at Willow Elementary School. Collaboration is the last of the four themes of expansive learning I highlight.

The expansive learning theme of collaboration. Vangrieken, Dochy, Raes, and Kyndt (2015) in a recent literature review found that "teacher collaboration pays off" (p. 35), and "all parties involved in education benefit" (p. 36) from teacher collaboration. The European Commission (2013) found that teachers who collaborated reported using more innovative pedagogies, experienced more job satisfaction, and felt higher self-efficacy. Vangrieken et al. (2015) found that when teachers collaborate, students show educational progress.

The four focal teachers in this study each spoke of collaboration at different levels of collaboration, and with different group makeups. All four teachers recognized the value of their collaboration with the Arboretum educators. Jackie, a third-grade teacher, and the sole participant in Project EXPLORE at her school, lamented that her only collaboration was with the Arboretum educators because she had tried to get other third-grade teachers at her school to apply to participate in EXPLORE, but they did not (Personal communication, March 25, 2015).

Blair saw an email from the Arboretum and thought that Project EXPLORE would fit well with the curriculum for her higher-level fourth-grade class. "That's why I went to Ruby," Blair said, "because she's got a higher level class too, to see if she wanted to help me with this project" (Interview, March 6, 2015). Working with Ruby on the EXPLORE program strengthened their relationship a bit according to Blair (Final

Interview, April 11, 2015). They conducted similar Project Squirrel experiments on the same four days and they combined their classes for the second Arboretum presentation in Blair’s classroom. They did not, however, share tasks across classrooms.

Carrie, a first-grade teacher, mentored the two other first-grade teachers, Jaime and Melodi. She helped them by taking their classes outside to collect eBird data, and she asked her assistant teacher to take Jaime's and Melodi’s classes outdoors. Of this group of teachers, only Carrie attended the Mountain Science Expo 2015, but she brought all three of the poster presentations from her school to the event.

Rorie, also a first-grade teacher, had strong, extensive team support at her school including Christina, the other first-grade teacher; Kathy, the school librarian, and at least four other specialized teachers (garden, AIG, music, and art), an assistant teacher and a student teacher. The team later grew to include her student teacher that went on to become a second-grade teacher at Willow Elementary, as per email correspondence from Rorie on December 3, 2015. I observed teachers who Rorie collaborated with who took collaborative supportive actions; they shared responsibility, realized group task interdependence, established clear roles, and enacted a combined clear focus for their collaboration projects, all collaborative practices recommended by Vangrieken et al. (2015). Rorie and another first-grade teacher, Jennifer, collaborated on presentations for Expo, one taking responsibility for facilitating the student artwork, the other for helping students write about the birds. Rorie, the garden teacher, the AIG teacher and the school librarian interdependently supervised her students’ bird watching.

Through collaboration with the school librarian, Rorie offered an example of expansive learning in response to tensions. Rorie and the School librarian devised a way to overcome weather constraints to birding. Rorie could not arrange for observations on days the school was closed due to snow, but she and the school librarian did set up a way to handle rainy day observations. They arranged for Rorie's students to observe wildlife outdoors from indoors using the floor-to-ceiling window in the second story Media Center. Small groups of students conducted their observations there when the weather prevented them from going outdoors. The classroom window in Rorie's classroom was small and positioned too high on the wall for her students to easily see outdoors. I observed that sometimes first-grade students did bird observations while in the Media Center simply because they had the option to do so on their own with freely accessible binoculars, data sheets, and field guides.

The other seven EXPLORE teachers in this study who chose the eBird citizen science program had birdfeeders outdoors that children could see from their accessible classroom windows; Rorie and Jennifer at Willow did not. The librarian and Rorie's innovative collaboration afforded her class more frequent experiences gathering data than they would have had if they were limited to their classroom with its small inaccessible window on inclement weather days. The expansion of birding to the Media Center gave Rorie's students more frequent opportunities to read and write bird names. Rorie noted that gathering data on birds was beneficial to her students' reading knowledge. I observed while supervising a small group from Rorie's class during fieldwork that it was challenging for her younger than average first-grade class to read the bird field guide and write the species names on the data collection sheets, but they were determined to do so correctly and asked me to help them spell challenging words. “It just naturally brought up their reading levels,” Rorie said, “because the bird tracking sheet had their hard names” (Final Interview, April 11, 2015).

Summary of Expansive Learning RQ #1a

In summary, EXPLORE teachers designed or co-designed educational components to supplement the tools and support provided by the Arboretum educators. Teachers were not given a complete or exact or scripted pedagogy to use with their school ecosystem and particular class—each of which were unique to each teacher participant. They were given tools and support by the Arboretum to enact citizen science. The four focal participants exemplified some of the many incidences in which the 13 teachers in this study reflected upon expansive learning within and across activity systems. Later in this chapter, in answer to RQ #3, I further describe the expansive learning themes that I introduced here in answer to RQ #1a (discussion, inclusion, integration, and collaboration) specifically, one theme per focal teacher.

I next describe contradictions or tensions in the historical structures of teachers’ activity systems as they were depicted in all 13 teachers’ reflections in interviews, self-recordings, and essays. These tensions were often substantiated by observations and supporting participant interviews.

Contradictions or Tensions in the Structure: RQ #1b

All activity systems have tensions or contradictions (Engeström, 2001); or as Engeström (2001) wrote, tensions are contradictions. He stated, “[c]ontradictions are not the same as problems or conflicts. Contradictions are historically accumulating structural tensions within and between activity systems” (p. 137). These tensions, according to Engeström, may generate a disturbance in the activity system, but may also generate innovations, which transform the activity. Project EXPLORE was not without tensions or contradictions according to primary participants.

Teachers readily discussed the tensions that they felt as participants in Project EXPLORE. Tensions teachers spoke mostly of were constraints related to indoor vs. outdoor student behavior, mandated vs. teacher choice of use of time, and excitement vs. containment (see Table 10). However, I highlight three other contradictions that teachers also discussed: (a) normative vs. non-normative practices, (b) technology access required for participation in online science vs. technology limitations, and (c) time scheduling vs. the unpredictability of nature. I highlight these contradictions because (a) the literature indicates that non-normative practices are risky for teachers to attempt in high-stakes testing environments, (b) current STEM and citizen science initiatives in science education require technology access for teachers and students, and (c) all primary participants spoke of the tension to do with the unpredictability of nature. I discuss these three highlighted tensions in the following sections of the paper in more detail.

The contradiction of normative vs. non-normative practices. Teaching with citizen science outdoors for the primary participants in this study, involved students ‘doing’ science versus reading about science from a textbook, completing a worksheet, or having a lecture. Citizen science offered a change from normative elementary school science practices, which include didactic, textbook oriented instruction (Cabe Trundle, 2015), and Environmental Education lessons that are often generic rather than community specific (Hudson, 2001). Rorie noted that these instructional challenges were an internal battle for her, one that I repeatedly observed she was winning, to teach in a new way. She openly recognized the inherent contradiction between the traditional way of teaching science and Environmental Education, and what she did to teach outdoors while collecting data for eBird.

> So when I first started teaching, it was an ordered class, and I think I did more 'lecture-teaching.' Even though it was a hands-on school, I did more lecture teaching because that's how I was taught. (Interview, March 5, 2015)

The contradiction or tension Rorie expressed had to do with new methods of teaching science versus long established teaching traditions in elementary school science (Cabe Trundle, 2015). The traditional methods were easy to fall back into practicing because this is the way that Rorie was taught. Teaching with citizen science outdoors was different from teaching science by lecture, and Rorie spoke of how enacting a citizen science program with EXPLORE was different even from teaching outdoors as an environmental educator. Environmental educators had specific teaching materials (e.g., Project Learning Tree, Project Water Education for Teachers [Project WET Foundation, 2013] and *The Wonders of Wetlands* [Kesselheim, Slattery, Higgins & Schilling, 1995]) designed for teaching in many different geographic locations throughout the U.S. Hudson (2001) suggested over a decade ago there would be a need to design Environmental Education programs specific to the ecological environment and culture of the learners in the 21st Century that would require the involvement of the audience in determining the curriculum. While the Environmental Education materials mentioned above do not seem to meet Hudson's specifications, Environmental Educators do now incorporate citizen science in their local programs (NAAEE, n.d.). Citizen science is an innovation in Environmental Education.

Project EXPLORE citizen science programs required teachers and their students to collect data on flora and fauna in their own schoolyards, data that were to be used by scientists. Teachers were generally unable to predict the outcomes of the data collection and because of this, the fact that outcomes were unknown, this exposed long standing tensions in the structure of formal science education. Elementary school science instruction typically involves using a science lesson for which the answer is known (Roth, 2014). The unknown versus the teacher knowing ahead of time what the class might find exposed an embedded contradiction in the system. As Rorie explained, it was instructive and exciting for her to be a part of EXPLORE as a new way of teaching.

> I used to be an environmental educator and I would just, like, pick up the book, read the lesson, teach it. I had no feeling behind it. Now I'm as excited as the children are. I'm not just picking up the books. I'm asking people. I'm seeking out people who are experts on those particular subjects. I'm bringing them into the classroom. I'm having meetings with them outside of classroom and I'm learning as I'm teaching and it's opened me up to, I just think life is so more exciting now as a teacher. (Final Interview, April 11, 2015)

Rorie found excitement in not knowing the answer and resolved the tension or contradiction in the activity system by taking the initiative to learn and seek help from experts. Rorie had experience as an environmental educator in the past, on her questionnaire she reported she had a good deal of experience in nature as a child and frequently (more than once a week) incorporated the outdoors into her teaching, and this may have reduced the tension she felt about teaching an open-ended science lesson.

Ruby, a fourth-grade teacher working with Blair on Project Squirrel told me that she had taught outdoors before, using a nature scavenger hunt (a lesson with a specific format), and expressed she would like to have a lesson plan for outdoor teaching in the future: “Having lessons pre-made would be great. I can think of specific lessons that I’ve done. I’ve gone on nature scavenger hunts” (Interview, March 6, 2015).

While Ruby told me that she liked the outdoors, other than a nature scavenger hunt Ruby did not profess to have experience teaching outdoors. This was her first year participating in EXPLORE. On her questionnaire she said she was not exposed to Environmental Education in her teacher education program, and that she rarely taught outdoors, perhaps once a year. A school district science specialist described the phenomenon of trying new science pedagogy from teachers’ point of view. Elementary teachers take years to perfect a lesson they may only teach once a year. When asked, “Is curriculum a script or a guide?” he responded,

> From what I am hearing from the teachers I work with, the answer is “depends.” The first time the unit is taught, they want a full script that they can rely on to get them through it. After that, they then will feel more comfortable [taking] their own path. One thing we can’t forget is that elementary teachers get one shot at teaching a lesson to students the first time. In comparison, think about middle or high school teachers who may have three or four opportunities to teach the same lesson. The time it takes elementary teachers to become comfortable teaching a concept is measured in years and not hours. (Personal communication, Eric Cromwell, January 21, 2016).

As Eric pointed out, with only one class to teach all day, Ruby may have wanted a lesson plan for a lesson outdoors because she would have only one chance to get the new lesson right for her students that year. But, unlike Ruby, the other primary participants did not express a need for a lesson plan to accompany data collection for EXPLORE.

Outdoors in nature, Jackie adapted her lesson plans to the context and the children. One day students in her class wanted to pick up trash they found in the study area (Field notes, March 25, 2015), so the next time she took them out to collect scientific data she had one student bring along the big classroom trashcan. They collected litter until the trashcan was full, and took it back to class with them as part of the lesson (Field notes, March 31, 2015).

Jackie was experienced teaching outdoors as a state certified environmental educator. When I asked her to think of what was challenging for her about enacting a citizen science program she had a hard time thinking of a challenge. Jackie mentioned one tension, what parents might think of a natural hazard of playing outdoors, such as a child getting a poison ivy rash:

> Well, we have one area over with evergreen trees that in this late spring- early summer, right before school gets out, it gets heavy with poison ivy. And you know I always wonder if one day I'm going to get a phone call from a parent that's mad that their child got into a poison ivy outside, or you know something like that I guess is my biggest concern. (Final Interview, April 11, 2015)

The inherent child safety concerns when engaging in non-normative practices were different from indoor concerns. Jackie mentioned parents and what they would think of poison ivy rash as her biggest concern about teaching at public school in a 'non-normative' way while collecting scientific data outdoors. Jackie's study area was not mowed or pruned. The trees in the area Jackie's class was studying for Nature's Notebook were in a small forested area, and this was beyond the mowed lawn of a public playground area next to her school. While these were outside concerns that led to tensions, in the next section of this paper I discuss an indoor tension that could prevent a teacher from engaging in citizen science.

The contradiction of required technological access to participate in online science vs. technology limitations. Jean, a fourth-grade teacher participating in Nature's Notebook tree phenology with her class pointed out a tension in her citizen science activity that other teachers spoke of as well—a lack of access to technology at school to upload the data. All of the primary participants in this study worked at Title I public elementary schools and school-wide technology often offered a challenge when it came to uploading data for their citizen science projects. I asked Jean what she might do differently in the future if she were to continue to participate in EXPLORE. She explained to me that she wanted to work around her frustrations in uploading data because of the school's limited online network access and she wanted her students to see the data.

> I might do something a little differently with data collection. I've had trouble, it's our network, computer won't let me, I wanted the kids to put the [data] into the computer and I haven't been able to do that and that's just our network thing. The site doesn't pull up properly so I'd take it home and put the data in the computer. I'd like to do something along the way with the data so they can see what their data is showing. Again, like right now, there hasn't been a lot of change. (Interview, March 9, 2015)

Since the trees Jean's class were observing on the main field and playground at her school had not budded or sprouted leaves yet at the time of our interview (in early March) Jean seemed to be slightly less bothered by the fact that she did not have computer access at school to the citizen science website to show the data and website to her students.

Because, as she noted, there were no bud burst dates in the data or leaf appearance dates recorded yet in the data on the dormant deciduous trees, she hinted to me in her interview that the students may have had less to learn from the 'no data' reported, or that they would be less interested in static data than they would be later in the spring after there were changes noted in their trees.

Jean had to have a computer and online network access at home in order to upload the citizen science data her students collected, whether or not a change in the tree was noted. After all, as Jean clearly recognized, no change in the tree was still data that had to be collected and uploaded to the citizen science website. The time demands in a school day probably allowed little extra time for Jean to work out technology problems she had on a school-wide scale. Tensions to do with tight time scheduling at school were mentioned by many primary participants as a tension in the system and I will discuss this in the next section.

The contradiction of time scheduling vs. unpredictability of nature. At Jackie's school, and at many schools in our state, there is a mandated time schedule for teaching specific subjects at specific times as shown in EXPLORE Teacher CHAT charts from the Mountain Science Expo, April 11, 2015. Some teachers are so highly managed or micro-managed that they are required by their principals to use a specific mathematics workbook page on a specific date at a specific time (personal experience).

Even if the district or school did not mandate a daily schedule for teaching, participating EXPLORE teachers organized their teaching around a schedule. Most were expected to have a written plan for either the day or each lesson or a week's worth of lessons. In an interview with Andrew (pseudonym), an Arboretum educator who was married to Carrie, a focal participant in this study, he explained how Carrie's principal expected her to have the weekly lesson plan done a week ahead of time. EXPLORE teachers fit fieldwork into their schedules in different ways—Carrie, a first-grade teacher, went out on Thursdays at 1 pm.

Carrie was not alone in having to schedule a specific time for outdoor science, Blair and Ruby also had to set aside days for Project Squirrel experiments far in advance. Blair did not schedule whole class time outdoors with her class beyond what was already in the daily time schedule (i.e. recess).

> We did some of our observations that we're supposed to count how many squirrels we see. It honestly gets done through our windows sometimes, which is sad, because the times we go outside at recess, there's no squirrels out there because there are so many kids running around and screaming. We can't really do a good observation then. (Interview, March 6, 2015)

Blair and Ruby were first-year participants in EXPLORE working together on Project Squirrel. They had to postpone their outdoor experiments due to school cancellations because of snow conditions on the originally scheduled dates they had set up for students to go outside with parent volunteers. Teaching could be easily scheduled indoors without consideration for the weather, but could not be scheduled outdoors with the same certainty. Teachers voiced their frustrations with the weather as seen in the following statements:

> Interviewer: If you had to say there were some challenges?
>
> Christina: I would say weather. (Interview, March 5, 2015)
>
> Ruby: I think one of the things that I have the hardest time with is what I love most about it too, interestingly enough, but [it's] going outside. You're dealing with something very unpredictable. (Interview, March 6, 2015)
>
> Cindy: We've had a lot of snow and stuff in January, so we didn't really get out in January, so [we collected data] maybe six or eight times. (Interview, March 18, 2015)
>
> Stephanie: Each week I'll decide what we want to aim for and make sure that's done. With the snow it's harder because our schedules are messed up, but when it's not, it's easier to make time and kind of plan for that. (Interview, March 10, 2015)
>
> Rorie: For two weeks, kind of in mid-winter [our city] had very odd weather so there would be a cold day and then a warm day and then a cold day. The least productive part was we tried rotating small groups of children through to get in their bird studies in the morning and because of winter and the short staffing and because of the weather sometimes I felt like not all of the children were having that experience, just certain ones, because of the way the weather fell that day or the way our time was set up. (Final Interview, April 11, 2015)
>
> Jackie: Our bulk of the day is given to reading and math. It leaves science, social studies and health all to fit into the same hour of the day, so then they have to alternate . . . The other challenge, the weather is a factor . . . sometimes that kind of makes it difficult. (Interview, March 31, 2015)
>
> Melodi: It's getting them used to the warm weather again, because they complain about it now, but, in come the summer, it'll be like, "Oh,

> this is great!" and they'll be playing outside all day. I guess it's just getting them used to it being warm outside again, because today a few of them were complaining. I said, "You'll be okay. We'll get some water. You'll be fine." (Interview, April 1, 2015)

> Dana: Well, with the weather lately . . . [as to me] being consistent . . . sometimes the weather has been a factor. (Interview, March 2, 2015)

Dana, a first-grade teacher who had biology fieldwork experience in college, went out to targeted areas of the schoolyard when there were birds there and when the weather allowed. Her observational times were flexible. She found that birds came to different parts of the schoolyard at different times on different days. Because of her flexible scheduling and planning around when the birds showed up in the schoolyard, I could not schedule a time to observe her take her class outdoors because she had no idea when the opportunity would present itself.

Primary participants in EXPLORE did identify tensions in the activity and did transform their activity system, as in the case of Rorie and her partnership with the Media Center, so that her students could have more time to observe birds.

The tensions teachers spoke of that existed in their activity systems were not always resolved. However, for many teachers resolving tensions resulted in expansive learning. The teachers who reported resolving tensions with expansive learning had developed skills directly related to the expansive learning and consequent transformations they reported. They had developed skills to work their way around contradictions or tensions and could apply these skills to varied challenges, such as the challenge of learning how to make citizen science a learning experience for their elementary school students.

How EXPLORE Transformed or Changed Over Time: RQ #1c

Project EXPLORE changed over time in this study due to 1) transformations that the Arboretum environmental educators initiated, and 2) transformations that were initiated by the primary participants at their schools. I used data from digital recordings of Arboretum educators' presentations to classes and interviews with Arboretum educators to help me ascertain how EXPLORE changed over time. The Arboretum's initial intent for EXPLORE was to offer programing to elementary schools that were not able to visit the Arboretum on a field trip. EXPLORE grew in the first year (2013–2014) to include middle and high school teachers as well. This was because upper grades teachers heard about the program and asked if they could be included. Grades K-12 were also included in EXPLORE the second year (2014–2015) in response to this demand for the program, in other words, the system was transformed over time and grew to become available to all grades.

The EXPLORE activity system had structural tensions that through expansive learning provoked changes in the system. An example of a contradiction or tension at the Arboretum level was the question of should the classroom teacher make sure the students know the new material before the Arboretum arrives, or should the Arboretum educator teach new material during visits? Madie (lead Arboretum educator for EXPLORE) mentioned that in the beginning, in the first semester of the first year of EXPLORE (Fall 2013) she sent her lesson plans to the teachers ahead of time, and when she arrived the teachers had already taught the material to the students, leaving her little to teach and little to surprise the students with in her lesson. I observed that she used the elements of surprise and wonder in her presentations to students, and this was consistent in her lessons as she visited schools. She learned from that experience the first semester. She then decided to change the way she did things. She did not send the lesson plan ahead of time, and she taught the new material on her own. She also changed the lessons slightly from the first year to the second year to adapt to what she learned through practice.

In the first year (2013–2014) teachers who participated in Project EXPLORE were given binoculars, but in the second year they were given $100 instead. I observed focal teachers who were second year participants in 2014–2015 using binoculars given to them by the Arboretum in their first year in the program (e.g., Carrie and Rorie), but I did not see that first time focal participants in the second year had class sets of binoculars (Blair and her colleague Ruby). Because there was no required accounting for how the $100 was spent, EXPLORE decided to return to buying materials to give to participating teachers in 2015–2016, rather than giving them money, in the third year of the program. Arguably, dedicated public elementary school teachers working in Title I schools have limited time to shop for specialty items such as a classroom set of binoculars. And there were exceptional costs associated with participation in Project EXPLORE. Blair did have to buy some materials to run squirrel experiments. And Jackie could not print in color at her school. For Jackie, simply printing color pictures of the trees her students studied for a poster to display at the Arboretum's Mountain Science Expo 2015, would have meant buying color ink printer cartridges for home use. For schools without color printing supplies, $100 could cover the basic supplies teachers would need to buy to make color copies or to print color bird field guides at home. The Arboretum supplied digital copies of field guides in 2014–2015.

Identifiable transformations in EXPLORE as a larger activity system also happened across multiple smaller activity systems initiated by teachers at different schools, from the ‘bottom up’ (Plakitsi, 2013). I found transformations (at the classroom level) in elementary school science education of one form or another initiated by all 13 primary participants. When the Arboretum educators conducted their two visits to schools they used whole class instructional methods. However, first-grade teachers, all of who were conducting eBird projects, all used small student grouping in order to enhance discussion and the completion of science learning tasks.

Small groups of students in Rorie and Jennifer’s first-grade classes generally collected data outdoors as one of their ‘center’ activities. The four other first-grade teachers, Carrie, Jaime, Melodi, and Dana, assigned a specific bird species to student pairs to become experts on in order to share information with the whole class, and later with the public at the Mountain Science Expo 2015. Children went out to do fieldwork with their research partner at Carrie’s school, and in small groups at Rorie’s school. Discussion of specific bird species and habitats was a small group practice indoors and outdoors in first grades. This was a system-wide teacher initiated transformation. These teachers initiated similar changes in first grades across the EXPLORE activity system. This was not required by eBird or the Arboretum, nor was it a coordinated effort between different schools. The traditional normative instructional practice was that science discussions were conducted in a whole class lecture format (often with students more interested in supplying the answer the teacher wanted than thinking of answers on their own [Roth, 2014]), all of the first-grade public school EXPLORE teachers designed and implemented new groupings and formats for science discussion and learning tasks. By designing new ways of teaching elementary school science, EXPLORE first-grade teachers across the system transformed the way elementary school science was taught. This transformation was a transformation from what Cabe Trundle (2015) described as inappropriate pedagogies, to pedagogy more in keeping with what we know about how children learn science (NRC, 2012).

EXPLORE, when viewed through teachers' meanings, informed by CHAT, was a large activity system offering an opportunity for professional development to primary participants. Primary participants overwhelmingly put importance on expansive learning, and spoke most frequently of expanded thinking, as well as of engaging students in science, and integrating science with other subjects (see Table 10). They also spoke of expansive learning themes that research shows are important but are lacking in science education (e.g., discussion, inclusion, and collaboration) (Roth, 2014). Teachers described contradictions or tensions in their activity systems that help us understand the challenges they faced in teaching science outdoors (e.g., the unpredictability of nature and the risks of trying something new). Even with these tensions, teachers did manage to take their classes outdoors multiple times to collect data for citizen science projects. Teachers also described and demonstrated transformations in teaching science (e.g., small group science tasks and outdoor small group discussions) that expanded upon the whole class format used by Arboretum educators.

Guided by my first research question, I found what expansive learning outcome themes there were in EXPLORE activity systems. According to Engeström (2001), *"What do they learn?"* is but one dimension of expansive learning. In order to further my analysis of expansive learning in EXPLORE, my second research question focused on how teachers learned. Their meaning making and my observations of corresponding practices evidenced how they learned. In order to better understand this dimension of learning, *"How do they learn?"* I describe teacher meanings expressed in interviews and essays that I observed in teacher practices in the section to follow.

How Did Carrie Learn? RQ #2

Four practices I looked for in my observations as evidence of *how* teachers learned to enact citizen science were professional development, lesson planning process, teaching practice, and data collection (as mentioned in Chapter III). There were many instances where teachers' meanings of expansive learning in their reflections were triangulated by my observations, and those instances are noted throughout this chapter. In this section I highlight only one focal teacher's expansive learning because she clearly reflected upon how her practices were influenced by the Arboretum educator's professional development. Additionally, she spoke clearly about how she learned to modify her instruction by using the practices that the Arboretum modeled for her own professional development. She also spoke of her plan for teaching, and reflected upon her teaching practices, and learning while collecting data. I found that in their reflections most teachers did not address how they learned in this way. Carrie was an exception and as such is highlighted in this section to answer RQ#2.

How Carrie Learned: Professional Development

Carrie utilized the EXPLORE Arboretum educators' model of practices as a form of professional development. Arboretum environmental educators showed teachers rules of birding outdoors; one rule was 'to be quiet.' Another rule Arboretum educators modeled for teachers was to take the lead when outdoors. All students were to stay behind the adult leader of the group when moving outdoors. This was reflected upon by a mentee of Carrie's, another first-grade teacher at her school, Jaime. She reflected upon the first visit of Arboretum educators to her school.

> I think when the people from the Arboretum come the first day they teach the rules of birding. We usually repeat those same rules, because I think there [are] just basically three. It's simple, and it's quick, and they [the students] remember it, we go over it, and then we go. (Interview, March 12, 2015)

Carrie clearly followed these birding rules as evidenced in my observations.

> Carrie explained the rules for going outdoors to the students . . . She asked them, "What is the #1 birding rule?" (Field notes, March 26, 2015)
>
> The assistant teacher took the lead and kids followed. (Field notes, March 12, 2015)
>
> Before we went out, Carrie said to her class, "Remember the quieter we are, the more birds we'll see." Carrie later called them [her students] back and reminded them to stay behind Madie. (Field notes, March 16, 2015)
>
> I was amazed at how much freedom of movement the children had and at the same time how they stayed in a general group. They knew to stay behind Carrie. (Field notes, March 16, 2015)

Carrie carefully observed and listened to Madie, and established the same rules for birding outdoors and implemented them successfully with her class. This is an example of how Carrie learned by replicating information supplied by Arboretum educators, utilizing the visit from the Arboretum as a professional development opportunity.

How Carrie Learned: Lesson Planning Process

The second practice that I looked for to increase my understanding of how Carrie learned to implement the citizen science project in her class was the lesson planning process. Over time, with more content knowledge and pedagogical knowledge, Carrie expressed she was clearer about lesson objectives and was able to incorporate broad concepts into lessons.

> Carrie: This year it went a little more smoothly, just seeing the whole project from a distance, knowing how it went last year. Last year I was kind of going along with the kids, right along with them. This year I've had a vision for what I wanted them to get out of the whole experience.
>
> Interviewer: What was that vision?
>
> Carrie: I wanted them to have a better understanding of the birds local to our area. Kids tend to know birds generally but not specifically. I wanted them to integrate their knowledge about habitats and the birds' needs, expand on that. I wanted them to get to know one bird really well and have ownership of that species and have fun with it. (Final Interview, April 11, 2015)

I observed evidence of Carrie's vision for her students' understandings while students were embarking on fieldwork one day.

> When out in the field, Carrie grouped students in their bird research pairs, and instructed them to, "Spot your bird!" [the bird they were researching]. We heard many birdcalls and saw many birds outdoors. The students were mostly quiet and some were whispering. I heard them talking about birds. Students would approach Carrie to quietly tell her what they'd seen. There were two pairs of students around Carrie, and one pair with the Assistant teacher. She and her assistant teacher would occasionally point out birds as we walked or stood still to observe, such as a Bluebird, for the students to see and compare with photographs in their field guides. (Field notes, March 12, 2015)
>
> Before going out birding, she [Carrie] asked each student who their partner will be for the [bird] research and told them to walk with their partner. Carrie had them review what they knew about birds. They went through a lot of birdcalls [Carrie would imitate a birdcall and ask the students to guess the species of the bird]. (Field notes, March 26, 2015)

Carrie, like most of the experienced teachers in this study, did not write extensive lesson plans. However, it was obvious from her quotes and my observations that her learning objectives were clear, and clearly met by first-grade students in her class.

How Carrie Learned: Teaching Practice

The third practice of how teachers learned to implement citizen science projects with their class that I observed was how Carrie learned by teaching. Through the repeated practice of teaching outdoors, Carrie and her mentees became more proficient at the use of citizen science for science and Environmental Education for elementary age students. Carrie expressed in her final interview how her bird identification skills had improved with practice going outdoors from her first year to her second year in Project EXPLORE.

> I took them outside and my assistant has become really good with birds also. Last year was her first year working with [birds] and we learned our birds together. (Final Interview, April 11, 2015)

I also noted evidence of this when I observed her colleague's class outdoors collecting data with Carrie's assistant teacher.

> And Carrie is so much a mentor that she lets her classroom assistant lead the bird program for the other teachers, as her classroom assistant has become more proficient at identifying birds. (Field notes, March 16, 2015)

Carrie felt she became a better birder by birding. This is not surprising, but reaffirming. The act of teaching was a self-directed learning experience for Carrie and her Assistant as adult learners (Rohlwing & Spelman, 2014). Part of that learning experience was the collection of data for scientific research.

How Carrie Learned: Data Collection

The fourth practice that I looked at was learning by engaging in scientific data collection in the field. Carrie developed her own protocols for verification of data collected by students before submitting data reports. As Carrie explained it, she and her assistant teacher would both verify a bird sighting before recording it as data to report to eBird.

> She [my assistant] is very valuable when we're going out, just to be an extra set of eyes to really confirm that we are seeing such and such bird. My kids still will come up with sometimes crazy things that they think they see, and we don't write it down [on] the checklist unless we have both confirmed that, yes that was a Downy Woodpecker or whatever. (Final Interview, April 11, 2015)

I observed that Carrie's assistant teacher took that one step further and practiced the same protocol when outdoors with another teacher, Jaime, and Jaime's class.

> We saw a Mockingbird. The Assistant teacher checked with the students, "Is that what Ms. Jaime [the teacher] says?" (Field notes, March 16, 2015)

Carrie was very articulate and clear about how she and others in her activity system learned through practice. This made it easier for me to connect her meanings to my observations in the field.

Carrie learned to teach science and Environmental Education outdoors in practice by implementing Madie's models and rules for birding with her first-grade students. She expanded her vision of what a lesson to accompany eBird was by learning to help her students take ownership of deeper knowledge of specific local birds. Carrie improved her birding skills over time as she practiced bird identification in the field alongside her students and assistant teacher. Carrie learned by doing. These practices highlighted by Carrie's experiences as she described them, and as I observed her teach outdoors, help us to see another dimension of expansive learning, the *how* of expansive learning, in action, in practice.

Teachers' Reflections Highlight Expansive Learning: RQ #3

To answer the third research question, I used CHAT as a framework for data analysis of teacher reflections. I describe the meanings teachers made of learning to conduct a citizen science project outdoors through their reflections using exemplary evidence from the four focal teachers in this study. I found that all 13 primary participants identified expanded thinking as a theme of expansive learning, and that many of them identified the themes of engaging science, integration, skills, collaboration, discussion, and inclusion as forms of expansive learning as well (see Table 10). These multiple themes of expansive learning were all present in the focal participants' words (see Table 11).

The following four vignettes, focus on Blair, Jackie, Carrie, and Rorie and offer more in-depth descriptions of four purposefully selected themes of expansive learning as expressed in focal teacher reflections: discussion, inclusion, integration, and collaboration. Although I described in detail one theme for each focal teacher, many primary participants embodied these four themes in different ways. I selected these themes not because they were the most frequently reflected upon, but because they are practices that researchers felt were important yet not being done at the elementary school level (Roth, 2014). Each vignette focuses on one focal teacher and one particular kind of expansive learning they reflected upon as an outcome in their activity system.

Focal Teacher Blair—Discussion

Teachers in this study utilized discussion in different ways and to different extents to expand the activity of citizen science data collection. Blair spoke often and compellingly of her class discussions. She was a fourth-grade teacher with seven years of upper elementary school teaching experience. Another fourth grade teacher at Tulip Tree Elementary, Ruby (not a focal participant), participated in EXPLORE. Blair grew up in the suburbs, was a mountain biker, and had a good deal of experience in nature as a child. She remembered she often went on hikes with her family and visited beaches every year. One of her objects in participating in EXPLORE was for her students to learn about human impact on the environment. The experiment the class did compared squirrel corn-eating habits in high human traffic areas on campus (unsafe sites) to areas with less human traffic or noise (safe sites) in the back of the schoolyard in a fenced-in area.

Blair's community and her students' interactions with the larger community are important interrelated elements in her activity system. As such, understanding her community is helpful to understanding her decision to implement discussions as an element of her citizen science instruction. Blair's students designed a colorful poster and shared that with the public at the Mountain Science Expo 2015. A parent in the classroom community, Tara (a pseudonym), told me that she valued her son's participation in the squirrel experiment and the presentation at the Arboretum. Students who attended the Expo with their parents and teachers stood in front of their class posters arranged in rows with the posters from other EXPLORE schools on long tables in a large room at the Arboretum. Students had an hour designated by the Expo to stand with their posters and explain their citizen science project to the public as people walked down the rows of poster displays. My colleagues working with me that day to collect data observed that the students in Blair's class discussed their experiences in great detail with the public.

> . . . they were persistent and they were able to complete their project and they were able to talk about it, which I was totally impressed because it was all kid-based. They did everything from beginning to end, so I was very proud of this class. (Tara, Parent Interview, 22 May, 2015)

Tara's comment that the students "were able to talk about it" may have been a result of extended discussions in class. Her reflection is also further evidence of the students' ability to discuss the Squirrel Project experiment. Parents in Blair's community shared responsibility for the squirrel experiments each day by reading the lesson plan, making cardboard boxes to place the corn in, taking the children outdoors, supervising the weighing of the corn on a digital balance, and helping them do the hands-on work and mathematics required to find the weight of the corn residuals, doing this exactly according to the instructions in the written lesson plan that had been supplied by the Arboretum. Blair took pictures of her students indoors and outdoors as they worked. She always had her camera ready as a teacher tool so that she could put photos on her class website for all of the parents to see. In this way Blair could provoke discussion about Project Squirrel at home with parents by posting photographs on her class webpage for students and their families to see.

Blair took on a leadership role with Ruby. She had taken the initiative to propose they make time for science with the squirrel experiments for their AIG and 'at or above grade level reading' students. Blair was interested in doing the experiment lesson plan the Arboretum included with Project Squirrel teaching materials when she applied, lessons that included mathematics and social studies.

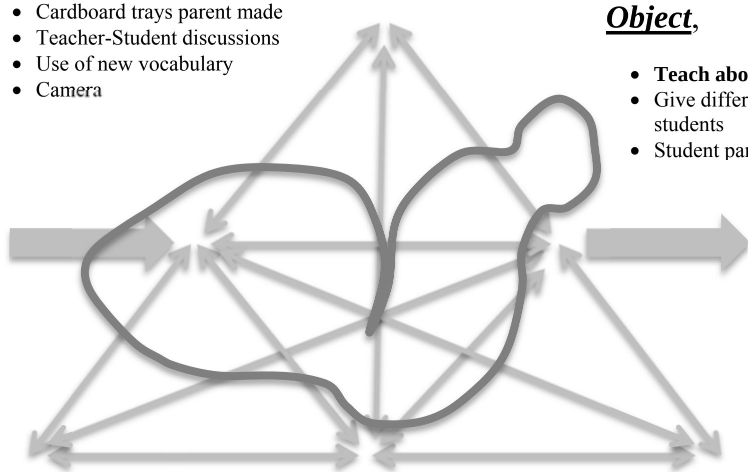
The Tulip Tree EXPLORE teachers arranged for parent volunteers to take the children outdoors for the four afternoons of the experiments, and gave copies of the printed lesson plans to the supervising parents. For a snapshot description of Blair's activity system and highlights from her interrelated elements, see Figure 16. Blair said the best experience that she and her class had with EXPLORE was enhanced daily discussions about data collection and analysis, and ultimately scientific methodologies.

Mediating Artifacts, Tools

- Arboretum/Project Squirrel lesson plan
- Creation of step-by-step guide to introduce activity
- Integrating technology e.g., research in computer lab and mapping sites with Google Earth.
- **Used the state curriculum as tool for integrating Project Squirrel (social studies/science)**
- Website that parents can access
- Cardboard trays parent made
- Teacher-Student discussions
- Use of new vocabulary
- Camera

Cultural History, Subject

- 7 years' experience upper elementary
- Teaches fourth grade
- Graduate Degree Elem Ed K-6
- Grew up in the suburbs
- Good deal of experience in nature as a child
- "I would often go on hikes with my family and visit beaches almost every year"
- **"soft-spoken" which makes class management "difficult outdoors"**
- Depends on lessons for teaching
- Wants to incorporate more hands-on outdoor activities
- First year EXPLORE participant



Object,

- **Teach about human impact on environment**
- Give different experience and a different perspective to students
- Student participation in science/science learning

Outcomes

- Introduced the scientific method
- Expansive learning: extended the curriculum; designed lessons
- Got students to "think outside the box"
- **Having students come up with their own ideas and draw their own conclusions.**
- Taught about impact of humans of environment
- Students engaged in doing science

Reference: Engeström, Y. (2001). *Expansive learning at work: Toward an activity theoretical reconceptualization.*

Rules

- Emphasized purpose of the activity to build enthusiasm pre-activity
- Effective class management
- Research in tech lab pre-experiment
- **Reading and math are prioritized over science**
- Dependent on lesson plan packet given to her by Arboretum
- Activity fits with science and social studies curriculums

Community

- Supportive administration
- AIG/at or above grade level readers class
- Take field trips
- Her class worked tandem w/ Ruby's class
- **Active parent volunteers**
- School grew produce to serve in cafeteria
- Weekly garden program/composting managed by AmeriCorps member
- Some students not interested in nature
- Community traditions (black light show)
- Suburban school

Division of Labor

- Blair picked outdoor experiment sites with students
- Blair pre-weighed/measured materials
- **Small groups of students involved in activity**
- Students left/retrieved materials. Outdoors w/Assistant teacher mornings; parents in the afternoons
- **Students reported findings to whole class**
- Blair led discussion, students participated
- Blair took photographs/ maintained a class website
- Talked with colleague to set the program up together
- Blair uploaded data to citizen science website

Figure 16. EXPLORE CHAT Chart for Focal Teacher Blair.

Blair designed daily discussions as an additional educational component to the four-day-long citizen science experiment. The squirrel experiment sought to promote a better understand of squirrels' feeding habits in the schoolyard. Blair's facilitation of discussion was a good example of expansive learning (designing and mastering new practices [Engeström, 2001]). Blair spoke frequently of how she facilitated discussions related to the squirrel experiment and her students' part in the experience.

> [The best experiences] are quick conversations at the end of the day or the beginning of the day where we talked about it. The kids were so excited to tell me why they think our corn was not eaten, and the more I talked about it the more excited they became, and so it was really cool just to have discussions and to talk about what we saw. (Final Interview, April 11, 2015)

Blair developed a format for daily discussions. Students in Blair's class collected data in small groups (which were facilitated by parent volunteers, although Blair did supervise the students on the day that I observed the first afternoon of the experiment).

> Blair told me that the students who were the first to arrive this morning put the cardboard out [flat cardboard lids that held the dried corn cobs]. The second location was right across from the playground. I went with the children headed for this second location, and the volunteer parent. The kids handed over the cardboard with the corn on it to the parent. Once inside the school building, the parent handed them back to the students and four out of a group of five carried the cardboard to the area where we collected the data just outside the classroom [an area with a table, a scale, and worksheets]. When we arrived at the work area just outside the classroom, Blair was there to supervise. (Field notes, March 16, 2015)

Thus, only a small number of students were outside collecting data at any one time. However, since that was the case, the whole class might have missed significant events that occurred when they were not in the field. But, Blair organized her classroom instructional time to make room for small groups of data collectors to share their small group experiences from the outdoors collecting data. Blair reported that students who had taken food materials outdoors in the morning with the class' assistant teacher or had retrieved uneaten food materials and collected data in the afternoon with parent volunteers enthusiastically participated in the discussion as firsthand observers. Discussion gave them an opportunity to publicly share their experiences and thoughts not only with their classmates, but with their teacher as well. Blair felt that daily discussion was an excellent learning opportunity for the students.

Appleton (2007) pointed out that there is little in the system to encourage elementary school teachers to discuss causal factors in science. He noted that it is not necessarily the elementary school teachers' inability to grasp these bigger scientific ideas, but rather that they are not taking the time to discuss these things in the classroom. Blair did take the time to include daily discussions about data collected. Why was the corn that the students left out in the mornings not eaten at all most days, and hardly eaten one day by squirrels when they checked the corn in the afternoon? She and the Arboretum educators used Google Earth as a tool for discussion, showing students a birds-eye view of the schoolyard in order for them to better understand the relative size of the schoolyard's wooded area compared to the children's athletic field, play areas, and the parking lot. Blair said her students realized squirrels had a large safe natural area and that this may have been one reason why squirrels did not eat the corn students put out for them.

The Google Earth satellite map of the schoolyard was not the only tool Blair used in discussion. Each day of the four days that I observed the activity at Blair's school I noticed a growing list of discussion points on large poster paper in Blair's handwriting titled "What risks are squirrels willing to take?" It was posted and visible to the whole room near the exit door of the classroom. In this way students were constantly reminded of the ongoing discussion points throughout the four days of Project Squirrel experiments that they conducted in their schoolyard, and, as Blair described it, these points led to ideas that the students would bring up in discussion.

> [A major impact on the students has been] [t]hem wanting to do another experiment. Further their education. You know, growing them as learners, I think [this] has been really cool so they can see the [scientific] method first hand and say, "Oh, this happened. Well now, let's do this to see if we can get a different result." So I think just seeing them want to continue this has been really cool . . . We were thinking about setting some kind of camera up. We have a WeatherBug camera so it would be neat to set [corn] where that WeatherBug camera is so we can watch it all day and see what animals come and go. (Final Interview, April 11, 2015)

Blair shared with me in this quote her happy realization through discussion that her students were excited about witnessing the scientific method first hand and she felt that this promoted curiosity and interest in continuing their science experiments. We can see from her quote that her students were building an understanding of the nature of science by their ability to come up with ideas for designing science experiments.

Blair's classroom discussion was an expansive learning outcome in her school-bounded activity system. In data from Blair's interviews, I found there were interrelated elements that were part of her decision to facilitate discussion. I discovered how some elements of the activity system, as she described it, worked together to help her facilitate this expansive learning outcome. Blair described discussion repeatedly in interviews. She included descriptions of new tools she used during discussion (Google Earth), and how she asked students to come up with conclusions in discussion. She repeatedly used the word "we" to describe discussions.

> . . . you can be outside but you can't have discussion [outside] as well. It's loud and there [are] kids all over the place. Coming in and talking about what we saw, pulling up Google Earth, and looking at our area, and just coming up with our conclusions, that was the best part for me. The discussion part because I think they had a lot to talk about because we were outside and we saw a lot. (Final Interview, April 11, 2015)

As a well-educated teacher of gifted and above-grade level students, Blair chose to pursue science learning goals above and beyond the state fourth-grade science curricular requirements. She voiced her frustration that due to time restrictions ". . . we just don't have a lot of time for science" (Interview, March 6, 2015). Scarce time for discussion of science was a system tension also noted by Appleton (2007) in his description of elementary school science. Blair expressed that she had to integrate science in order to teach it. Her purpose in participating in the EXPLORE program was to give children time outdoors. Blair had parent volunteers help in the afternoons. These parent volunteers included a former second-grade teacher from Maryland and one parent who had worked in the medical profession. They were both proficient in helping facilitate data collection and recording. Blair did not take class time to go outdoors with her students. She delegated the morning tasks to an assistant teacher and the afternoon tasks to two parent volunteers.

Another purpose Blair had for participating in EXPLORE was to extend and enrich the curriculum for her class. She wanted the students to learn the scientific method, to fulfill the state science ecosystem curricular learning requirement “to understand the effects of environmental changes, adaptations, and behaviors that enable animals to survive in changing habitats” (NCDPI, 2015, Grade 4, p. 7), and to understand human impact on the environment. Blair was impressed that her students came up with their own hypotheses and ideas for further experiments. She wanted her students to literally think “outside of the box” (Post observation, March 19, 2015). The record of class discussion that Blair posted in the room was evidence of her intended purpose for participating in EXPLORE; she wanted practical opportunities for her students to learn the scientific method.

Blair’s class worked in small groups led by parent volunteers to put dried corn in shallow cardboard boxes anchored in areas students designated (through prior class discussion) as ‘safe’ feeding areas for squirrels and ‘unsafe’ feeding areas for squirrels in their schoolyard. They then used mathematics skills to calculate any difference in dried corn weight from morning to afternoon. Blair would weigh the corn before students put it out in the morning, and after they collected it from the schoolyard at the end of the school day, students with parent volunteers would weigh what was left. With a far-reaching purpose (object) of extending learning beyond the curriculum for her gifted and above grade level students, her recording of students’ discussion points on a poster (an artifact Blair designed and used) was an idea list for a curriculum extension project to design experiments based upon the scientific method.

Blair's design of discussion as a form of expansive learning in her activity system included many interrelated elements of the CHAT triangle. The subject, Blair, was an experienced teacher (her personal cultural history) who could use her prior pedagogical knowledge to transform citizen science into an educational experience for her students via the use of discussion as a tool. She complemented her discussion by using Google Earth as a tool for her students to see an aerial view of the schoolyard. This tool was used to help students make predictions and draw conclusions in discussions about their Squirrel experiments. This expansive learning was concentrated in the subject-tool-object section of Blair's CHAT triangle diagram.

As a mountain biker Blair had spent extensive time outdoors, and saw value in time outdoors for her students. Her personal cultural history as both an experienced teacher and experienced outdoors person were elements of her decision to design discussion as part of citizen science education in her class. Blair's object or purpose of encouraging an understanding of the scientific method as part of her teaching, as well as her purpose of expanding the curriculum for her community of gifted and above grade level students were also interrelated elements in her discussions.

Blair's support from well-educated and dedicated parent volunteers to take the students outdoors in small groups can also be viewed as the 'community' element of a CHAT activity system and their time with the children as the 'division of labor' element. Parent volunteers took the time to go outdoors with students, taking on that task and responsibility (power sharing between teacher and parents). This time parents took to work with the students was teaching time Blair did not have to spare. The division of labor (parents supervising the outdoor activity) is an element of the system that interacted with the aforementioned elements of CHAT (subject, tools, and community) and helped enable Blair to utilize her scarce time available to innovate the use of classroom discussion in conjunction with citizen science data collection.

Focal Teacher Jackie—Inclusion

Including all students in the opportunity to be engaged in scientific practices was something citizen science education outdoors offered all teachers in this study. Some teachers spoke of their inclusion of otherwise marginalized students in science learning outdoors. Jackie was especially adept at voicing what it meant to her to include all learners in the lesson. Jackie taught third grade and was in her 12th year of teaching. She had taught in elementary, middle and high schools in the past. Jackie was the only teacher at her school participating in Project EXPLORE. She acted as a mentor for her intern, Bridgett, who went out with the class and literally made the trees more accessible to the children.

> . . . when we went out, I think it was two days ago, when we went outside the one group was having trouble seeing any changes and I held the branch down for them. (Interview, April 2, 2015)

Jackie worked in an impoverished community and wrote on her questionnaire that her reason for participating in citizen science in partnership with the Arboretum for a second year was because “Project EXPLORE gave us the opportunity to be citizen scientists, which makes my students feel really important because they are part of something larger.” Jackie’s principal, Allison, described the school community where Jackie worked as a place where the students did not have many opportunities to learn about the larger world outside of their own neighborhoods. Allison viewed the school as a portal to that bigger world:

> This is a high-risk school. We have a high poverty level. We don't collect that data anymore because of the way our breakfast and lunch system is set up, but at last count 79 percent. I feel certain that it's higher than that. Again, it's just when children come here, we try to give them all the experiences that we can so that when they leave us, they know that there's a world out there *for them* that maybe is different than the one they live in right now. (Interview April 2, 2015, italics mine)

Two key words in Allison's quote are "*for them.*" These two words indicate that Allison had a worldview that included opportunity for her high-risk students at a school where all students received free breakfast and lunch. She believed children at her school had a right to participate in the larger world. This worldview supported what Jackie was doing as a participant in EXPLORE. Collecting data for upload to Nature's Notebook from trees marked with ribbons in the schoolyard made Jackie, her students, and intern all part of a global science effort bigger than the schoolyard. For a snapshot description of Jackie's activity system, see Figure 17.

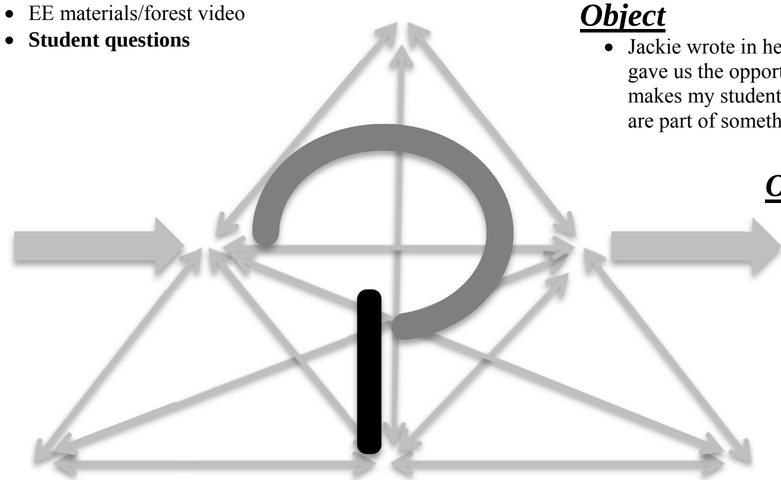
Jackie was able to take her class out to do fieldwork with a small time window available in the school schedule for science instruction available to teach science, as long as her lessons were tied into the state curricular standards. In interviews, Jackie put great emphasis on learning outcomes for herself and for her students. She spoke most

Mediating Artifacts, Tools

- Teacher content and pedagogical knowledge imparted by teacher talk/questions outdoors
- Ribbons to mark study trees
- Science notebooks, labels on illustrations of the trees
- Tablet individual computers w/ keyboards
- EE materials/forest video
- **Student questions**

Cultural History, Subject

- 12 years of teaching experience
- Teaches third grade
- Experience teaching 2-12
- Grew up in a rural area
- Undergraduate degree in English
- "My grandfather was outside from dawn till dusk every day. We gardened together and harvested the vegetables. I spent much of my childhood climbing trees."
- **State EE Certification**
- "Most of what I know came from the classes in my EE certification."
- Jackie wrote, "We don't go out often in winter, if it is really cold, . . . during the warmer months I try to take them outside once a week or more to observe, "catch" animal tracks, practice writing about nature, or reading outside for pleasure."
- Second year EXPLORE participant



Object

- Jackie wrote in her questionnaire "Project EXPLORE gave us the opportunity to be citizen scientists, which makes my students feel really important because they are part of something larger."

Outcome

- Expansive learning: developed a protocol for students to make more observations than were required for citizen science
- Jackie led discussions after making observations outdoors
- **Accessible science to those with low reading skills; they learned science concepts "hands-on" outdoors**

Rules

- School district had an initiative to obtain a computer for every student
- **Explicit times when subjects taught**
- Had to fit lessons in with state curriculum

Community

- Admin/teachers dedicated to working with high needs students
- Teachers/principal participated in PTO dance program with the students
- **Low-income**
- Only teacher at her school who participated in EXPLORE
- Rural Appalachian Mountains school
- Low Black population; high White population

Division of Labor

- Jackie's students worked in small groups to study trees
- **Jackie gave students responsibility** for thinking about their observations with questions like, "But what kind of clues does the tree leave us…?"
- Students were encouraged to participate in discussions
- Student intern participated, did not lead outdoor activities
- Jackie absent day Arboretum educator visited in spring

Figure 17. EXPLORE CHAT Chart for Focal Teacher Jackie.

frequently of how she sought to better herself as a science teacher and of learning outcomes for her students from teaching innovations she designed. The first time I met Jackie, a whole wall of her classroom was blocked by a six-foot tall, three-yard wide, black fabric accordion museum display about Abraham Lincoln. This display had large poster-size photographs and extensive historical text about Abraham Lincoln's life and presidency. Jackie explained to me when I met her that she had found this display offered for free online as a loaner to classrooms, and the organization had sent it to her by mail. This display filled an otherwise very sparsely decorated classroom and gave me the sensation that we were sitting in a museum in an otherwise sparsely decorated school. This display led me to believe that Jackie was willing to put extra time and effort into her teaching. This was evidence Jackie focused on giving all her students rich learning experiences.

Jackie told me that she was adept at searching the Internet for professional development programs that were free or paid her to attend as well as to locate resources for her classroom. She sought out professional development opportunities on her own. As an undergraduate English major, Jackie realized her need to learn more about teaching science. She found a nearby professional development program for teachers, Project *WILD*, to boost her science content knowledge. She also took the Project *WILD* science related professional development course to obtain science education resources for the high needs elementary school where she taught third grade.

> When I first went to my [Environmental Education] class, it was Project *WILD*. I went because they had it here at the lake in our town . . . I noticed it was for teachers, and I needed some more science resources because I didn't know a lot

> about science. I went to that and it was so enjoyable that I completed my [Environmental Education] certification and heard about Project EXPLORE and thought that would be a really good thing for my kids. (Interview, March 31, 2015)

This quote is another testament to Jackie's student-centered worldview. She pursued environmental educator education certification because she thought it would be good for her students for her to be a teacher who was knowledgeable about science and Environmental Education.

Jackie went on to participate in more Environmental Education workshops (completing over 250 hours of required coursework and teaching time) and obtained her state Environmental Education certification—not an easy feat to attain while teaching elementary school full time, completing a Master's degree, and raising two pre-teen children while her husband was suffering from back injuries and unable to work. This also speaks to her commitment to including all of her students in learning science by her including Environmental Education lessons in her instruction for students who most benefit from outdoor learning. She also used Environmental Education materials from her courses in the classroom, such as a video of the forest.

"I have learned a lot about trees," Jackie said, "because I came into it not knowing anything, other than, you know, a few trees that were in my Mom's backyard at home" (Final interview, April 11, 2015). Jackie took a course in forestry as part of her state Environmental Education certification, perhaps making her the most qualified teacher in this study to teach about trees on her schoolyard, yet she still felt she lacked content knowledge. Jackie set a very high bar for herself as it ultimately related to her students' learning outcomes.

> I definitely want to brush up more on my tree knowledge this summer, because I would like to be able to answer questions a little bit more readily when they ask me outside. I won't be able to answer everything, but the more knowledge I have, the more that, you know, I can give them right there on the spot, without having to go back and look for the answers. And that may even cause us to have some deeper observations. So just me, myself, I want to brush up on that before my next group. (Final Interview, April 11, 2015)

Often Jackie spoke of the importance of learning outcomes for her students as a result of their participation in EXPLORE, regardless of the students' life experiences and cultural backgrounds. Jackie's class included five ESL students, four AIG, and the rest she considered as at low to average academic level. Out of her 19 students, 14 were classified as low socioeconomic. Her racial/ethnic mix in the classroom, as she described it, was 5 Hispanic students, 1 student from Yemen, and 1 Black student, and the rest of her students were White. Jackie's principal noted in an interview on April 2, 2015 that Jackie offered learning opportunities to all of her students, opportunities that they may not have otherwise had the chance to experience (e.g., going into the woods to study trees, and having an opportunity to explore a natural area). When asked to define her perception of how she supported teachers, Jackie's principal, Allison, said as long as what the teachers were doing was to benefit the children, she would help in any way she could.

> I think [support] means that when teachers want to do things to better their own practice, they want to do things to better children, then I'm going to do everything I can to make sure that can happen for them, whether that is welcoming guests into our building, that I can support her that way. She goes places. I say that generically because I'm not sure [of] all the places she has gone. She participates

> in a lot of things related to the project, and then can bring it all together because our children don't have those experiences. We don't have a community where parents have the ability to, sometimes the desire to, expose their children to a lot of things. She, through this project, is able to expose them to things that they wouldn't normally be exposed to. (Interview, April 2, 2015)

This quote from Allison provided corroborating evidence of Jackie's efforts to include her low-income students in learning opportunities they might otherwise not experience.

What Jackie liked best about the program was the emotional aspect of learning for her students: "I like whenever I go outside and I see them so excited about it" (Interview, March 31, 2015). Jackie and her class had never collected data for citizen science before, so this was a first time experience for them. "When you go outside," she said, "it becomes a lot more important and interesting to be a keen observer than when you are just in the classroom reading about something" (Interview, March 31, 2015). She referred to all of her students as 'scientists' when outdoors collecting data, again providing learning opportunities in her instruction inclusive of all students, an opportunity to learn science outdoors most students do not ordinarily have. Jackie expected all of them to take responsibility to remember their group work tasks to collect data. "Go to your tree," Jackie said at the entrance of the tree phenology study area one day when I observed the class, "Remember you are scientists; collect your data" (Field notes, March 25, 2015). She did not give specific descriptions of how to collect data, perhaps because they had been outdoors repeatedly and by then had learned data collection protocols. Jackie did answer questions from students gathered in small groups around their trees.

She recognized the importance of first-hand observations and saw that over time when her students came into the classroom and drew in their science journals that they were labeling “a lot more” on their drawings. Jackie was able to integrate a third-grade writing project with her citizen science instruction through the use of science journals and a report she had her students write about the species of tree that they had studied in small groups. As Blair had done, Jackie too facilitated discussions after outdoor lessons. Jackie said that her students talked more over time about their observations as they had gone outdoors repeatedly to check their trees. “I think that they ask more questions in class now,” Jackie said, “and they feel more willing to discuss things that they don’t understand” (Final interview, April 11, 2015).

As Jackie described it, her students who did not know answers were comfortable asking questions in a whole class environment. Jackie facilitated the learning of these questioning students who might be marginalized in class discussions with a teacher who fishes for only the ‘right’ answers. Her students who had questions without pre-set answers were taking center stage in discussions. In Jackie’s class, all students had a voice, illustrative of Jackie’s desire for her students to feel included in the learning process. Jackie felt she collaborated with her students in finding answers to questions the students had, and in this way both student and teacher learning expanded beyond collecting data for citizen science and beyond thinking only about trees.

An important outcome of Jackie’s participation in Project EXPLORE was expansive learning, and she spoke of this frequently. Through participation in EXPLORE she not only learned to implement a citizen science project for the first time, she found a new way to teach outdoors that included all her students’ learning needs. Even though at the beginning she signed up for participation in EXPLORE to give all her students the opportunity to participate as citizen scientists. As she worded it, “Well, I really just thought it would be a good thing to tell the kids that they were part of a citizen science project.” She ended up expanding her definition of what teaching outdoors meant:

> . . . I would go out before and I might would do a project outside, a hands-on activity. And it would be outside. But, the hands-on activity didn’t always coincide with where we were outside, or have anything to do with being outside, other than just knowing that, you know, that it’s nice to get outside and do something outdoors . . . and the other thing is that now we’ve done this, and it was an ongoing project. And you keep coming back and revisiting it. Changing things. Observing new things. It wasn’t a one-time thing, and so that has changed how I think about teaching outdoors. (Final Interview, April 11, 2015)

Jackie’s vision of teaching outdoors expanded to using the specific environment as a tool with which she could include all learners and facilitate their gaining knowledge of their schoolyard surroundings. By mastering a new way of teaching that used the outdoors as a platform for learning while participating in scientific data collection in a citizen science program, Jackie also found that she was able to reach and teach science to otherwise marginalized students.

> And it’s been such a great thing for my class. I just think it’s good for everybody . . . I think [the most helpful thing for students is] the fact that they are able to get up and move around and touch things and it gives them a chance to really explore. And I think that your EC [Exceptional Children] and ELLs [English Language Learners], they benefit tremendously from being able to do that, especially those that are learning new vocabulary. When they have it in their hand and they’re touching it, they’re working with it. They’re using it in what they’re doing. It’s a lot different than just reading it in a book and trying to remember what something is. And so, I think that it’s very beneficial for those students. And I know that in my classroom. I’ve got, you know, all of those in with the rest. So, that’s been a way for me to differentiate and hit all of those learning styles. (Final Interview, April 11, 2015)

Jackie offered educational enrichment for all students, not just the academically intellectual and gifted (AIG) students, and this was a form of empowering all her students with new scientific knowledge and skills.

Focal Teacher Carrie—Integration

Integrating science with other school subjects was done to some extent by all of the teachers in this study; some integrated the activity more fully with other subjects than others. Carrie and her whole first grade team integrated Language Arts with science through a research report on birds, and this was a small but noticeable systemic transformation at her school. Carrie had 11 years of experience teaching first and second grades. She participated in EXPLORE along with other teachers at her school, Jaime and Melodi (who were not focal participants), all of whom taught first grade. Carrie did not describe her colleagues as mentees, but her colleagues described her as their mentor. Carrie and her first grade team had some support from the computer teacher and school librarian. She described her principal as supportive of teacher initiatives, such as finding grant money for the school community. Carrie was often outdoors for leisure activities in her personal life, but still found she had more to learn about birds. She spoke of learning along with her assistant teacher and the students how to identify bird species. She and her colleagues voiced and demonstrated that they learned how to take their classes outdoors from the model set by Arboretum educators.

Carrie said she participated in EXPLORE because she wanted her students to build an appreciation for the natural world. This was evidence she integrated Environmental Education into her instruction. Many of the children attending the school where she worked lived in mobile home parks in the community and had very little experience outdoors. She wanted to bring energy and a love of the environment to her class. Many of them had deep roots in the community, she explained, and they would be the ones to make environmental decisions in the area in the future. For a snapshot description of Carrie's activity see Figure 18.

Carrie reflected upon expansive learning outcomes in her interviews more than any other aspect of her activity system. She said her participation in EXPLORE was a way to address many of the existing curricular goals she already had for her first grade students in multiple subjects. Carrie saw her science instruction outdoors as important for the population of students she taught at her Title 1 rural school. She felt that teaching science in the schoolyard, as required by Project EXPLORE, teaching that was integrated with Environmental Education, led to an important awareness of the local ecosystem for her students.

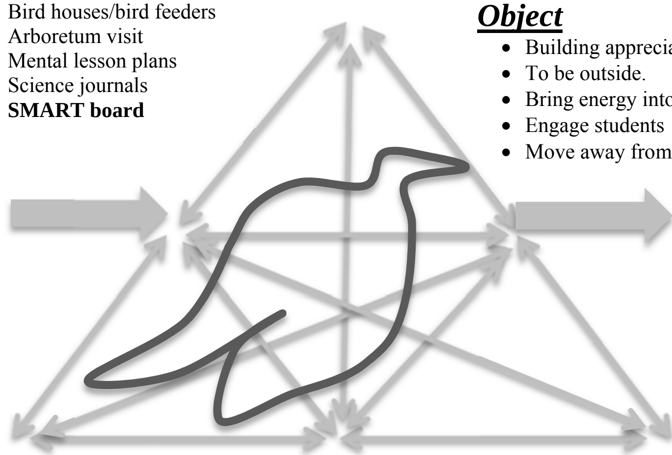
> I think they're just more aware of the cool stuff that's around them . . . I think it's important for this population in particular, because these kids are going to grow up and most likely stay in this community. We have families with very deep roots in this area, and they're the ones who are going to make the decisions that are either going to protect these natural areas and these species, or they're not. I think the seeds are planted now, to have that appreciation and that understanding, and that love for what's around them. (Interview, March 12, 2015)

Mediating Artifacts, Tools

- Project EXPLORE $100 grant second year
- Arboretum gifts 1st year of tools necessary to carry out the project: field guides, data sheets **“bi-noc’s”**
- Citizen Science as a tool to give students significance and pride in their work
- In-depth conversations about bird habitats
- Bird houses/bird feeders
- Arboretum visit
- Mental lesson plans
- Science journals
- **SMART board**

Cultural History, Subject

- 11 years’ experience
- Teaches first grade
- Experience teaching K-3
- Undergrad Elem Ed w/EE concentration
- Grew up in the suburbs
- Good deal of experience in nature
- **“I am often in nature for leisure activities”**
- Pressure placed on teachers takes a toll
- Husband works for the Arboretum
- Finds weaknesses in her bird ID skills
- Confident educator
- Learning along with students
- Doesn’t consider herself a mentor
- Wants to make eBird school-wide
- Felt supported by Arboretum
- Second year EXPLORE participant



Object

- Building appreciation and love for surroundings in students
- To be outside.
- Bring energy into the classroom;
- Engage students
- Move away from pressures of standardization.

Outcomes

- Expansive learning-**independent thinking**
- Students learn to be bird **experts**
- Carrie learned with students
- **Carrie improved in bird ID**
- Students learned how to behave and interact in nature, and had fun!
- Birding spread to students’ home activity

Reference: Engeström, Y. (2001). Expansive learning at work: toward an activity theoretical

Rules

- **Routine strips teachers of creativity**
- Administration looks to teachers to be creative and try different approaches to practice
- eBird activity fits with state curriculum
- Students have to be quiet while they are birding and stay behind an adult
- Teachers and students confirm data

Community

- Families have deep roots in that area and will probably stick around.
- **Many students come from trailer parks**
- Many students have very little experience outdoors
- Three first grade teachers participating in eBird
- Computer teacher added a symbaloo icon for eBird
- Librarian helps with research references
- Parents got involved by making kids bird costumes
- Principal looks for teachers who are self-starters and think outside the box
- Arboretum great support and resource
- Works in a school that has teachers doing “amazing things.”
- School is planning to build an outdoor classroom.
- Rural school

Division of Labor

- Carrie uploads data to citizen science website because it’s not “kid friendly” on SMART board so kids can see
- Organized bird research teams of two by asking who wanted to do what bird (worked in pairs)
- Carrie led her colleagues through the EXPLORE project
- **Carrie took other classes out birding**
- **Carrie’s Assistant teacher took classes out birding**
- Carrie took all three class posters to Expo
- Arboretum staff came and got the project started
- The other teachers working with her (one first year and one second year participant) consider Carrie a mentor
- Was teamed up with Jaime a few years ago by principal, now they work closely on eBird.
- Students keep science journal

Figure 18. EXPLORE CHAT Chart for Focal Teacher Carrie.

Her students' love of birds spilled over into other parts of nature, and into other nearby places. Her students integrated school science (eBird) with home observations. Carrie noted that her students found new places to look for birds and evidences of birds on their own. They reported to her about observing birds at home, and on family outings. Carrie's students also brought in found objects (other relevant items) from home, which she displayed on a low round table near the classroom door, such as an abandoned bird nest from under a bridge found by a student while out on a walk with his father. This observation supported Carrie's reflection upon her purpose for engaging in eBird as integrating the natural world into her science teaching.

Carrie had her students use journals to integrate art with science and during one of our post observation interviews told me, "I told them when we came in," she told me, "that I'd like to get blankets sometime and just have us sit out there and be totally quiet, and see how close the birds would get, and bring our journals, and draw them right in the environment" (Interview, March 12, 2015).

Returning to the classroom after observations, she integrated technology and mathematics into their citizen science data reporting. Carrie uploaded data by pulling up the eBird website on her computer. The students observed her uploads of data on the website on the SMART board in the classroom that projected Carrie's computer screen.

> The arboretum really sets the groundwork for this, why you're doing this project . . . Having them, having someone from the outside come in and say, "You're going to help scientists," that's a big thing we stress with them. They feel important. They know they're doing an important job. They see the information we put on the website and they take it seriously. (Interview, March 12, 2015)

This quote illustrates how Carrie integrated the subjects of technology and science. While Carrie uploaded data online via the projector and screen in the classroom, "The kids watch me put it in," she explained. ". . . we've been making our own graphs, so they can still have the data right there, and still also incorporate math into their learning with that" (Interview, March 12, 2015). This quote demonstrates Carrie's integration of mathematics and science in her class.

The computer teacher at their school, also a parent of a first grader Carrie taught her first year as a participant in EXPLORE, incorporated research materials about birds as a link to a school icon—a 'symbaloo'—on students' school wide computer screens. Carrie explained that the computer teacher told her that since birds sparked such curiosity in her daughter she wanted to help the first-grade teachers. The librarian was also very helpful with the required Language Arts research report required in the first-grade curriculum as Carrie integrated this writing requirement with eBird and called it "our birding project." As Debbie, the librarian, explained, she integrated birds into her reading and writing lessons in the media center.

> I provide things for them to use in the classroom. I provide things for the students to use in here, and then we'll work together sometimes. They'll say, "You do this part and have them find out these things while they're with you. Will you have them write up these things?" I tie in and try to do books and stories and projects that tie into what they're doing. We just completed an egg book with the kids that were doing birds. We started with birds and then we went to other animals that lay eggs. I just try to tie in with [teachers]. But I do that with any of the teachers that I'm working [with], whether it's EXPLORE or other curriculum they're doing. (Interview, April 20, 2015)

This quote from Debbie corroborates Carrie's integration of Language Arts and Science.

Debbie, the librarian at Carrie's school, integrates what she does in the library with what teachers are doing in their classrooms. This integration supports children's research and writing as well as science curriculum. Debbie helped first-grade students participating in eBird write a research report required in their first-grade language arts curriculum. Students in groups of two were assigned a specific bird about which to write a research report. Carrie assigned birds that were typically seen in her schoolyard. One day as I observed Carrie gathering eBird data with her class outdoors she called on one pair of students to share what they knew from their Language Arts bird research project with the whole class about the bird they had researched and were observing. In this way, Carrie managed to integrate a student research presentation with their schoolyard data collection outing.

> I think that's been an impact, just introducing them to what they can learn in science, with nature right in their own backyards. You don't have to go to a museum, or you don't have to have an expert come out. They're learning to be the experts themselves. (Interview, March 12, 2015)

Here again, Carrie demonstrated her integration of science with an understanding of the natural world, something that is an integral part of Environmental Education. Carrie felt that she learned about birds too. She was recognized as a mentor by the other two first-grade teachers on her grade level team who also participated in EXPLORE. Her classroom assistant teacher helped facilitate the eBird citizen science activity and led groups of students outdoors to bird watch. Weather allowing, all three classes went out on Thursdays at a specific time so that they could make their weekly observations. Carrie sometimes led one or more classes outdoors, if another teacher were absent, or to help another teacher out. She mastered a new way of doing things.

> I’m really not a birdwatcher myself, and I’ve learned most of these birds that I know just through learning them with the kids . . . so, it’s been really good for me personally, just to kind of learn right alongside of them and have a way to get them outdoors that I didn’t realize I was capable of doing before. (Interview, March 12, 2015)

By integrating citizen science with science education, Environmental Education, mathematics, art, and Language Arts instruction, Carrie was able to take her students outdoors, something she did not know she could do, but that she found she was capable of doing.

Focal Teacher Rorie—Collaboration

While all teachers in this study collaborated to a certain extent with at least one other colleague, assistant teacher, or intern, some teachers collaborated more than others. Rorie’s community collaborated in many ways and I observed a strong complex web of collaborative practices and relationships at Rorie’s school that stood out as exemplary. Rorie had 13 years of experience teaching Pre-K (Montessori) and lower elementary grades. Rorie was a first grade teacher who participated in EXPLORE along with another first grade teacher, Jennifer, as a partner, and they had support from many other teachers at their school. Jennifer was not a focal teacher, but she worked very closely with Rorie as both a friend and a colleague. Rorie grew up in the country and she remembered helping her grandfather in the garden, and being outdoors playing in the woods daily with her siblings. She was active in 4H programs, river studies, tree studies and other projects focused on the natural world. In addition, she had experience teaching Environmental Education in the past. I observed Rorie found eBird fieldwork easy to do. She wrote in her questionnaire that eBird ". . . opens the students' experience to their world. It allows an easy way of teaching literacy via the sciences."

She worked at a science-focused school where the principal believed in collaboration and in outdoor education. The community had plans to build an outdoor classroom in the front yard of the school. The architectural rendering for the outdoor classroom was on display on an easel in the main lobby of the school for all to see. This was a brightly colored elaborate drawing of the outdoor classroom plan and the construction crew was breaking ground at the time I was observing Rorie's students in the schoolyard. This project was evidence of the school's collaborative effort to complete a large ambitious project. Rorie's school's (Willow Elementary School) outdoor classroom plans were recognized with approval by the school board at the district school board meeting I attended, and they supported sustainability efforts district wide (e.g., the board highlighted one school obtaining a grant to replace non-recyclable disposable lunchroom plates with compostable ones).

The school had its own set of river rafts for rafting trips, and many organizations collaborated with the school in the afternoons, such as the YMCA, to offer programing for schoolchildren. It was a colorful, cheerful, and sunny school with many windows and I observed students sometimes painted murals on the inside walls supervised by an adult. The organizations that worked with the school to provide after school programs triangulated significant evidence of collaboration at Willow Elementary.

Collaboration was evident in Rorie’s voice as she reflected upon her teaching and was triangulated by multiple data sources (e.g., observations, school website, and supporting participant interviews). Rorie shared a great deal of the eBird responsibilities with the assistant teacher and student teacher in her classroom. They took turns with Jennifer, the garden teacher, the AIG teacher, the librarian and me to observe birds with students. Rorie’s student teacher, Dave, described birding as akin to a safari adventure:

> It was so cute yesterday. I saw them, they saw a bird that was probably five or ten feet away from them and instead of getting closer to it they kind of crouched down and looked in their binoculars. It was like little scientists out there in the field. It reminded me of scientists on a safari. They're getting close but not too close. It was just awesome to see them all get together in a little group, and crouch down, look at the bird, whisper about it, and talk about which one they knew it was. (Interview, April 10, 2015)

Dave found that the materials the Arboretum supplied were amazingly helpful. The children were able to see clearly with the binoculars the bird that they were trying to identify, and then look it up in the book. As a student teacher, and Rorie’s mentee, he learned to teach science outdoors and said being able to do that was “one of the best ways that you could ever teach science” (Interview, April 10, 2015). For a snapshot description of Rorie’s activity system please see Figure 19.

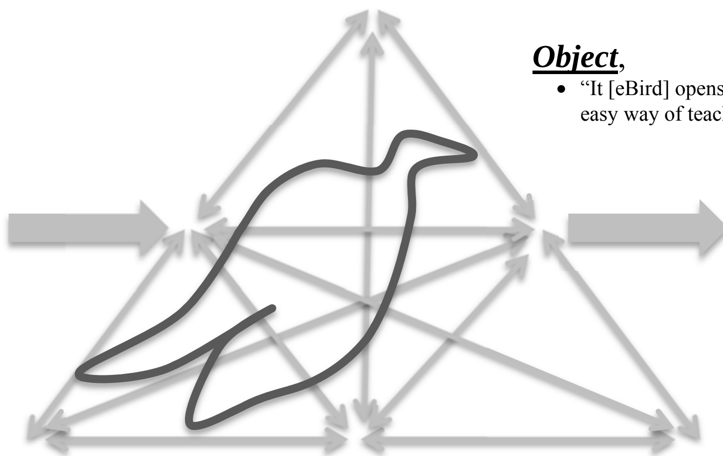
Rorie in her interviews gave extensive descriptions of all of the interrelated elements and components of her school based EXPLORE activity system. Her references to expansive learning as an outcome were frequent, and among the different types of

Mediating Artifacts, Tools

- Birdfeeder with gnawed holes, evidence of squirrels and tool to understand competition for food in ecosystem
- **Designed bird data collection sheet (including plants/insects) and bird drawing template**
- Used background knowledge to facilitate student learning
- eBird vocabulary helped students with reading skills

Cultural History, Subject

- 13 years of teaching experience
- Teaches first grade
- Experience teaching pre-K & K-3 & EE
- Undergrad Elem Ed K-8
- Grew up in a rural area
- "Played in the woods (forest floor) daily with my siblings"
- child gardening w/ grandfather
- 4H programs: river studies, tree studies, & natural projects **Excited to learn new ways**
- Second year EXPLORE participant



Object,

- "It [eBird] opens the students' **experience** to their world. It allows an easy way of teaching literacy via the sciences"

Outcomes

- Skills in Bird ID increased
- Many types of expansive learning (e.g., student engagement in science
- It's about the bird, not the neighborhood problems
- Innovative school-wide collaboration for birding
- **Student engagement**

Reference: Engeström, Y. (2001). Expansive learning at work: toward an activity theoretical reconceptualization.

Rules

- Well-established class discipline plan (fish and bubble symbols on board)
- School district science coordinator suggested citizen science should coordinate with state science standards
- School district encouraged reduction of carbon footprint
- **Students go to garden class1/week**

Community

- **Dedicated to science & learning outdoors**
- Many after school programs (YMCA Music; donors/volunteers; artists)
- Culture of cooperation and collaboration
- Title 1 school in an urban area
- School community science focused
- Librarian brought in area authors and bird experts
- Parents volunteer in garden
- Proactive and environmental sustainability focused school board
- Younger than average class, more boys

Division of Labor

- **Colleagues collaborated w/ her to teach eBird**
- Assistant teacher, student teacher led field work
- Rorie collaborated with librarian windows for bad weather day observations
- Art teacher collaborated students drew birds
- First grade students filled out data sheets
- Rorie uploaded data to eBird website

Figure 19. EXPLORE CHAT Chart for Focal Teacher Rorie.

expansive learning she spoke of, collaboration was an important theme for her. I also observed varied instances of collaboration woven throughout the school community.

> The Assistant teacher normally takes out groups to do bird watching as part of center time . . . A class parent, also the president of the Parent Teacher Organization (PTO), gives first graders a yoga class. The class lined up for Yoga, the student teacher, Dave [a pseudonym], and the assistant teacher went with the students. The PTO President, also a classroom mom, teaches Yoga at the [Business Name] and the assistant teacher goes to her Yoga classes on Monday nights. Kids can't go to watch birds [today]—yoga left only ten minutes before art class, so there will not be time to go outdoors to bird watch. (Field notes, March 6, 2015)

This quote is evidence of how the parents collaborated with the Willow Elementary School, and how the school was accepting of parents' collaborative efforts.

Rorie worked with a large collaborative team of educators and parents at her high-needs urban school. The EXPLORE team included the Arboretum educators, Rorie, her classroom assistant teacher, her classroom student teacher, her first-grade colleague in the classroom next door, the school librarian, the art teacher, the garden teacher, the gifted teacher, myself (during my dissertation data collection time period), and the students themselves. We all helped supervise her students' data collection and other educational activities related to eBird.

As a small group of Rorie's students crouched in the grass one day with their student teacher, still as statues, at the edge of their playing field, to observe Robins pecking in the grass and black American Crows flying overhead, I witnessed their amazing self-control. By participating in EXPLORE, Rorie and her collaborating student teacher, Dave, were also collaborating with the principal's initiative to promote self-control in students. As Rorie's principal, Alex, expressed it to me, one of the most important initiatives at Willow was for students to develop self-control.

> I've thought about it a lot and tried to boil it down to what are the essentials in education, and truly you will be successful people coming out of public education if you could do two things: If you could read really well for meaning, and if you have self-control. If you have those two things, you could pretty much figure everything else out. Math and all will come, but math is often expressed in word problems that you have to reduce to number sentences so you've got to be literate, and you've got to have enough self-control to be able to handle different social situations and to receive learning and to participate in it. (Interview, March 10, 2015)

This quote from Alex suggests Rorie collaborated with her principal's initiatives through evidence in her reflections of her recognition of eBird as beneficial to her students' reading levels, and evidence in my observations in the field of her high expectations of student self-control. Her students were expected to be quiet and still when bird watching. In other words, she and her staff expected students to control their own behavior so that they did not frighten the birds.

Some of Rorie's students were so engaged in the eBird activity that they learned enough to be able to 'teach' the adults. As Rorie described it, ". . . children can become quicker experts than adults because they are so open to the information that they are given." Students too could collaborate with the adults in teaching teachers. "Then it makes their experience more exciting," Rorie explained, because it's like, "we are teaching your teacher something too." They feel so good about that. "I don't think children are really allowed to feel good about their expertise sometimes" (Final interview, April 11, 2015).

One reason Rorie said that she wanted to participate in EXPLORE was so that her students could learn more about where they lived, more than just what they needed to survive, she wanted them to know about the animals that lived in their neighborhoods. She and her collaborative team helped her students soar above problems in their neighborhood—as she expressed it, “Like, the bird is one of the only animals who has adapted to rise above everything, literally” (Final interview, April 11, 2015).

The bird in flight was inspirational for one of her students in his choice of a mentor. Rorie told a story about a program she set up on her own for one student in her class that she felt needed time with a mentor, “The child needs positive male influences and a way to express himself artistically” (Email Communication, December 4, 2015). Rorie described her student’s reasoning for his choice of the art teacher as a mentor teacher.

> “You know, I want my mentor to be Mr. [art teacher].” I was like, “But you see him once a day every week.” He goes, “No, but I want 10 extra minutes every Monday so he can teach me the design process. I just need him to draw these birds and it’s so fascinating. I see him start at the top and he does these big sweeps.” It’s stuff he never would have paid attention to before. I said, “Yes, but what would be the purpose of that?” He’s like, “Because birds are like airplanes, and when I become an adult I’m going to go to an engineer school and learn how to design airplanes. So I need to work with a professional designer who can help me to do that.” . . . He’s six. He’s going to be seven in May . . . At the beginning of the year he was so difficult. You’d say red, and he’d say green. You’d say black, he’d say blue. You’d challenge him on anything; he’d buck up on you. He talked about shootings and how he was going to end up in prison. Now he’s like, “No, no, no, I can do anything I want to. I’m going to be an engineer. I’m going to college. I’m going to design airplanes.” This bird project really helped him because he found a great mentor that can get him there. He can verbalize his thinking and he can take any subject and make it work for whatever he wants to do. (Final Interview, April 11, 2015)

Rorie sought collaboration on her own initiative with the art teacher because of a need she saw for a student to have a mentor, and due to this, the student specifically requested that the art teacher be his mentor. This boy chose the art teacher as his mentor because, as Rorie told the story, the boy thought the art teacher could draw birds, which would help him design planes. Rorie's student realized an expert in art could help with his new dream of being an engineer. This is not only evidence of collaboration at the teacher-teacher level; it is evidence of a six-year-old child's recognition of the collaboration needed between artists and engineers to design airplanes.

Rorie felt it was an especially important part of the partnership with the Arboretum that adults, experts as she worded it, were working with the children. The importance she placed on working with experts also corroborated the theme of collaboration. It was important to her that an educator from the Arboretum would come and visit them. "So, that's always the purpose of the project for me, is just to open up their eyes to other experts," Rorie said (Final interview, April 11, 2015). And she felt it was important that the Arboretum expert tell them that they were chosen to participate in this project. (Some teacher applicants were not accepted into Project EXPLORE due to the limited number of participants that the project could serve.)

> It's like one of those projects where when you have the expert of the Arboretum come in, the children having somebody come to visit them and say, "We've chosen you to participate in this project," is different than me saying, "Hey, guys, we are going to do this project because I want you to learn this." To take the route of, "This is a group of people that really, really want to teach you about the area too. I'm not the best expert, but these are the team of teachers that are going to be working with you. Ms. [Kathy] is going to pull all of the research." She's already set up the bird watching tower [in the Media Center from the second floor windows] so that if I'm off grounds they can always go to her and say, "Hey,

> where are the supplies?" There are just so many adults working with them and taking so much interest in them that it pulls them out of that neighborhood kind of mindset . . . It physically showed them, "Oh my God! There's a world beyond wherever I live" and "I can do the research!" and "Science is helping me find this!" and "I'm working with all of these people, I can do much more than this." (Final Interview, April 11, 2015)

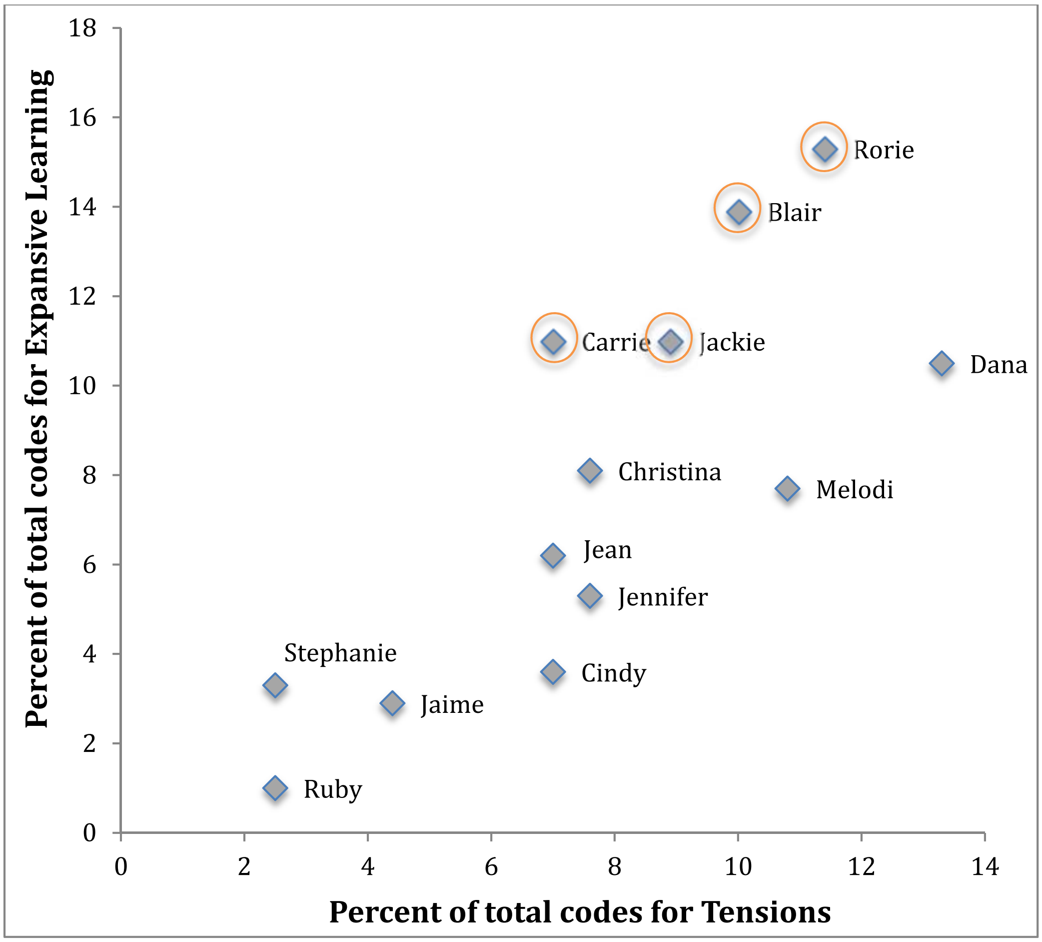
In short, Rorie felt that using a collaborative team of students, experts and teachers with EXPLORE was beneficial to her students. She felt that the team cared about students learning about the area and about what the students could learn on their own and that this instilled in students a broader confidence in their own abilities and a hope for the future.

These four themes of discussion, inclusion, integration, and collaboration found within and across activity systems in EXPLORE highlight stories of success with pedagogies that educational research finds lacking in elementary school science education (Roth, 2014). These highlighted themes of expansive learning were outcomes in this study, and they could be explained by looking at many different interrelated elements of the activity systems for a deeper understanding of how teachers learn. The focal teachers all sought student learning, and engagement in science and Environmental Education, in different ways. I now discuss the results for all three research questions.

Discussion: RQ #1, RQ #2, RQ #3

Tensions and outcomes of expansive learning involved innovations that transformed the teachers' activity systems. The findings in this study did show evidence of some tensions that may have directly provoked expansive learning and subsequent transformations of the activity system, such as in Rorie's arranging for bird observations in the Media Center in response to the inclement weather. Blair's activity system showed an example of an expansive learning outcome. Blair's outcome of expansive learning (discussion) provoked her use of a new tool (Google Maps) to facilitate a general understanding of the geographical area surrounding the school during discussion. In this way a new way of teaching was developed in the classroom—the activity was transformed.

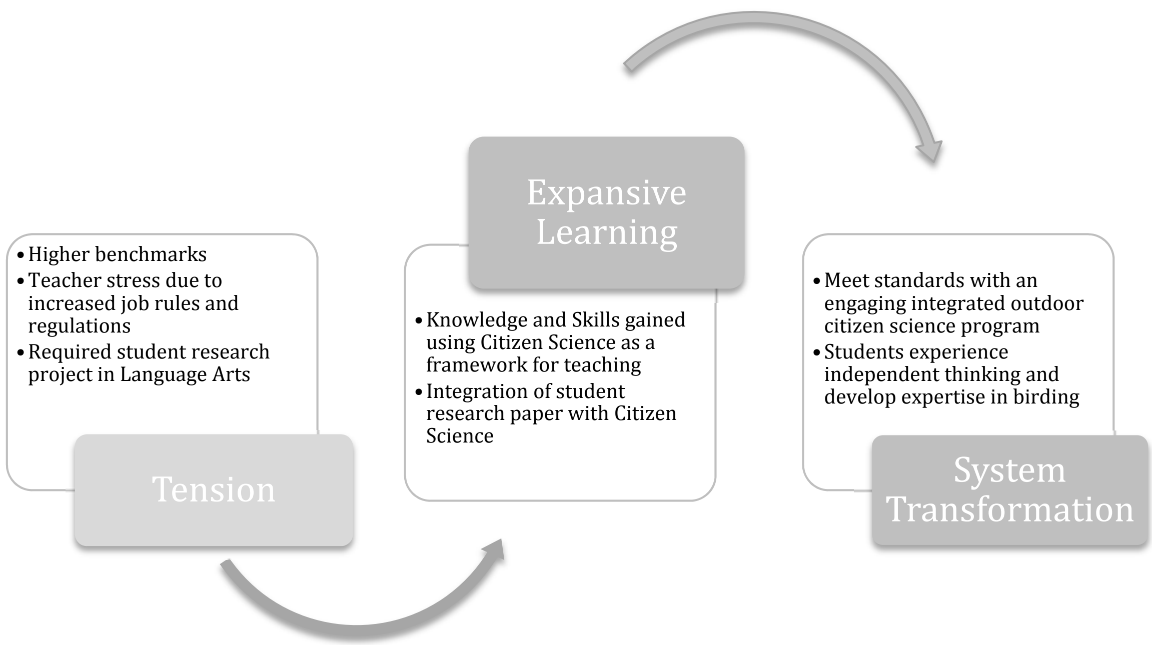
Findings also show a general trend of the more tensions teachers spoke of—the more they spoke of expansive learning. This is illustrated by a scatterplot graph (see Figure 20). The frequency of teacher excerpts from interviews and application essays that were coded for tensions is represented on the x-axis; expansive learning outcomes excerpts are represented on the y-axis. In the scatterplot, a circle around a gray diamond indicates focal participants; a gray diamond alone indicates all other participants. This trend coincides with what Engeström (2001) theorized—that tensions in an activity system could provoke expansive learning. This graph shows how often teachers spoke of tensions or expansive learning, but does not explain how many themes of expansive learning were included in each teacher's excerpts (for example, Blair spoke mostly of her expansive learning in designing and mastering discussion, whereas Rorie spoke more of expansive learning in multiple themes). It is interesting, however, that on average, teachers' recognitions of tensions and their reflections of expansive learning seemed to be related in the frequency of coded excerpts. Tensions and expansive learning were something all participating teachers spoke of in Project EXPLORE. As one of Carrie's reflections about EXPLORE exemplifies, this study highlighted not only descriptions of activity systems and how the teachers learned to enact citizen science programs at the elementary school level, but also helped me discover and reveal the relationships between tensions, expansive learning, and transformations in the teachers' activity systems.



Note: This graph was generated from percent of total codes for themes on Dedoose.com software from my coding of the interviews and application essays for all study participants (N = 13). The diamond-shaped markers inside orange circles denote focal teachers (n = 4).

Figure 20. EXPLORE Tension-Expansive Learning Codes Scatterplot.

Carrie described her activity system as having *tensions* (stress, pressure on teachers to demand higher standards of students, scheduled deadlines for covering curriculum, and benchmark tests) *expansive learning* (using EXPLORE as a framework expanded science teaching to include citizen science and Environmental Education, promoted outcomes of knowledge of the natural world, increased her knowledge of teaching outdoors and birding skills, and led to integration of subjects) and *transformations* (presenting curriculum engagingly to promote student interest, student independent thinking, and student expertise). See Figure 21.



Note. Summary of quotes from Carrie, Interview, March 12, 2015

Figure 21. EXPLORE Tension-Transformation.

This illustration of the relationship between tension, expansive learning as part of EXPLORE, and activity system transformations is based upon a quote from Carrie in an interview and is a good example of this relationship.

> . . . I did more of what I wanted to do. I think, we get into . . . Jaime and I have both been teaching for a while, and you just get into your ruts. Especially with common core coming in and there is more pressure put on teachers, there is, sad

> to say less fun, there's a lot more deadlines that they need to meet, higher benchmarks. It's stressful; it's more stressful being a teacher today than it was, even 10 years ago. This has allowed us to put more of that fun energy into the goals that we already have for our kids. To do research, to be independent thinkers, to find out things on their own, to use nature, to learn about the natural world, it's just given us a framework to be able to do that . . . Our population, a lot of our kids don't get out into nature for fun. A lot of our kids live in trailer parks, and their parents don't have the resources to take them out hiking on the weekends . . . So I think that's been an impact, just introducing them to what they can learn in science, with nature right in their own backyard. You don't have to go to a museum, or you don't have to have an expert come out. They're learning to be the experts themselves. (Interview, March 12, 2015)

> . . . the primary reason we use technology for research is our birding . . . I took them outside and my assistant has become really good with birds also. Last year was her first year working with [eBird] and we learned our birds together . . . it's easier than you think . . . I think it empowered my students to really know that they're important, that their findings are important. We talked a lot about, "Hey we're helping the scientists. The scientists cannot be everywhere, they can't come to [Magnolia] every week so we are here to find out what is in our yard every week." That really got them motivated and engaged, the fact that they can make contributions to science at their age . . . (Final Interview, April 11, 2015)

In addition to Carrie, Blair and Rorie also spoke of similar relationships between tensions, expansive learning, and system transformations (tension of weather conditions, designing observation protocols from indoors, transforming the activity system to include indoor class time for scientific research). Jackie spoke of a relationship between tension, expansive learning, and transformations in her activity system because she changed how she saw teaching outdoors. She was constrained by a school wide structure of little time to teach curricular requirements for science, and she learned to see citizen science programs outdoors as both a way to meet curricular demands and to offer a hands-on activity beneficial to literacy for her high needs students. In addition to designing new ways of doing things, teachers reflected upon new teaching skills and new knowledge as outcomes of their participation in EXPLORE.

Interviewees at the Mountain Science Expo 2015 defined successful science teaching outdoors (see Table 12) and identified students being engaged as a successful outcome of teaching science outdoors. In fact, it was the only criteria for success that was a theme across activity systems. For this reason, student engagement can be considered an object, or purpose, of the larger EXPLORE activity system.

Conclusion

This study found that the varied interrelated elements of the many activity systems that helped make up Project EXPLORE had some similarities. Principal among them was the Arboretum's participation. There were also some unique perspectives from each of the primary participants' activity systems. Teachers' individual ways of learning to enact citizen science programs in formal science education at the elementary school level made each primary participant's learning experience unique. Each teacher designed new ways of doing things for their students as part of the citizen science activity, and for each teacher the expansive learning outcomes were slightly different.

My study was deeply connected to teachers' voices as I struggled to listen closely for their meanings, and in many ways I took on their points of view with my developing understandings of the tensions they were dealing with in their activity systems. I searched for how, through expansive learning, they negotiated around and above tensions or contradictions in order to expand learning experiences for their students.

Table 12

EXPLORE Teachers' Meanings of Success in Teaching Science Outdoors 2014–2015

Meaning of Success in Teaching Science Outdoors	**Rorie**	**Blair**	**Cindy**	**Jackie**	**Dana**	**Carrie**
Success means teacher . . .						
Planning	✓					
Strategy	Gather at first; Break class up into small groups outdoors					
Rule setting	Go over expectations before going outdoors and when first going outdoors;					
Loose boundaries	Students required to keep teacher in sight; allow them to use up energy					
Success means students are . . .						
Engaged	". . . [students] can't just go off after a clump of birds"			✓	✓	✓
Finding conclusions/ answers on their own		Drawing their own conclusions based upon what they see happening			Students are looking for answers themselves	
Learning			✓	Students are picking up new things they did not know (multitudes)		

Table 12

(Cont.)

Meaning of Success in Teaching Science Outdoors	Rorie	Blair	Cindy	Jackie	Dana	Carrie
Success means students are … (cont.)						
Being able to go outside and learn anything			Integrating other subjects (reading, math) with science outdoors			
Exploring						
Coming up with own ideas		✓				
Having fun			✓			
Interested				✓		
Journaling what they did				✓		
Participating					✓	
Asking questions					✓	
Looking for clues					✓	
Understanding whole systems						✓
Connecting nature w/technology						✓
Coming up w/ own observations		✓				
Interacting with the environment						
Getting outdoors		✓				
Individual Summary Statement:	**Follow rules and explore**	**Independent thinkers**	**Integrated and fun learning**	**Learning new things**	**Participating in science**	**Holistic understandings**

These school-based transformations in EXPLORE, when compared with the literature, may not have changed elementary school science teaching as much as was recommended according to Tomasek (2006) or as much as educational researchers would like to see according to Roth (2014). Teachers could have added an inquiry component (guided, or open-ended), or inquiry projects for students to do, to answer the questions they generated from their experiences outdoors engaging in citizen science data collection.

For example, Blair's students had many ideas about why the squirrels were not eating the corn as they had expected, and their ideas for further experiments, as far as I know, remained only ideas. Further experiments were not designed or done. Jackie's students brought up questions in discussion and in their drawing, as evidenced in their poster for the Mountain Science Expo 2015. One of Jackie's students drew a tree and wrote that the snow broke a branch off of the tree. Without the time and ability to investigate that supposition the child could have left the experience with a misconception if it was not, in fact, the weight of the snow that broke the tree branch the child observed and drew. An inquiry activity to accompany citizen science fieldwork was found to be beneficial to students' science learning by both Tomasek and Roth. According to them, engaging in inquiry is the next step, and EXPLORE could take that step and include inquiry in the program as part of future collaborations with teachers.

The unexpected benefit of collaboration and mentorship in helping other teachers enact citizen science programs acted as a secondary form of professional development in learning communities. This model of citizen science professional development in partnership with an Arboretum may be a good one to emulate, as teachers chose participation in Project EXPLORE and chose to learn by doing and innovate. Similarly, Project EXPLORE expected teachers to facilitate learning by doing science with students. The partnership with the Arboretum gave primary participants valued support and teaching materials to help them enact citizen science as both science education and Environmental Education. And as evidenced by the findings from this study, primary participants' status as experienced teachers and their freedom to design and implement further innovations was a large part of what learning to enact citizen science programs in the schoolyard meant to them. The two teachers who were not as experienced, the only two primary participants with less than seven years' experience in the public school classroom (Jennifer and Christina), were mentored by or partnered with more experienced teachers (Cindy and Rorie). All primary participants designed their own uses of citizen science to some extent in order to fit their students' needs in the context in which they worked. The preparation and expertise offered by environmental educators from the Arboretum was critical to teachers' subsequent innovations. The Arboretum organization and support provided by their environmental educators were excellent, teachers noted. Both the Arboretum and the Arboretum educators were an integral part of teachers' activity systems. Teachers used this partnership as a framework to transform their teaching.

CHAPTER V

IMPLICATIONS

> It seems to me that this relation to "knowing" essentially boils down to a simple but fundamental cognitive pattern: in social life, a *question* is raised, in some institution, and persons in that institution try to do something in order to provide an *answer* to that question. The question is not intended to belong to any established field of study – it can be anything relating to any social practice . . . the answer *is knowledge* in the broad sense I advocate. It should be clear that the question/answer pattern is the heart and soul of the social diffusion of knowledge. (Chevellard, 2007, p. 7)

My research study was a qualitative descriptive case study conducted from a sociocultural point of view. I examined the meanings public elementary school teachers made of learning to enact citizen science projects in their schoolyards in partnership with a local Arboretum. Utilizing a framework of cultural-historical activity theory (CHAT) in this study, the Arboretum's Experiences Promoting Learning Outdoors for Research and Education (EXPLORE) program was viewed as a larger activity system composed of and acting in partnership with 13 participating teachers' smaller activity systems based at the schools where they worked.

Data collected included questionnaires, interviews, observations and review of pertinent artifacts for all participants in this study (e.g., primary participants and supporting participants such as Arboretum educators, school principals, colleagues, and district science education administrators). CHAT guided data analysis with special attention to the most frequently identified outcome expressed by primary participants—

expansive learning. EXPLORE teachers designed and mastered new ways of teaching and transformed their citizen science activity. Four prominent themes in expansive learning were highlighted: (a) discussion, (b) inclusion, (c) integration, and (d) collaboration. Citizen science was seen as a framework to instigate a new way of teaching science.

Primary participants' transformed science teaching incorporated outdoor instruction and many age-appropriate pedagogies they designed to extend and embrace the citizen science program that they completed with their students. EXPLORE teachers encouraged their students to engage in inquiry and inquiry-based discussion, to take part in presentations of their findings to classmates and the community, and even to participate in additional science programs in conjunction with citizen science data collection. For these teachers EXPLORE meant much more to them than doing citizen science—overwhelmingly it meant designing and mastering new ways to teach science to their students. This model of professional development could act as a springboard to promote student-led inquiry projects that could take student learning forward.

In this chapter, I explore the limitations of this study, the implications of this study for practitioners and researchers, ideas for future research, questions remaining, and my conclusions.

Limitations of This Study

In Chapter I, limitations that were identified and discussed included the limited resources and time that I had to complete the study. There were limited study sites that I could visit due to distance and weather conditions. And, as a small qualitative study, the results cannot be generalized. Future studies need to include larger, more diverse groups of teachers in order to make generalizable conclusions about teachers learning to enact citizen science projects. Although this study included a diversity of school locations, student populations, and types of teacher collaboration with colleagues, grades taught, and citizen science programs, there was little diversity among teachers with respect to race, gender and teaching experience. All of the participating teachers were females, and all but two were White. All were experienced teachers (most had between 10 and 20 years of teaching experience). Therefore, a limitation of this study is that it was conducted with a fairly homogenous group of experienced female teachers. The demographics for years of teaching experience showed that there was a larger percentage of teachers with 3–20 years of experience (84% in EXPLORE) than the national average, (69.7%) according to the National Center for Educational Statistics (2013). The racial demographics of the primary participants in this study paralleled national racial demographics (see Table 13). Studies that include teachers who represent a wider variety of races and genders could help build an understanding of valuable varied points of view.

Two additional limitations of this study were a lack of access to the scientific data that students collected and the lack of student learning outcome data. While teachers were expected to enter data into citizen science databases and they reported having uploaded data, verification of these uploads was not always possible. This is a limitation of the study because having these data would allow verification of the authenticity of the science fieldwork that teachers and their students completed.

Table 13

Teacher Race and Years of Teaching Experience

Race and Years Teaching Experience Categories:	National Averages 2011–12 Percentage Distribution All Grades K-12	EXPLORE Average 2014–15 Percentage Distribution Grades K-5 (N = 13)
Race		
White	81.0	84.0
Hispanic	7. 0	8.0
Other	12. 0	8.0
Years teaching experience:		
Less than 3 years	9.0	8.0
3–9 years	33.3	38.0
10–20 years	36.4	46.0
Over 20 years	21.3	8.0

Note. Source of National Averages Percentage Distribution was the National Center for Educational Statistics (2013). *Number and percentage distribution of teachers in public and private elementary and secondary schools: by selected teacher characteristics selected years 1987–88 through 2011–12*. https://nces.ed.gov/programs/digest/d13/tables/dt13_209.10.asp

Teachers often stated that an important outcome of engaging in citizen science was to promote student learning. They also spoke about how participating in EXPLORE had benefitted their students in many ways. However, this study did not include student learning outcome data collection.

Data from students' exit surveys administered by teachers at the end of the school year were available. These exit surveys, developed by the Arboretum, focused on environmental attitudes. The surveys did not evaluate learning outcomes in (a) the cognitive domain (e.g., higher order thinking and knowledge pre and posttests), (b) the emotional domain (e.g. measures of change in socialization and collaboration), or (c) the physical domain (e.g., skill to use scientific tools with precision). This study was not intended to examine student learning outcomes, but future studies could include examination of students' higher order thinking and learning outcomes, which could contribute to a more holistic understanding of the benefits of participating in outdoor citizen science projects for both teachers and students.

Implications for Practitioners

Findings from this study could be useful in establishing criteria for excellence in teaching outdoors, something the outdoor working group in the UK recommended for outdoor science education. "Successful implementation of citizen science in school settings requires attention to the potentially competing needs of students, teachers, and professional scientists. Scientific rigor cannot come at the sacrifice of student learning, or vice versa" (Trautmann et al., 2012). Trautmann et al. stressed that students should not do data collection solely as work for scientists without an educational component, nor should data collection be used solely for the purposes of education without providing the data to scientists. Primary participants created additional educational components to enhance participation of their students in the citizen science projects. Blair had her students do online searches for additional information about the state mammal, the gray squirrel. Jackie had her students draw and label trees on her schoolyard in a science journal. Carrie had students write a research report on a species of bird that could be found in the schoolyard.

Teachers participating in this study were able to help their students collect data and engage in inquiry. For example, many EXPLORE teachers allowed students to pose questions related to citizen science data collection in class discussions and then follow up with teacher supported or student independent World-Wide Web searches to find answers to their questions. Follow up inquiry investigations using scientific methods, however, were not done and this type of investigations could be a valuable next step for programs like EXPLORE, if we are to truly carry the fields of science and Environmental Education forward.

Teachers in this study were able to get students outdoors for science fieldwork for the required 15 minutes a week for approximately six to eight weeks, with the exception of Blair and Ruby, who mostly limited their students' outdoor learning time to the opportunity to help conduct four days of squirrel feeding experiments, during which time most students only went outdoors once as a member of a small group either setting up or collecting materials.

However, EXPLORE students gathered data beyond the data required for their citizen science participation in all 13 classrooms, and many teachers, such as for example Cindy, Rorie, Carrie, and Jackie, consistently took their students outdoors for more than 15 minutes at a time for fieldwork, and all primary participants allowed their students to come up with some independent questions about their observations. Even Blair and Ruby, by conducting a scientific study of squirrel feeding preferences, extended the original notion of Project Squirrel, the purpose of which is to record presence data only.

But, in my observations, none of the teachers in this study took time to allow their students to conduct further scientific investigations in the field of their own design. None allowed time in the classroom to conduct student-designed inquiry investigations to answer student-generated questions, with the exception of Jackie.

The learning communities that many EXPLORE teachers formed, when viewed as a model of professional development in partnership with the Arboretum, is a good start for a model of what we need in elementary school science education. This EXPLORE model helped teachers feel comfortable teaching citizen science outdoors. This model would especially benefit teachers who are less comfortable teaching outdoors, if environmental educators and/or experienced interested teachers at their school mentor them, but, this model falls short when we consider the incredible cost-free infinite possibilities for student learning that the outdoor environment offers.

A professional development program based upon self-directed learning built upon the EXPLORE model would need to incorporate the promotion of higher order thinking for teachers and students, and allow time for student-designed inquiry, in order to meet the current urgent needs for improvements in elementary science education. The outdoors is a critical part of this need for improvements because the current ecological problems we face are outdoors. Logically, we need to promote familiarity with the outdoors and the true nature of science outdoors in order to promote innovative solutions. While the EXPLORE program did not promote student open inquiry, not all questions the students had were left unanswered. Some student-generated questions from EXPLORE fieldwork were answered with help and support from their teachers, librarians, and the World-Wide Web.

Computer and reference book searches were conducted with support from librarians, and/or with support from computer/technology specialists. Melodi sent me a link to a school-wide accessible icon, or ‘symbaloo,’ on computers for bird research at her school. This icon was linked to a full-length page of websites (these were bookmarked websites for students to locate information) for bird facts (Email correspondence, April 13, 2015).

Many EXPLORE teachers felt they had learned science content knowledge and skills by doing science along with their students. This finding is promising because research on elementary school teachers shows that they lack science content knowledge (Roth, 2014). And, these experienced teachers as mentors of assistant and student teachers as well as interns, showed in this study that through self-directed learning and by varied models of mentorship, mentor teachers encouraged less experienced teachers to boost their science, environmental, and pedagogical knowledge and skills in science education outdoors. While the varied types of mentorship found in this study alone cannot carry science education outdoors forward far enough to take advantage of all the possible benefits of science education outdoors, this example of variety in EXPLORE is an encouraging start. This model, while meeting the teachers’ most common meaning of success (student engagement), could, with an added component of student-led inquiry, help advance science education in more dimensions (e.g., allow for expanded thinking, allow for marginalized students’ voices to be heard and their needs addressed, and promote citizen science activities and expand participation, time, and quality in these projects).

Primary participants in this study defined successful science teaching outdoors in ways that other practitioners might find helpful. For example, these EXPLORE teachers defined success in teaching outdoors as student engagement, integrated learning, asking and answering questions, drawing their own conclusions, and critical thinking. These teachers' criteria for success, expressed in interviews, are worthy of consideration by any organization that seeks a measure of criteria for excellence in teaching science outdoors. Teachers' definitions of success are useful because all of the primary participants had experience teaching elementary school science, and experience teaching outdoors before Project EXPLORE. Overwhelmingly, teachers agreed that student engagement was a characteristic of successful fieldwork. Cindy stressed the importance of integrated learning as a definition of successful science teaching outdoors, and this concept of integrated instruction may be especially useful in the U.S. where science is not tested in lower grades and often not taught in the elementary school. Teachers managed to teach engaging science outdoors by integrating it with other subjects that were tested (reading and mathematics) in order to meet multiple curricular requirements.

Many of the primary participants' criteria for success are well supported by research in outdoor science learning. Student learning as evidence of success was suggested by both Jackie and Cindy, and is supported by a literature review done by Rickinson et al. (2004). A measure of success Dana suggested, that students are asking questions and looking for answers themselves, is supported by research done by Tomasek

(2006). Blair's definition of success, that students are drawing their own conclusions based upon what they see happening outdoors, also has support from research. Fazio and Karrow (2015) described how, in common places, such as the schoolyard, children can be prompted to engage in critical thinking. Malone (2008) found evidence of a connection between environment based education and critical thinking skills. These teachers who shared their definitions of successful science education outdoors had a variety of ways of describing it, yet each of their respective perspectives was reflected in the research literature.

Also of value to practitioners is the importance that this study's primary participants attributed to their partnership with the Arboretum. All spoke highly of the project and the Arboretum educators. Environmental educators at the Arboretum examined many citizen science programs and then made choices about which programs would be most readily adaptable to K-12 science education and meet curricular requirements for schools. The Arboretum educators also developed lessons to excite, engage and inform students about the content in the citizen science programs. They adapted some of the citizen science data collection sheets for younger children's use, making them easy to understand. For example, Project Squirrel suggests that citizens look for the types of trees where squirrels are spotted. The Arboretum educators expanded upon the idea of identifying tree species and designed worksheets for children that suggest students look for evidence of squirrel habitats, such as dead trees (as a home) and acorns (as a food source). The Project Squirrel data sheet was designed by the Arboretum to be accessible for pre-readers and pre-writers by including drawings that could be circled, and a place to record one hash mark for each time a new squirrel was observed. Data recording sheets such as these could be highly useful to practitioners as a model for how to help young children collect data for this and other citizen science programs.

Teachers in this study found that citizen science makes science accessible, authentic, and engaging, not only for their students, but for them too. This partnership offered successful professional development for practitioners. Components of EXPLORE could be used to model professional development programs for other elementary schools and as a springboard to promote scientific inquiry investigations in the field. From seeking a partner to support their participation in a citizen science program to scaffolding teachers in teaching outdoors, facilitating the first outing and modeling where and how to teach on the school grounds, teachers were able to learn by doing. As experienced teachers, they felt confident enough to become mentors to others, forming learning communities at their schools. Although all of the teachers in this study had taught outdoors before their participation in Project EXPLORE, for intern preservice teachers and student teachers working with them, participation in citizen science was a lesson in how to engage students in science fieldwork. This model of mentorship could help interns and student teachers feel comfortable teaching outdoors when they begin teaching.

Practitioners could use this model of partnerships to incorporate fieldwork and Environmental Education into future school science everywhere. Funding for such partnerships would be needed, but there is a current White House initiative encouraging federal agencies to promote citizen science, and funding will be forthcoming for Environmental Education in K-12 schooling through the new education act, the ESSA

(2015). Also important would be education policy initiatives to accompany this funding that would encourage district administrators and principals to support this type of teacher initiative.

Implications for Researchers

Researchers in science education may be interested in cultural-historical activity theory (CHAT) as it was used in this study (Engeström, 2001). CHAT allowed me to take a holistic view of the teacher in a system context, which in turn allowed me to highlight a variety of teacher innovations and show the many complexities of learning. CHAT is a complex and comprehensive way to analyze data and illuminate data that might have otherwise gone uncovered. In the following paragraphs I describe how the use of CHAT for science education is novel, and how viewing teachers as the subject of the CHAT activity system expands the application of the theory. I go on to describe how giving voice to the teacher viewpoint is also a new direction for research on citizen science as science education.

CHAT and the study of the interrelated elements of the activity system is a relatively new way for researchers to look at science education (Plakitsi, 2013). CHAT appeared in academic literature as a possible methodology for studying science education in 2004 (Roth & Lee, 2007). Research in the field of science education could generate system wide research questions using CHAT that could help us better understand how to broaden and improve science education in communities, especially when focusing on citizen science at the intersection of science and Environmental Education (Wals et al., 2014). In this descriptive case study, the interacting elements of CHAT added a depth of understanding to how citizen science in education works. CHAT highlighted how changes in human behavior or expansive learning (Engeström, 2001) happen as teachers learn to enact citizen science programs. In Engeström's model of CHAT the relationships between all the parts of the activity system triangle (subject, cultural history, artifacts/tools, rules, community, division of labor, object, outcomes, tensions and expansive learning) were not well defined (Bakhurst, 2009). Looking more deeply at the nature of the interrelatedness of elements in the activity system and the varied dimensions of expansive learning could add greatly to our understandings of teacher meanings and teacher learning. Elementary school teachers, by taking the initiative to incorporate citizen science and Environmental Education in science education outdoors in learning communities, could enact change in science education, as Plakitsi (2013) proposed. We can use CHAT to help us understand how the individual and the system can change and grow and how they are linked, and "each specific situation can contribute to a bottom up approach to rethinking science education" (Plakitsi, 2013, p. 3).

Bakhurst (2009) saw it as problematic that activity theory is open to different interpretations, whereas I see this flexibility as a strength of the theory (Engeström, 2001). The ability to incorporate varied views of how change can occur in an activity system offered me as a researcher a variety of ways to approach a critical view of the current state of science education using one framework for data analysis.

While prior CHAT research examined students as the subject in the activity system (Roth & Lee, 2007) in my study I viewed teachers as subjects in their bounded activity systems. Taking on the viewpoint of teachers as the subject of study is a way to broaden CHAT methodology for use in the study of teaching, teacher education and teacher professional development. A study of science teacher induction into a school community placed teachers as the subject in a recent study using CHAT (Saka, Southerland, & Brooks, 2009). This study's view of teachers as the subject in the activity system was a fairly new way of applying the theory, and my study expanded upon this. Both teachers and students were viewed as the subject of the activity system in a recent Ivey and Johnston (2015) study of literacy that utilized CHAT methodology. Incorporating the teachers' viewpoints as well as the students' viewpoints added a greater depth of understanding to Ivey and Johnston's study. Because teachers were the subject in my study, CHAT allowed me to highlight many (as opposed to few) interrelated elements of the meanings teachers made of learning to enact citizen science programs.

This study adds to a new but quickly growing body of research to better understand citizen science and its educational applications, and it helps fill the need for new directions for research on citizen science programs that are specifically designed for both scientific and educational benefits (Bonney, Phillips, Ballard, & Enck, 2016). Finding the most effective ways that people of all ages can learn through the process of participation in citizen science is needed (Bonney et al., 2009). This study contributes to a diversification of this body of research by looking at how teachers describe learning to enact citizen science as an educational tool. This research could act to broaden our understandings of how teachers can learn and the importance of their cultural aspects of learning (Rogoff & Angelillo, 2002). Further research on teachers, about how they learn and master the use of citizen science in education as the drivers of change should be encouraged (Cochran-Smith & Lytle, 2009). Research from many diverse fields using collaborative and integrated endeavors will be needed in the future, noted Bonney et al. (2009), in order fulfill the needs for research in citizen science. “What was once a novel idea--lay people engaging in the scientific enterprise--is becoming mainstream” (Bonney et al., 2016, p. 13).

Researchers in Environmental Education and science teacher professional development in North Carolina may be interested in findings in this study. Information from the questionnaire about teachers’ experiences in nature as a child could act to further validate findings in the field that show that childhood experiences in nature promote environmental action in adults (Chawla & Cushing, 2007: Dillon & Dickie, 2015). Local science teacher professional development researchers in North Carolina may be interested in data gathered on the questionnaire because the questionnaire in this study was designed with some identical questions from a questionnaire administered to all teacher participants in teacher workshops and treks offered by our state natural science museum. Data from this study offers opportunities for comparisons and could situate this single study in a broader context as appropriate. I further describe how this study supports ideas for future research in the next section.

Ideas for Future Research

Based on the findings from this study I have ideas for future research in three areas. The first two areas build directly on this study while the third area would be a new area of research for me. The first area is to examine student learning (versus teacher meaning making) at the elementary school level as students participate in citizen science programs. A second area of research is professional development and how it happens in learning communities, such as those that were formed by teachers participating in Project EXPLORE. A third area is that of studying how scholarly science content becomes teachable content and when, why and how this happens. The process of preparing scholarly science content, the science that scientists understand, to be teachable science content for elementary school students is called didactic transposition (Chevallard, 1999). Each of these areas of proposed future studies are elaborated on in the following paragraphs.

Student Learning Outcomes

The Association for Science's Outdoor Science Working Group (2011) in the UK recommended, "[a] co-ordinated research programme should be developed to further investigate the full range of educational impacts of fieldwork in science" (p. 5). The Outdoor Science Working Group noted there is mounting evidence that fieldwork promotes enthusiasm and motivation to study science, and that it has the potential to positively influence students' eventual choice of science careers. Accordingly, I suggest extending this study over time and including an investigation of students' learning outcomes. The challenge is devising ways to assess outcomes, especially expansive learning outcomes that are not pre-set, because current standardized testing does not align with learning that I found happened in this study. I would ask: What are the learning outcomes for students participating in fieldwork as part of a citizen science activity? What is the impact of fieldwork on the activity system as a whole? Is the use of fieldwork in elementary science education an enduring practice in the schools where primary participants worked? Will it live on after the partnership with the Arboretum ends?

Future studies might include student evaluations to measure all dimensions of learning in a way that aligns with the learning that would be happening outdoors, such as the cognitive, emotional, and physical domains of learning. Evaluations might include tests of cognitive learning outcomes that align with experiences outdoors from science/environmental higher order thinking and knowledge tests, pre and post measures of self-efficacy, or tests of emotional learning via affective measures, measures of changes in socialization and collaboration, and tests of physical learning such as measures of fieldwork skills improvements, or measures of physical health as manifested in days absent from school or the measurement of time outdoors and body fat indexes over time to see if there was a positive correlation between the two measures. In actuality, how to design effective measures of science learning outdoors would be an interesting avenue of study in and of itself.

Teacher Professional Development

Another possible research topic is to examine teachers' proficiency in conducting citizen science projects to help establish pedagogy training and performance level designations (Association for Science Education Outdoor Science Working Group, 2011). Researching if and how teachers continue to teach using citizen science as a tool could contribute to the body of knowledge about teacher learning and professional development. Current research supports the value of learning communities (Cochran-Smith & Lytle, 2009). Experienced teachers in EXPLORE mentored assistant teachers, student teachers, and student interns. They also mentored colleagues, or partnered with colleagues, and closer study of successful collaborations and mentoring could greatly benefit teacher professional development. By synthesizing teachers' meanings, this study is an example of how smaller activity systems may be viewed both as partners and as integral elements of the larger EXPLORE system in data analysis. An even larger study group may be beneficial for better understandings of large systems.

How Scholarly Knowledge Becomes Teachable Knowledge

In EXPLORE, the scholarly knowledge, ornithology (eBird), phenology (Nature's Notebook), and zoology (Project Squirrel), as well as ecology, became teachable knowledge for K-5 students. How this scholarly knowledge became teachable knowledge is something that is often taken for granted. As Chevallard (1988) pointed out, teachers tend to avoid questioning the knowledge they are given to teach. Findings from this study could be used to establish a reference frame for a better understanding of how scholarly knowledge is formulated into teachable knowledge using the theory of didactic transposition, also referred to as the anthropological theory of the didactic (ATD) (Chevallard, 1991; Bosch & Gascón, 2006). This theory originated in mathematics education, but is used now in other disciplines as well (such as science museum education [Achiam, 2014]).

Scholarly knowledge obtained from citizen science projects and other sources was adapted to be teachable knowledge by environmental educators at the Arboretum, and then again by teachers at area public schools. Some sources of scholarly knowledge were scientific studies. Some sources of teachable knowledge were published Environmental

Education lessons, as well as public school curricula suggestions. Scholarly knowledge was de-constructed and re-constructed to transform it into a teachable form (Benavides, 2015). In short, as Chevellard described it, didactic transposition is “[t]he transition from knowledge regarded as a tool to be put to use, to knowledge as something to be taught and learnt, . . . the didactic transposition of knowledge” (Chevallard, 1988, p. 6).

In EXPLORE, students were participating in citizen science research that had not necessarily been designed for elementary school children participants. Teachers designed new ways of doing things that transposed scholarly knowledge into teachable knowledge at the elementary school level (Benavides, 2015). Based on my informal observations, scholarly knowledge was transposed into teachable knowledge for use in elementary school fieldwork in EXPLORE. I created a framework to depict how I saw this transposition, based upon Chevallard’s (1988, 1999) ATD theory. See Figure 22.

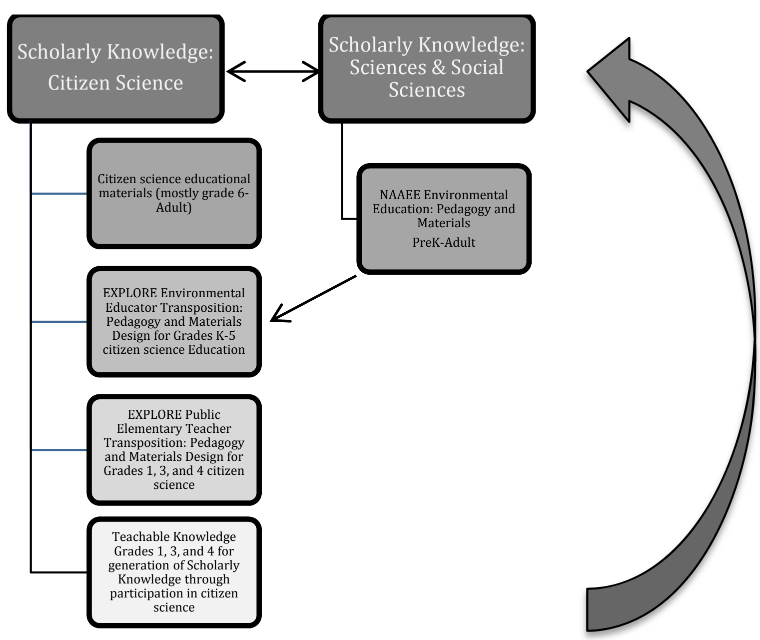


Figure 22. EXPLORE Reference Hierarchy for Didactic Transposition.

Figure 22 shows a hierarchy of academic and scholarly knowledge at the top to teachable knowledge at the bottom. A sequence of steps occurs during this transposition. The following steps represent one route that this transposition may take: (a) Scientists generate academic scholarly knowledge and conduct citizen science projects to gather more data; (b) Citizen science invites the public to collect and share data with scientists and often with the public; (c) Some university/non-profit sponsored citizen science websites offer educational materials to accompany data collection; (d) NAAEE curriculum for Environmental Education K-12 is a teachable knowledge resource; (e) In the case of EXPLORE, the Arboretum environmental educators used some lesson plans from the citizen science websites and adapted educational material for K-12; designed customized K-12 lessons using Environmental Education curriculum knowledge and citizen science educational materials for school visits; designed custom data recording sheets for children; (f) Teachers designed and mastered materials (such as bird templates or data collection sheets) and lessons (integrated with bird projects in Language Arts) to make the citizen science teachable in their school context to their class, lessons that were inclusive of science education and Environmental Education, as well as engaging for their students and themselves; (g) In the case of citizen science, the students' research generates a form of scholarly knowledge (data the students collect); and (h) As shown by the upwards arrow at the right of the framework diagram, that scientific research students generate, a form of scholarly knowledge, goes directly back up to the top of the hierarchy to be later disseminated by scientists. Citizen science in education, when the students are collecting data that will be used to generate scholarly knowledge, is a new way of looking at ATD, as a cycling of scientific scholarly knowledge. This an area of study ripe for investigation as Bosch and Gascón (2006) noted that ATD had become integrated into European educational thought since its introduction by Chevallard (1988) for mathematics, and science education researchers are beginning to explore the theory in their studies.

Questions Remaining

After completion of this study, questions remain that were not answered that would be interesting to investigate. Is partnership (such as schools' partnerships with the Arboretum in this study) key to successful first time implementation of citizen science programs at elementary schools? To better understand this it would be interesting if all citizen science programs commonly used online by teachers could keep track of and identify teachers who upload data, and determine whether (or not) data were collected by the class or by the teacher as an individual. In this way we could compile a large database of teachers who are participating in citizen science programs that require data collection outdoors, and we could better identify how often and how many schoolrooms are involved in science education outdoors. The problem remains, as Bonney et al. (2009) pointed out, that this would be expensive and we would need to think about how such a program could be funded. With new White House initiatives to promote citizen science there may be funding available for programs such as this.

How can we promote citizen science as a way to enact science fieldwork and student inquiry on a larger scale? With the success the Arboretum experienced in getting students outdoors to do science, we should be able to apply what we have learned to be able to implement this model as innovative teacher professional development on a larger scale and promote student inquiry in science fieldwork. We cannot discount the importance of the Arboretum educators in this partnership endeavor. There remain many questions as to exactly how to do this on a larger scale. Taking what we have learned over time in research on science education, citizen science, Environmental Education, and science fieldwork, could we design a larger scale program to support teachers who are interested in learning more about teaching science outdoors and making science engaging for their students?

How could we help teachers who do not have experience teaching outdoors feel comfortable teaching outdoors? Would this require more instruction in teacher education, as well as continued teacher education and professional development?

How could we offer experiences that teach the use of fieldwork, using citizen science as a tool and the outdoors as a platform for learning? The model proposed in this study would start with experienced teachers who had a good amount of experience outdoors as a child, and they could mentor other teachers. To further science learning outdoors for their students, teachers could dedicate time to student-directed scientific inquiry outdoors. If principals and district school administrators support such an effort, then teachers could form learning communities. If state governments seek funding from ESSA (2015) for Environmental Education, there would be support for teachers who take a citizen science initiative to help reform science education. Administrators would need to be educated about the benefits of incorporating fieldwork and Environmental Education into science education. If the benefits of fieldwork to children are generally known, and if fears and dangers are not a hindrance to taking students out into the schoolyard to learn, principals might encourage teachers to use the outdoors as a platform for teaching.

Could the findings from this study and future findings about teachers' personal cultural histories help school administrators know what to look for when hiring teachers at a school where Environmental Education and teaching outdoors is incorporated in the science curriculum? These and many more questions remain to be answered.

Conclusions

Researchers overwhelmingly agree that science education is not well (Roth, 2014). Science education is not currently meeting the demands of the challenges we face as a global society, the damaging effects of global warming (Adams, 2013), ecological degradation (Kelly, 2014), and defaunation (Dirzo et al., 2014). Researchers seldom recognize the tensions teachers deal with day-to-day as important components of education, but I discovered tensions that teachers deal with in this study using CHAT as a framework for analysis. Elementary school teachers lacking science content knowledge and the normative use of shallow standardized vocabulary-focused test-based teaching do not provide opportunities for deeper understandings of the nature of science for all of our students--doing science can (Roth, 2014).

Citizen science could be a remedy for the state of science education, but we may need further research to better understand how, because there is growing evidence according to Bonney et al. (2016) that participation in citizen science promotes public knowledge and understanding of science. "To understand the influences of citizen science on participants, the field needs to employ research methods that capture the depth of participant experiences and perspectives and also can encompass the wide range of projects and activities" (p. 13). Citizen science needs widespread data collection (Bonney et al., 2009), and science education needs fieldwork (Slingsby, 2006). Children need the benefits of learning outdoors, something they are not getting (Louv, 2005).

All participating teachers in this study had a common history in that they all had a significant amount of experience outdoors as children. It only takes 15 more years to educate the next generation of teachers who are in first grade now. Without experiences outdoors that excite them about learning science and deepen their cognitive, physical and emotional knowledge of the natural world, who among them, when they grow up, will even be interested in teaching out there at all?

An encouraging finding in this study comes actually from no finding. Not finding much commonality in teachers' personal cultural histories beyond experience in the outdoors and experience teaching is in and of itself a finding. Not finding teachers using identical pedagogies means there are different ways of approaching educational solutions when enacting citizen science projects outdoors with elementary school students. Primary participants expressed that they had a wide range of prior science knowledge and experience, from zoology fieldwork as an undergraduate Biology major, to no more than high school science as an undergraduate English major. Yet all participants were able to use citizen science to help transform their science instruction by taking their class outdoors and using the unpredictable natural world as a platform for learning science and Environmental Education. They allowed students to generate questions, and if we allow students to go on to investigate answers, this could carry science education further forward.

We are facing global ecological challenges and a declining interest in science among children (Kelly, 2014). We are experiencing a marginalization of both science and Environmental Education at the elementary school level (education that could be useful in addressing global challenges) (Roth, 2014). Citizen science and schoolyard fieldwork may act as a viable remedy for these challenges to science education (Fazio & Karrow, 2015). Successful reforms of science education lie at the classroom level with an effective teacher (Zeidler, 2014). Project EXPLORE offers an innovative model of teacher professional development to help bring this about in a way that addresses many of our concerns about children and science packaged in one initiative. The teachers in this study, in partnership with the Arboretum, all learned to design and master new ways of teaching science and Environmental Education.

The outcomes of expansive learning, knowledge gains, and skills gains became part of the EXPLORE system and changed the interrelated elements in the activity. An expansive cycle of change ensued. Historically, teachers recruited other teachers to join them in EXPLORE and the number of teachers participating in EXPLORE at some schools continued to grow over time. Teachers in this study alluded to the pressures they felt, tensions such as time constraints and the unpredictability of the natural world. Despite tensions such as these, or at least partly because of tensions, they transformed the activity of science teaching for their classes. The simple act of doing citizen science data collection in the schoolyard with students transformed their science teaching. There is mounting evidence in the literature that elementary school teachers are not well prepared to teach science (Appleton, 2007; Roth, 2014). However, the primary participants in this study engaged in many of the pedagogical practices researchers recommended but found lacking in the general teacher population.

Teachers and their principals spoke of, and I observed, pedagogical innovations that were made that were unique to particular classrooms and schoolyards in order to promote beneficial learning outcomes. These pedagogical innovations required complex decision-making, content knowledge, utilizing prior pedagogical knowledge in new places, and original lesson designs that fit the natural space teachers had to work in. Such innovations could serve as a model for future education at the classroom level because they help us as a society address ecological challenges. Student interest in science can either begin or end in elementary school (Carrier et al., 2013). Citizen science projects which were a part of EXPLORE were not only a step towards getting elementary age students to engage in authentic scientific practices, they may be that step outdoors that all of science needs.

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APPENDIX A

SAMPLE DATA UPLOAD REPORT FROM EBIRD

ns Explore Data My eBird Help

[redacted] :es | Sign Out Language

EXPLORE 2015 eBird Data upload verification for focal participant 'Carrie'

tions, locations, and account settings.

Your Life List: 20 Species

Updated 2 sec ago.

Your Stats

	Life	Year	Month
Total Species	20	5	0
Total Checklists	16	1	0
ABA Area Total Ticks	20	5	0

Your Lists

Major Regions Country State/Province County

	Life	Year	Month
World	20	5	0
Western Hemisphere	20	5	0
Eastern Hemisphere	0	0	0
North America	20	5	0
South America	0	0	0
Central America	0	0	0
West Indies	0	0	0
AOU Area	20	5	0
ABA Area	20	5	0
USA Lower 48	20	5	0
Western Palearctic	0	0	0
Europe	0	0	0
Asia	0	0	0
Eurasia	0	0	0
Africa	0	0	0
Southern Africa	0	0	0
Australasia (ABA)	0	0	0

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My Checklists

Summarize My Observations
Create frequency, abundance, and other tables of my observations.

Manage My Checklists
View, edit, print, share or download my checklists.

My Shared Checklists
Checklists that other eBird users have shared with me

Manage My Locations
Edit existing locations

Import Data
Import data from a spreadsheet, database, or birding program.

Manage Imported Data
View, fix, and submit your imported data

Download my Data
Download and save your data on your computer

Manage My Alerts
Modify or view your eBird Alerts

Account Settings

Edit my profile
My eBird Preferences
Manage My Contacts

APPENDIX B

SAMPLE DATA UPLOAD REPORT FROM NATURE'S NOTEBOOK

5259657	2015-03-10	12:00:00 AM	American beech-1	No	Fruits present (10000)	NULL	NULL	Fruits	Fruits	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5259658	2015-03-10	12:00:00 AM	American beech-1	No	Ripe fruit percentage	NULL	NULL	Fruits	Ripe fruits	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5259659	2015-03-10	12:00:00 AM	American beech-1	No	Recent fruit or seed drop (10000)	NULL	NULL	Fruits	Recent fruit or seed drop	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5259660	2015-03-10	12:00:00 AM	red maple-2	No	Breaking leaf buds (10000)	NULL	NULL	Leaves	Breaking leaf buds	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259661	2015-03-10	12:00:00 AM	red maple-2	No	Leaf canopy fullness (dead branch)	NULL	NULL	Leaves	Leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259662	2015-03-10	12:00:00 AM	red maple-2	No	Leaf size	NULL	NULL	Leaves	Increasing leaf size	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259663	2015-03-10	12:00:00 AM	red maple-2	No	Colored leaf percentage	NULL	NULL	Leaves	Colored leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259664	2015-03-10	12:00:00 AM	red maple-2	No	NULL	NULL	NULL	Leaves	Falling leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259665	2015-03-10	12:00:00 AM	red maple-2	No	Flowers and flower buds (10000)	NULL	NULL	Flowers	Flowers or flower buds	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259666	2015-03-10	12:00:00 AM	red maple-2	No	Open flowers percentage	NULL	NULL	Flowers	Open flowers	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259667	2015-03-10	12:00:00 AM	red maple-2	No	Pollen release	NULL	NULL	Flowers	Pollen release	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259668	2015-03-10	12:00:00 AM	red maple-2	No	Fruits present (10000)	NULL	NULL	Fruits	Fruits	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259669	2015-03-10	12:00:00 AM	red maple-2	No	Ripe fruit percentage	NULL	NULL	Fruits	Ripe fruits	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259670	2015-03-10	12:00:00 AM	red maple-2	No	Recent fruit or seed drop (10000)	NULL	NULL	Fruits	Recent fruit or seed drop	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259671	2015-03-10	12:00:00 AM	white oak-1	No	Breaking leaf buds (10000)	NULL	NULL	Leaves	Breaking leaf buds	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259672	2015-03-10	12:00:00 AM	white oak-1	No	Leaf canopy fullness (dead branch)	NULL	NULL	Leaves	Leaves	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259673	2015-03-10	12:00:00 AM	white oak-1	No	Leaf size	NULL	NULL	Leaves	Increasing leaf size	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259674	2015-03-10	12:00:00 AM	white oak-1	No	Colored leaf percentage	NULL	NULL	Leaves	Colored leaves	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259675	2015-03-10	12:00:00 AM	white oak-1	No	NULL	NULL	NULL	Leaves	Falling leaves	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259676	2015-03-10	12:00:00 AM	white oak-1	No	Flowers and flower buds (10000)	NULL	NULL	Flowers	Flowers or flower buds	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259677	2015-03-10	12:00:00 AM	white oak-1	No	Open flowers percentage	NULL	NULL	Flowers	Open flowers	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259678	2015-03-10	12:00:00 AM	white oak-1	No	Pollen release	NULL	NULL	Flowers	Pollen release	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259679	2015-03-10	12:00:00 AM	white oak-1	No	Fruits present (10000)	NULL	NULL	Fruits	Fruits	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259680	2015-03-10	12:00:00 AM	white oak-1	No	Ripe fruit percentage	NULL	NULL	Fruits	Ripe fruits	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259681	2015-03-10	12:00:00 AM	white oak-1	No	Recent fruit or seed drop (10000)	NULL	NULL	Fruits	Recent fruit or seed drop	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259682	2015-03-13	12:00:00 AM	red maple-1	No	Breaking leaf buds (10000)	NULL	NULL	Leaves	Breaking leaf buds	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259683	2015-03-13	12:00:00 AM	red maple-1	No	Leaf canopy fullness (dead branch)	NULL	NULL	Leaves	Leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259684	2015-03-13	12:00:00 AM	red maple-1	No	Leaf size	NULL	NULL	Leaves	Increasing leaf size	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259685	2015-03-13	12:00:00 AM	red maple-1	No	Colored leaf percentage	NULL	NULL	Leaves	Colored leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259686	2015-03-13	12:00:00 AM	red maple-1	No	NULL	NULL	NULL	Leaves	Falling leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259687	2015-03-13	12:00:00 AM	red maple-1	No	Flowers and flower buds (10000)	NULL	NULL	Flowers	Flowers or flower buds	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259688	2015-03-13	12:00:00 AM	red maple-1	No	Open flowers percentage	NULL	NULL	Flowers	Open flowers	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259689	2015-03-13	12:00:00 AM	red maple-1	No	Pollen release	NULL	NULL	Flowers	Pollen release	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259690	2015-03-13	12:00:00 AM	red maple-1	No	Fruits present (10000)	NULL	NULL	Fruits	Fruits	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259691	2015-03-13	12:00:00 AM	red maple-1	No	Ripe fruit percentage	NULL	NULL	Fruits	Ripe fruits	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259692	2015-03-13	12:00:00 AM	red maple-1	No	Recent fruit or seed drop (10000)	NULL	NULL	Fruits	Recent fruit or seed drop	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259693	2015-03-13	12:00:00 AM	American beech-1	No	Breaking leaf buds (10000)	NULL	NULL	Leaves	Breaking leaf buds	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5259694	2015-03-13	12:00:00 AM	American beech-1	No	Leaf canopy fullness (dead branch)	NULL	NULL	Leaves	Leaves	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5259695	2015-03-13	12:00:00 AM	American beech-1	No	Leaf size	NULL	NULL	Leaves	Increasing leaf size	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5259696	2015-03-13	12:00:00 AM	American beech-1	No	Colored leaf percentage	NULL	NULL	Leaves	Colored leaves	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5259697	2015-03-13	12:00:00 AM	American beech-1	No	NULL	NULL	NULL	Leaves	Falling leaves	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5259698	2015-03-13	12:00:00 AM	American beech-1	No	Flowers and flower buds (10000)	NULL	NULL	Flowers	Flowers or flower buds	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5259699	2015-03-13	12:00:00 AM	American beech-1	No	Open flowers percentage	NULL	NULL	Flowers	Open flowers	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5259700	2015-03-13	12:00:00 AM	American beech-1	No	Fruits present (10000)	NULL	NULL	Fruits	Fruits	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5259701	2015-03-13	12:00:00 AM	American beech-1	No	Ripe fruit percentage	NULL	NULL	Fruits	Ripe fruits	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5259702	2015-03-13	12:00:00 AM	American beech-1	No	Recent fruit or seed drop (10000)	NULL	NULL	Fruits	Recent fruit or seed drop	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5259703	2015-03-13	12:00:00 AM	red maple-2	No	Breaking leaf buds (10000)	NULL	NULL	Leaves	Breaking leaf buds	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259704	2015-03-13	12:00:00 AM	red maple-2	No	Leaf canopy fullness (dead branch)	NULL	NULL	Leaves	Leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259705	2015-03-13	12:00:00 AM	red maple-2	No	Leaf size	NULL	NULL	Leaves	Increasing leaf size	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259706	2015-03-13	12:00:00 AM	red maple-2	No	Colored leaf percentage	NULL	NULL	Leaves	Colored leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259707	2015-03-13	12:00:00 AM	red maple-2	No	NULL	NULL	NULL	Leaves	Falling leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259708	2015-03-13	12:00:00 AM	red maple-2	No	Flowers and flower buds (10000)	NULL	NULL	Flowers	Flowers or flower buds	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259709	2015-03-13	12:00:00 AM	red maple-2	No	Open flowers percentage	NULL	NULL	Flowers	Open flowers	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259710	2015-03-13	12:00:00 AM	red maple-2	No	Pollen release	NULL	NULL	Flowers	Pollen release	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259711	2015-03-13	12:00:00 AM	red maple-2	No	Fruits present (10000)	NULL	NULL	Fruits	Fruits	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259712	2015-03-13	12:00:00 AM	red maple-2	No	Ripe fruit percentage	NULL	NULL	Fruits	Ripe fruits	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259713	2015-03-13	12:00:00 AM	red maple-2	No	Recent fruit or seed drop (10000)	NULL	NULL	Fruits	Recent fruit or seed drop	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5259714	2015-03-13	12:00:00 AM	white oak-1	No	Breaking leaf buds (10000)	NULL	NULL	Leaves	Breaking leaf buds	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259715	2015-03-13	12:00:00 AM	white oak-1	No	Leaf canopy fullness (dead branch)	NULL	NULL	Leaves	Leaves	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259716	2015-03-13	12:00:00 AM	white oak-1	No	Leaf size	NULL	NULL	Leaves	Increasing leaf size	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259717	2015-03-13	12:00:00 AM	white oak-1	No	Colored leaf percentage	NULL	NULL	Leaves	Colored leaves	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259718	2015-03-13	12:00:00 AM	white oak-1	No	NULL	NULL	NULL	Leaves	Falling leaves	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259719	2015-03-13	12:00:00 AM	white oak-1	No	Flowers and flower buds (10000)	NULL	NULL	Flowers	Flowers or flower buds	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259720	2015-03-13	12:00:00 AM	white oak-1	No	Open flowers percentage	NULL	NULL	Flowers	Open flowers	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259721	2015-03-13	12:00:00 AM	white oak-1	No	Pollen release	NULL	NULL	Flowers	Pollen release	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259722	2015-03-13	12:00:00 AM	white oak-1	No	Fruits present (10000)	NULL	NULL	Fruits	Fruits	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5259723	2015-03-13	12:00:00 AM	white oak-1	No	Ripe fruit percentage	NULL	NULL	Fruits	Ripe fruits	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN

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5259724	2015-03-13	12:00:00 AM	white oak-1	No	Recent fruit or seed drop (10000)	NULL	NULL	Fruits	Recent fruit or seed drop	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5361941	2015-03-26	12:00:00 AM	red maple-1	No	Breaking leaf buds (10000)	NULL	NULL	Leaves	Breaking leaf buds	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361942	2015-03-26	12:00:00 AM	red maple-1	No	Leaf canopy fullness (dead branch)	NULL	NULL	Leaves	Leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361943	2015-03-26	12:00:00 AM	red maple-1	No	Leaf size	NULL	NULL	Leaves	Increasing leaf size	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361944	2015-03-26	12:00:00 AM	red maple-1	No	Colored leaf percentage	NULL	NULL	Leaves	Colored leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361945	2015-03-26	12:00:00 AM	red maple-1	No	NULL	NULL	NULL	Leaves	Falling leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361946	2015-03-26	12:00:00 AM	red maple-1	No	Flowers and flower buds (10000)	NULL	NULL	Flowers	Flowers or flower buds	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361947	2015-03-26	12:00:00 AM	red maple-1	No	Open flowers percentage	NULL	NULL	Flowers	Open flowers	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361948	2015-03-26	12:00:00 AM	red maple-1	No	Pollen release	NULL	NULL	Flowers	Pollen release	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361949	2015-03-26	12:00:00 AM	red maple-1	No	Fruits present (10000)	NULL	NULL	Fruits	Fruits	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361950	2015-03-26	12:00:00 AM	red maple-1	No	Ripe fruit percentage	NULL	NULL	Fruits	Ripe fruits	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361951	2015-03-26	12:00:00 AM	red maple-1	No	Recent fruit or seed drop (10000)	NULL	NULL	Fruits	Recent fruit or seed drop	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361952	2015-03-26	12:00:00 AM	American beech-1	No	Breaking leaf buds (10000)	NULL	NULL	Leaves	Breaking leaf buds	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5361953	2015-03-26	12:00:00 AM	American beech-1	No	Leaf canopy fullness (dead branch)	NULL	NULL	Leaves	Leaves	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5361954	2015-03-26	12:00:00 AM	American beech-1	No	Leaf size	NULL	NULL	Leaves	Increasing leaf size	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5361955	2015-03-26	12:00:00 AM	American beech-1	No	Colored leaf percentage	NULL	NULL	Leaves	Colored leaves	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5361956	2015-03-26	12:00:00 AM	American beech-1	No	NULL	NULL	NULL	Leaves	Falling leaves	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5361957	2015-03-26	12:00:00 AM	American beech-1	No	Flowers and flower buds (10000)	NULL	NULL	Flowers	Flowers or flower buds	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5361958	2015-03-26	12:00:00 AM	American beech-1	No	Open flowers percentage	NULL	NULL	Flowers	Open flowers	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5361959	2015-03-26	12:00:00 AM	American beech-1	No	Fruits present (10000)	NULL	NULL	Fruits	Fruits	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5361960	2015-03-26	12:00:00 AM	American beech-1	No	Ripe fruit percentage	NULL	NULL	Fruits	Ripe fruits	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5361961	2015-03-26	12:00:00 AM	American beech-1	No	Recent fruit or seed drop (10000)	NULL	NULL	Fruits	Recent fruit or seed drop	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5361962	2015-03-26	12:00:00 AM	red maple-2	No	Breaking leaf buds (10000)	NULL	NULL	Leaves	Breaking leaf buds	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361963	2015-03-26	12:00:00 AM	red maple-2	No	Leaf canopy fullness (dead branch)	NULL	NULL	Leaves	Leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361964	2015-03-26	12:00:00 AM	red maple-2	No	Leaf size	NULL	NULL	Leaves	Increasing leaf size	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361965	2015-03-26	12:00:00 AM	red maple-2	No	Colored leaf percentage	NULL	NULL	Leaves	Colored leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361966	2015-03-26	12:00:00 AM	red maple-2	No	NULL	NULL	NULL	Leaves	Falling leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361967	2015-03-26	12:00:00 AM	red maple-2	No	Flowers and flower buds (10000)	NULL	NULL	Flowers	Flowers or flower buds	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361968	2015-03-26	12:00:00 AM	red maple-2	No	Open flowers percentage	NULL	NULL	Flowers	Open flowers	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361969	2015-03-26	12:00:00 AM	red maple-2	No	Pollen release	NULL	NULL	Flowers	Pollen release	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361970	2015-03-26	12:00:00 AM	red maple-2	No	Fruits present (10000)	NULL	NULL	Fruits	Fruits	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361971	2015-03-26	12:00:00 AM	red maple-2	No	Ripe fruit percentage	NULL	NULL	Fruits	Ripe fruits	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361972	2015-03-26	12:00:00 AM	red maple-2	No	Recent fruit or seed drop (10000)	NULL	NULL	Fruits	Recent fruit or seed drop	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361973	2015-03-26	12:00:00 AM	white oak-1	Yes	Breaking leaf buds (10000)	11 to 100	NULL	Leaves	Breaking leaf buds	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5361974	2015-03-26	12:00:00 AM	white oak-1	No	Leaf canopy fullness (dead branch)	NULL	NULL	Leaves	Leaves	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5361975	2015-03-26	12:00:00 AM	white oak-1	No	Leaf size	NULL	NULL	Leaves	Increasing leaf size	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5361976	2015-03-26	12:00:00 AM	white oak-1	No	Colored leaf percentage	NULL	NULL	Leaves	Colored leaves	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5361977	2015-03-26	12:00:00 AM	white oak-1	No	NULL	NULL	NULL	Leaves	Falling leaves	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5361978	2015-03-26	12:00:00 AM	white oak-1	No	Flowers and flower buds (10000)	NULL	NULL	Flowers	Flowers or flower buds	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5361979	2015-03-26	12:00:00 AM	white oak-1	No	Open flowers percentage	NULL	NULL	Flowers	Open flowers	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5361980	2015-03-26	12:00:00 AM	white oak-1	No	Pollen release	NULL	NULL	Flowers	Pollen release	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5361981	2015-03-26	12:00:00 AM	white oak-1	No	Fruits present (10000)	NULL	NULL	Fruits	Fruits	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5361982	2015-03-26	12:00:00 AM	white oak-1	No	Ripe fruit percentage	NULL	NULL	Fruits	Ripe fruits	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5361983	2015-03-26	12:00:00 AM	white oak-1	No	Recent fruit or seed drop (10000)	NULL	NULL	Fruits	Recent fruit or seed drop	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5361984	2015-03-31	12:00:00 AM	red maple-1	Yes	Breaking leaf buds (10000)	11 to 100	NULL	Leaves	Breaking leaf buds	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361985	2015-03-31	12:00:00 AM	red maple-1	No	Leaf canopy fullness (dead branch)	NULL	NULL	Leaves	Leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361986	2015-03-31	12:00:00 AM	red maple-1	No	Leaf size	NULL	NULL	Leaves	Increasing leaf size	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361987	2015-03-31	12:00:00 AM	red maple-1	No	Colored leaf percentage	NULL	NULL	Leaves	Colored leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361988	2015-03-31	12:00:00 AM	red maple-1	No	NULL	NULL	NULL	Leaves	Falling leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361989	2015-03-31	12:00:00 AM	red maple-1	No	Flowers and flower buds (10000)	NULL	NULL	Flowers	Flowers or flower buds	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361990	2015-03-31	12:00:00 AM	red maple-1	No	Open flowers percentage	NULL	NULL	Flowers	Open flowers	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361991	2015-03-31	12:00:00 AM	red maple-1	No	Pollen release	NULL	NULL	Flowers	Pollen release	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361992	2015-03-31	12:00:00 AM	red maple-1	No	Fruits present (10000)	NULL	NULL	Fruits	Fruits	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361993	2015-03-31	12:00:00 AM	red maple-1	No	Ripe fruit percentage	NULL	NULL	Fruits	Ripe fruits	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361994	2015-03-31	12:00:00 AM	red maple-1	No	Recent fruit or seed drop (10000)	NULL	NULL	Fruits	Recent fruit or seed drop	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5361995	2015-03-31	12:00:00 AM	American beech-1	No	Breaking leaf buds (10000)	NULL	NULL	Leaves	Breaking leaf buds	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5361996	2015-03-31	12:00:00 AM	American beech-1	No	Leaf canopy fullness (dead branch)	NULL	NULL	Leaves	Leaves	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5361997	2015-03-31	12:00:00 AM	American beech-1	No	Leaf size	NULL	NULL	Leaves	Increasing leaf size	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5361998	2015-03-31	12:00:00 AM	American beech-1	No	Colored leaf percentage	NULL	NULL	Leaves	Colored leaves	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5361999	2015-03-31	12:00:00 AM	American beech-1	No	NULL	NULL	NULL	Leaves	Falling leaves	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5362000	2015-03-31	12:00:00 AM	American beech-1	No	Flowers and flower buds (10000)	NULL	NULL	Flowers	Flowers or flower buds	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5362001	2015-03-31	12:00:00 AM	American beech-1	No	Open flowers percentage	NULL	NULL	Flowers	Open flowers	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5362002	2015-03-31	12:00:00 AM	American beech-1	No	Fruits present (10000)	NULL	NULL	Fruits	Fruits	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5362003	2015-03-31	12:00:00 AM	American beech-1	No	Ripe fruit percentage	NULL	NULL	Fruits	Ripe fruits	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5362004	2015-03-31	12:00:00 AM	American beech-1	No	Recent fruit or seed drop (10000)	NULL	NULL	Fruits	Recent fruit or seed drop	Fagus grandifolia	American beech	36.13714	-81.1098	school	340	USANPN
5362005	2015-03-31	12:00:00 AM	red maple-2	Yes	Breaking leaf buds (10000)	11 to 100	NULL	Leaves	Breaking leaf buds	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5362006	2015-03-31	12:00:00 AM	red maple-2	No	Leaf canopy fullness (dead branch)	NULL	NULL	Leaves	Leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5362007	2015-03-31	12:00:00 AM	red maple-2	No	Leaf size	NULL	NULL	Leaves	Increasing leaf size	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5362008	2015-03-31	12:00:00 AM	red maple-2	No	Colored leaf percentage	NULL	NULL	Leaves	Colored leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5362009	2015-03-31	12:00:00 AM	red maple-2	No	NULL	NULL	NULL	Leaves	Falling leaves	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5362010	2015-03-31	12:00:00 AM	red maple-2	No	Flowers and flower buds (10000)	NULL	NULL	Flowers	Flowers or flower buds	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5362011	2015-03-31	12:00:00 AM	red maple-2	No	Open flowers percentage	NULL	NULL	Flowers	Open flowers	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5362012	2015-03-31	12:00:00 AM	red maple-2	No	Pollen release	NULL	NULL	Flowers	Pollen release	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5362013	2015-03-31	12:00:00 AM	red maple-2	No	Fruits present (10000)	NULL	NULL	Fruits	Fruits	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5362014	2015-03-31	12:00:00 AM	red maple-2	No	Ripe fruit percentage	NULL	NULL	Fruits	Ripe fruits	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5362015	2015-03-31	12:00:00 AM	red maple-2	No	Recent fruit or seed drop (10000)	NULL	NULL	Fruits	Recent fruit or seed drop	Acer rubrum	red maple	36.13714	-81.1098	school	340	USANPN
5362016	2015-03-31	12:00:00 AM	white oak-1	Yes	Breaking leaf buds (10000)	101 to 1,000	NULL	Leaves	Breaking leaf buds	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5362017	2015-03-31	12:00:00 AM	white oak-1	No	Leaf canopy fullness (dead branch)	NULL	NULL	Leaves	Leaves	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5362018	2015-03-31	12:00:00 AM	white oak-1	No	Leaf size	NULL	NULL	Leaves	Increasing leaf size	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5362019	2015-03-31	12:00:00 AM	white oak-1	No	Colored leaf percentage	NULL	NULL	Leaves	Colored leaves	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5362020	2015-03-31	12:00:00 AM	white oak-1	No	NULL	NULL	NULL	Leaves	Falling leaves	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5362021	2015-03-31	12:00:00 AM	white oak-1	No	Flowers and flower buds (10000)	NULL	NULL	Flowers	Flowers or flower buds	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN

5362022	2015-03-31	12:00:00 AM	white oak-1	No	Open flowers percentage	NULL	NULL	Flowers	Open flowers	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5362023	2015-03-31	12:00:00 AM	white oak-1	No	Pollen release	NULL	NULL	Flowers	Pollen release	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5362024	2015-03-31	12:00:00 AM	white oak-1	No	Fruits present (10000)	NULL	NULL	Fruits	Fruits	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5362025	2015-03-31	12:00:00 AM	white oak-1	No	Ripe fruit percentage	NULL	NULL	Fruits	Ripe fruits	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN
5362026	2015-03-31	12:00:00 AM	white oak-1	No	Recent fruit or seed drop (10000)	NULL	NULL	Fruits	Recent fruit or seed drop	Quercus alba	white oak	36.13714	-81.1098	school	340	USANPN

APPENDIX C

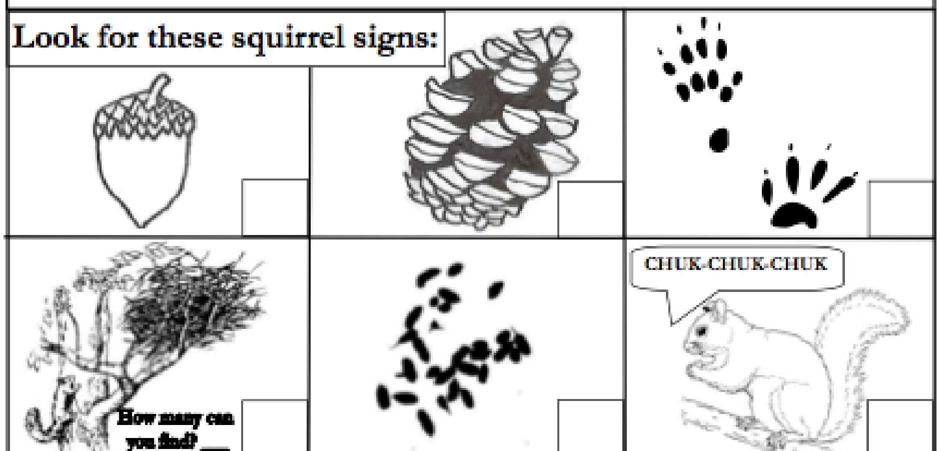
PROJECT SQUIRREL DATA COLLECTION SHEET FOR YOUNGER GRADES

Project Squirrel

Date: _______ Time: _______ Zip Code:_________-________

Describe Setting:

Look for these squirrel signs:



Number of Squirrels:

Gray Squirrels:

Total Number:

Submit data at http://www.projectsquirrel.org/

Types of Trees Present		**Yes, No, or Not Sure**
Nut-bearing	Walnut, Oak, Hickory	
Seed-bearing	Elm, Maple, Locust	
Fruit-bearing	Crabapple, ginkgo, Hawthorn	
Tiny-seeded	Cottonwood, willow, ash	
Coniferous	Pine, Spruce, Fir	

The North Carolina Arboretum

North Carolina GlaxoSmithKline Foundation

APPENDIX D

TEACHER (PRIMARY PARTICIPANT) QUESTIONNAIRE

UNIVERSITY OF NORTH CAROLINA AT GREENSBORO
GRADUATE RESEARCH

Teacher Name:		**Email:**	**Tel:**
Date:	**Name of School:**		

County: ____

School Address ____

State: ______________________ **City:** ______________________

1. What grade do you teach now?

- ❑ Kindergarten
- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 4
- ❑ 5

2. What grades have you taught or served? (Please check all that apply.)

- ❑ Kindergarten
- ❑ 1
- ❑ 2
- ❑ 3
- ❑ 4
- ❑ 5
- ❑ Other *(Please specify …)* ______________

3. How many years have you been teaching? _____ years

4. What subject areas do you teach? ____

____

5. Approximately how many students do you teach on a yearly basis?
______# of students

6. How would you describe the school where you currently teach?

- ❑ Urban
- ❑ Suburban
- ❑ Rural
- ❑ Other (Please specify) ______________________

7. Is your school Title I?

- ❑ Yes
- ❑ No

8. What percentage of your students had little to no outdoor experience before Project EXPLORE?

- ❑ 0-25%
- ❑ 26-50%
- ❑ 51-75%
- ❑ 75-100%

9. How often do you incorporate the outdoors into your teaching (do not include recess time)?

- ❑ Never
- ❑ Rarely (~1 time per year)
- ❑ Occasionally (~1 time per month)
- ❑ Frequently (≥1 time per week)

10. How would you describe your experience in and knowledge of the natural world?

- ❑ Very little experience in nature
- ❑ Some experience in nature
- ❑ A good deal of experience in nature
- ❑ Extensive experience in nature

Please describe your current experience and knowledge of the natural world:

____

____

____

____

11. How would you describe your experiences in nature as a child?

- ❑ Very little experience in nature
- ❑ Some experience in nature
- ❑ A good deal of experience in nature
- ❑ Extensive experience in nature

Please describe your experiences in nature as a child:

____

____

____

____

____

12. How would you describe the area where you grew up as a child?

- ❑ Urban
- ❑ Suburban
- ❑ Rural
- ❑ Other (Please specify) ____________________

13. How would you describe your race?

- ❑ White
- ❑ Black
- ❑ Hispanic
- ❑ Pacific Islander
- ❑ Native American Indian
- ❑ Asian
- ❑ Mixed Race
- ❑ Other (Please specify) ____________________

14. How would you describe your family income level *when you were a child*?

- ❑ Low Income
- ❑ Middle Class
- ❑ High Income
- ❑ Other (Please specify ____________)

15. How would you describe your family income level *now*?

- ❑ Low Income
- ❑ Middle Class
- ❑ High Income
- ❑ Other (Please specify ____________)

16. What is the level of your highest educational degree earned?

- ❑ High School
- ❑ Undergraduate
- ❑ Graduate
- ❑ PhD
- ❑ Other (Please specify ____________)

17. What was your major? (Please specify ____)

18. Do you have state Environmental Education Certification?
____

19. Were you exposed to Environmental Education in your teacher education program? __________________

20. How long have you participated in Project EXPLORE?

- ❑ 1 school year
- ❑ 2 school years

21. If this is your second year as a participant in Project EXPLORE are you a mentor for first year teachers?

- ❑ yes
- ❑ no

22. Please describe your first experience with Project EXPLORE (Arboretum educator(s) first visit to your school):

____

____

____

____

____

23. How did you find out about Project EXPLORE?

- ❑ From the North Carolina Arboretum
- ❑ From my school administration
- ❑ From a colleague
- ❑ Other (Please specify _______________)

24. During the previous year, how many professional development (PD) workshops about science/environmental issues have you participated in (not including EXPLORE)?

- ❑ 0-1 workshops
- ❑ 2-3 workshops
- ❑ 4-5 workshops
- ❑ 6+ workshops

Please describe any workshops about science/environmental issues you have participated in in the past:

____

____

____

____

25. Please check the source of funding that paid for these PD workshops:

- ❑ Staff development fund
- ❑ Self
- ❑ School
- ❑ Other (Please specify _______________)

26. Please specify the organization that provided the workshop(s):

- ❑ NSTA
- ❑ State EE organization
- ❑
- ❑ Other (Please specify _______________

27. How supportive is your school community of your teaching science outdoors?

- ❑ Not supportive
- ❑ Somewhat supportive
- ❑ Very supportive
- ❑ Other (Please specify _______________

28. How supportive is Project EXPLORE is of your teaching science outdoors?

- ❑ Not supportive
- ❑ Somewhat supportive
- ❑ Very supportive
- ❑ Other (Please specify _______________

29. What and how often do you teach outdoors?

30. We welcome additional comments about how EXPLORE may support your learning to teach science outdoors with an Environmental Education component:

Please return to or send to:

Aerin W. Benavides, UNCG, 361 School of Education Building,
1300 Spring Garden Street, P.O. Box 26170, Greensboro, NC 27402

APPENDIX E

EXPLORE INITIAL INTERVIEW PROTOCOL

Information for the interviewer: Each interview should last from 35 to 45 minutes.

Part I. Key Informants Interview

Introduction to the key informant research participant: I would like to talk with you so that I can learn more about your knowledge of Project EXPLORE and the participating teachers. I am recording our conversation so that I do not miss anything important. Is that ok with you? Talk as much as you want about each question. I want to better understand the process of teachers learning to teach science outdoors. Do you have any questions before we begin? (If no questions, proceed.)

[Interviewer: This is a *semi-structured* interview protocol.]

1. What do you know about Project EXPLORE?

2. What changes have you noticed in the teacher from her participation in Project EXPLORE?
[Interviewer: Probe "describe," "why."]

3. What supports did teachers receive in order to participate in Project EXPLORE? Do teachers receive other support for learning to teach science outdoors? If so, please describe.
[Interviewer: Probe "why."]

4. Describe the community where you work/teach.

5. Describe any similar projects to Project EXPLORE that your community has had in the past.

6. Is there anything else you would like to tell me about a teacher's experiences learning to teach science outdoors with Project EXPLORE?

Part II. Teacher Initial Interview

Introduction to the teacher research participant: I would like to talk with you so that I can learn more about your thoughts and feelings about learning to teach science outdoors as a participant in Project EXPLORE. I am recording our conversation so that I do not miss anything important. Is that ok with you? Talk as much as you want about each question. I want to better understand the process of your learning to teach science outdoors. Do you have any questions before we begin? (If no questions, proceed.)

[Interviewer: Review teacher questionnaire before interview. This is a *semi-structured* interview protocol. Ask the following questions in order, and if the interviewee in an answer to a prior question has already answered one of the questions, do not ask it of them again. Seek vivid descriptions and great detail in the answers.]

A. Teacher interview questions:

1. First, I'd like you to just talk about what got you interested in Project EXPLORE.
    [Interviewer: can probe by saying, "Tell me more about . . ."]

2. What did you, or do you expect to get out of participation in Project EXPLORE
[Interviewer: What is (are) the purpose or purpose(s) for doing this?]

3. What do you like best about Project EXPLORE? Least?
    [Probe: Why?]

4. Think back to before you participated in Project EXPLORE, did you teach differently?

5 If yes: What has it been like, changing how you teach as a participant in Project

EXPLORE?

If no: Tell me about how you taught before Project EXPLORE.

6. Are you satisfied with the change (if teacher has changed) in teaching curriculum for science, teaching outdoors? Can you talk about that?
7. What do you see as the major impact(s) on the students of the Project EXPLORE

program?

8. What do you see as helpful to students' learning in the activity of science education outdoors?
[Interviewer: This can be content knowledge, prior knowledge, pedagogical, mental, or physical tools such as data collection sheets or binoculars. Probe: How? Why?]
9. What do you see are the challenges to teaching science outdoors?

10. Were these challenges you foresaw? Were there any challenges you thought you were going to have but didn't have? (Explain.)

11. Do you have any ongoing concerns about teaching science outdoors? Do you have any ongoing concerns about any changes you have made in the way you teach? (Explain.)

12. Is there anything you plan to do differently in the future?

13. Have any of your relationships with students, colleagues or others changed through participation in Project EXPLORE?

14. Is there anything else you'd like to tell me about the process of learning to teach science outdoors?

15. Would you advise others to participate in Project EXPLORE? Why or why not?

16. What advice would you give them?

17. Is there any advice you would give administrators about how to support this sort of instruction?

18. What about next year? Do you plan to make any further changes? Is there anything new you would like to learn or think about?

Part III. Teacher Post Observation Interview

Introduction to the teacher research participant: I would like to talk with you so that I can learn more about your thoughts and feelings about learning to teach science outdoors as a participant in Project EXPLORE. I am recording our conversation so that I do not miss anything important. Is that ok with you? Talk as much as you want about each question. I want to better understand the process of your learning to teach science outdoors. Do you have any questions before we begin? (If no questions, proceed.)

[Interviewer: Review teacher questionnaire and first interview transcript before observation and interview. This is an *open-ended* interview protocol.]

Reflecting upon your teaching today, how does it relate to what you have learned from Project EXPLORE?

[Probe: Why?]

How does your teaching today fit in with your purposes for participating in Project

EXPLORE?

[Probe: "Why?" Or, "Can you tell me more about…"]

Thank you for your support of this research.

Part IV. Teacher Final Interview

Introduction to the teacher research participant: I would like to talk with you so that I can learn more about your thoughts and feelings about learning to teach science outdoors as a participant in Project EXPLORE. I am recording our conversation so that I do not miss anything important. Is that ok with you? Talk as much as you want about each question. I want to better understand the process of your learning to teach science outdoors. Do you have any questions before we begin? (If no questions, proceed.)

[Interviewer: This is a *semi-structured* interview protocol.]

1. First, I'd like you to just talk about what you have learned participating in Project EXPLORE.

[Interviewer: can probe by saying, "Tell me more about . . ."]

2. Think back to our first interview, how have you changed since then?

3. What do you see now was the purpose of participating in Project EXPLORE?

4. What do you see as different now from when we first talked at the beginning of the semester?

5 Are you satisfied with this year's science teaching outdoors? Can you talk about that?

6. What do you see as the major impact(s) on the students of the Project EXPLORE program now that you have finished data collection for the year?

7. What do you see as most helpful to students' learning in the activity of science education outdoors? (This can be content knowledge, prior knowledge, pedagogical, mental, or physical tools such as data collection sheets or binoculars) Probe: How? Why?

8. What do you see are the challenges to teaching science outdoors in the future?

9. Do you have any concerns about teaching science outdoors in the future? (Explain.)

10. Is there anything you plan to do differently in the future?

11. Have any of your relationships with students, colleagues or others changed through participation in Project EXPLORE?

12. What do you like best about Project EXPLORE? Least?
    [Interviewer Probe: Why?]

13. Is there anything else you'd like to tell me about the process of learning to teach science outdoors?

14. Would you advise others to participate in Project EXPLORE? Why or why not?

15. What advice would you give them now you have completed your (first/second) year?

16. Is there any advice you would give administrators about how to support this sort of instruction?

17. Is there anything new you would like to learn or think about?

Thank you for your support of this research.

APPENDIX F

CHAT RESEARCH ALIGNMENT INSTRUMENT

Research Instrument	Cultural History	Activity System Overall	Subject (Teacher)	Object	Artifacts	Tools	Rules	Community	Division of Labor	Outcome
Questionnaire	Past teaching experience; past experience in natural world; frequency teaching outdoors; geographical area where spent childhood; family income level as child; past exposure to EE certif.; first visit of Arboretum educators; how found EXPLORE?; past PD workshops; Additional comments	What do teachers teach outdoors? How often? Additional comments	Name; job; current experience and knowledge of natural world; race; income level; education level; major; EE certif. Y or N?; mentor Y or N?; Additional comments	Additional comments	Additional comments	Additional comments	Additional comments	School location; economic status of students; students' past outdoor experience; who funded PD workshops?; school support for teaching science outdoors?; EXPLORE support for teaching outdoors; Additional comments	Additional comments	Additional comments
Initial Interview	What got you interested in EXPLORE? How did you teach before EXPLORE? What are your supports/ challenges/ concerns to teaching science outdoors? Additional comments	What do you like best about EXPLORE? Least?; What is it like changing how you teach? What are your supports/ challenges/ concerns to teaching science outdoors? Additional comments	What are your supports/ challenges/ concerns to teaching science outdoors? Additional comments	What do you expect to get out of EXPLORE?; What is the major impact on the students? What are your supports challenges/ concerns to teaching science outdoors?	What are your supports/ challenges/ concerns to teaching science outdoors? Additional comments	What are your supports/ challenges/ concerns to teaching science outdoors? Additional comments	What are your supports/ challenges/ concerns to teaching science outdoors? Additional comments	What are your supports/ challenges/ concerns to teaching science outdoors? Additional comments	What are your supports/ challenges to teaching science outdoors? Additional comments	Any changes since EXPLORE? Are you satisfied with the change(s)? Do you see this as helpful to students? What are your supports/ challenges to teaching science outdoors?

Research Instrument	Cultural History	Activity System Overall	Subject (Teacher)	Object	Artifacts	Tools	Rules	Community	Division of Labor	Outcome
				Additional comments						Continue in future? Additional comments
Observations	Cultural history of teacher? cultural differences in group? teacher use of prior knowledge? cultural history of scientists recognized in system?; time planning, researching? Additional observations	Description of place where activity takes place and natural area; relationships between the elements of system; follow up in classroom? Additional observations.	Age, gender, race, social class, dress, act, display of knowledge, skills, Additional observations.	Purpose for the activity; is learning outdoors connected to science, bigger socio-scientific ideas or issues? lesson objective?; any other purposes? Additional observations.	Language, symbols, how is student learning mediated by teacher?; does teacher use EXPLORE artifacts?; does teacher adapt or add to artifacts?; lesson plan methods content and design description. Additional observations.	Describe tools & materials, and how do students and does teacher use tools/ materials?; use of field guide?; does teacher adapt tools? Additional observations.	Adherence to rules? What are they?; Which citizen science project (eBird, Project Squirrel, or Nature's Notebook); inquiry or problem solving? reviewing concepts? using scientific method?; required facts/ vocabulary learning?; measuring?; observation skills required? Additional observations.	Collaborative? social interactions?; multi-voiced?; relationships?; contradictions?; Additional observations.	Social activity or individual? teacher as authority?; Who assesses student reasoning, knowledge or understanding? ; teacher role?; assess accuracy of student - collected data?; Teacher/ student question asking? data upload research by who?; students work as whole group?; individually?; small group?; do groupings vary over time?; teacher mimic Arboretum educators? Additional observations.	Changes over time?; learning outcomes?; did teacher change teaching while teaching? teacher finding evidence of student cognitive, affective change; is teacher a learner with Arboretum educators?; Additional observations over time
Post-observation Interview	How does your teaching today relate to what you learned from EXPLORE? Additional comments	How does your teaching today relate to what you learned from EXPLORE Additional comments	How does your teaching today relate to what you learned from EXPLORE Additional comments	How does your teaching today fit in with your purposes for participating in Project EXPLORE? How does today relate to what you learned from EXPLORE?	How does your teaching today relate to what you learned from EXPLORE? Additional comments	How does your teaching today relate to what you learned from EXPLORE? Additional comments	How does your teaching today relate to what you learned from EXPLORE? Additional comments	How does your teaching today relate to what you learned from EXPLORE? Additional comments	How does your teaching today relate to what you learned from EXPLORE? Additional comments	Additional comments

Research Instrument	Cultural History	Activity System Overall	Subject (Teacher)	Object	Artifacts	Tools	Rules	Community	Division of Labor	Outcome
				Additional comments						
Teacher Self-Recorded Reflections after Teaching Outdoors	Reflection may include information about teacher cultural history	reflection may include information about activity system overall	Reflections upon self	Evidence of meanings teacher makes of activity	The tools, language, or symbols teacher mentions	Specific tools such as field guides or data sheets	The normative practices or class rules	Descriptions of students, other adults, or natural areas	Who taught; how were students sharing (or not) in responsibility?	Evidence of learning outcomes by students or by teachers; evidence of changes in activity system?
Expo Observation	Additional observations.	Poster display room layout and how it functioned; judges and judging interactions with teachers and/or students; interactions with the public, Additional observations.	Additional observations.	Additional observations.	Additional observations.	Additional observations.	Additional observations.	Poster or conversation evidence of: collaboration?; social interactions?; multi-voiced?; relationships?; contradictions?; Additional observations.	Poster or conversation evidence of: social activity or individual work?; teacher as authority assess student reasoning, knowledge or understanding? Teacher role? Additional observations.	Evidence on poster or in conversation of teacher change over time?; learning outcomes? teacher found evidence of student cognitive or affective? Additional observations.
Final Interview	Challenges in future? Additional comments	Satisfied with this year's teaching science outdoors? Talk about that? Challenges in future? What do you like best, least about EXPLORE? Additional comments	Challenges in future? Additional comments	What do you see as the purpose for participating in EXPLORE? Challenges in future? Additional comments	Challenges in future? Additional comments	Challenges in future? Additional comments	Challenges in future? Additional comments	Challenges in future? Additional comments	Challenges in future? Additional comments	What have you learned? How have you changed? Anything different now from when we first talked? What do you see as the major impact on the students? Most helpful to students' learning? Challenges in future? Any changes in relationships? Additional comments

Research Instrument	Cultural History	Activity System Overall	Subject (Teacher)	Object	Artifacts	Tools	Rules	Community	Division of Labor	Outcome
Key Informant Interviews	Similar projects in school culture? Additional comments	Description of EXPLORE; Additional comments	Additional comments	Additional comments	Additional comments	Additional comments	Additional comments	Description of community; Supports for teacher from community? Additional comments	Additional comments	Noticed changes in teacher from participation in EXPLORE? Additional comments
Artifact review (documents review) -EXPLORE grant	Arboretum history of activity	System design		Objectives, goals, reason for EXPLORE outreach				The description of the Arboretum community	The roles of Arboretum educators	
Artifact Review -Teacher applications	Personal Cultural History			Reasons for participating, what their goals are						
Artifact Review -teacher Emails		Questions asked by teachers and answers from Arboretum	Teacher prior knowledge or skills				School rules and normative practices		Role of Arboretum educator; role of teacher participant	Expansive learning outcomes or systemic transformations
Artifact Review -Student surveys								Community interest in learning outdoors; community experience in the outdoors		EE attitudes
Teaching Materials (both Arboretum and teacher created)										

APPENDIX G

EXPLORE FINAL INTERVIEW PROTOCOL

Teacher Final Interview

Interviewer introduction to the Arboretum educator research participant: I would like to talk with you so that I can learn more about your thoughts and feelings about learning to teach science outdoors as a participant in Project EXPLORE. I am recording our conversation so that I do not miss anything important. Is that ok with you? Talk as much as you want about each question. I want to better understand the process of learning to implement teaching citizen science outdoors. Do you have any questions before we begin? (If no questions, proceed.)

[Interviewer: This is a *semi-structured* interview protocol.]

1. First, I'd like you to just talk about what you did while you were participating in Project EXPLORE (eBird, Nature's Notebook w/npn, and Project Squirrel). In chronological order:

[Interviewer: can probe by saying, "Tell me more about . . ." Probe for how was it enacted, who actually went outdoors with the students; what is the meaning of this activity for this teacher, and what tools, rules, division of labor and community do they see in their activity.]

Interviewer: I want to ask you a few questions about your participation in Project EXPLORE.

2. What was the purpose of in Project EXPLORE?

3. Describe the best experience you and teachers/classes had while participating in Project EXPLORE?

[Interviewer Probe, "Why?"]

4. Describe the least productive experience you and teachers/classes had while participating in Project EXPLORE.

[Interviewer: Probe, “Why?”]

5. What do you see as the major impact(s) on students of the Project EXPLORE program now that you have finished for the year (2014-2015)?

6. Have any of your relationships with teachers, students, colleagues or others changed through participation in Project EXPLORE?

7. What do you feel *teachers* learned through your participation in Project EXPLORE?

[Interviewer: Probe, we want to *understand educator meaning of learning to teach science outdoors through Project EXPLORE*. Probe, Ask: Did this learning expand to other areas/people/subjects? Can you give me an example of learning? Describe a time when you did learn . . .]

8. How has your approach to EE evolved through participation in Project EXPLORE?

[Interviewer Probe: Can you talk about that? Can you give me an example of that?]

Interviewer: Now I am going to ask you about science education outdoors in general.

9. How do you define successful science teaching outdoors?

10. What do you see as most helpful to students’ learning in the activity of science education outdoors?

[Interviewer: This can be content knowledge, prior knowledge, pedagogical, mental, or physical tools such as data collection sheets or binoculars, visits from The Arboretum, the Expo itself. Probe: How? Why?]

11. What are the challenges to teaching science outdoors in the future?

12. How have you overcome challenges [to teaching teachers to conduct citizen science outdoors] in the past?

13. Do you have any personal concerns about teaching teachers to conduct citizen science programs outdoors in the future? (Explain.)

14. What do you plan to do differently in the future [when teaching teachers to conduct citizen science programs outdoors]?

15. Would you advise other organizations to participate in Project EXPLORE? Why or why not?

16. What advice would you give The Arboretum now you have completed your second year as an educator [in Project EXPLORE]?

17. What advice would you give administrators (Arboretum or Schools) about how to support this sort of instruction?

18. Is there anything new you would like to learn or think about?

Thank you for your support of this research

APPENDIX H

ARBORETUM STUDENT PRE SURVEY 2014

1. Where do you go to school?

2. What grade are you in?

3. Are you a boy or a girl?

- ☐ Boy
- ☐ Girl
- ☐ Prefer not to say

4. Do you like learning about science?

Yes

Sometimes

No

5. Do you think you would like being a scientist?

Yes

Maybe

No

6. Would you like school more if there were no science lessons?

Yes

No

7. Do you think a job as a scientist would be boring?

Yes

Sometimes

No, it would be fun!

◉ Yes

○ Sometimes

○ No, it would be fun!

8. Do scientists want your help?

9. Do you like to learn outside?

Yes, I love to learn outside

Yes, it can be fun

I've never tried it, I don't know
No, I'd rather be inside

APPENDIX I

ARBORETUM STUDENT POST SURVEY 2015

1. Where do you go to school?

2. What grade are you in?

3. Are you a boy or a girl?

4. Do you like learning about science?

Yes Sometimes No

5. Do you think you would like being a scientist?

Yes Maybe No

6. Would you like school more if there were no science lessons?

Yes No

7. Do you think a job as a scientist would be boring?

Yes Sometimes No, it would be fun!

8. Do scientists want your help?

Yes No

9. Do you like to learn outside?

Yes, I love to learn outside

Yes, it can be fun

I've never tried it, I don't know
No, I'd rather be inside

10. Did you attend The Mountain Science Expo at The NC Arboretum?

Yes No

11. After doing this project (birds, squirrels or trees) are you more likely to (circle all that apply):

Take another science class

Do a citizen science project at home

Learn more about plants and animals

None of the above

12. Did this project (bird, squirrels, or trees) increase your interest in science?

Yes Somewhat No

13. Did this project (birds, squirrels, or trees) increase your interest in nature?

Yes Somewhat No

14. Did this project increase your understanding of what scientists do?

Yes Somewhat No

15. What was your favorite part of this project?

16. What was your least favorite part of this project?

APPENDIX J

2015 PROJECT EXPLORE FEEDBACK/TEACHER EVALUATION

#17 **COMPLETE**

Collector: Web Link (Web Link)
Started: Thursday, May 14, 2015 2:37:19 PM
Last Modified: Thursday, May 14, 2015 4:04:28 PM
Time Spent: 01:27:08
IP Address: 128.109.7.34

PAGE 1

tional)

optional)

[redacted] Buckey Valley Elementary

1st

n providing opportunities for your students to take part in the scientific method (i.e. making a hypothesis or observations, posing questions or collecting data)?

Strongly Agree

Q5: Were you able to engage your students in weekly outdoor citizen science data collection? Please include any comments/suggestions/criticisms.

Yes - We first tried going out to observe birds at the same time each day. We were not seeing a large number/variety of birds, so we started observing at different times of day. This was a good decision, as it resulted in us observing lots of birds feeding at various times.

Q6: Do you think that Project EXPLORE helped increase your students' enthusiasm towards science?

Strongly Agree,

Please include any comments/suggestions/criticism
Students were excited about the project and looked forward to our weekly observations. They developed an interest in observing birds throughout the day at school and away from school.

Q7: Was this project relevant to your curriculum goals? Please include any comments/suggestions/criticisms.

Strongly Agree,

Please include any comments/suggestions/criticism
The project aligned to our study of the needs of plants and animals.

Q8: Do you think the second guided program was beneficial to you and your students? Please include any comments/suggestions/criticisms.

Yes - The students commented that they enjoyed having the people from the Arboretum come and teach them more about birds. They loved the hand-on activities.

Q9: Was the suggested/recommended materials list helpful? Do you have any additional materials you would suggest? Please include any comments/suggestions/criticisms.

Yes

2015 Project EXPLORE Feedback/Teacher Evaluation

Q10: **Were any of your students able to attend The Mountain Science Expo at The NC Arboretum?**	Yes

Q11: **How can we help all students attend The Mountain Science Expo?**

I feel that providing the Golden Tickets for free entry was a great way to make the opportunity accessible to families. The timing being of the Expo being around spring break resulted in many of my students being unable to attend due to family vacations.

Q12: **We would like to involve the greater school population and/or parents in Project EXPLORE. Do you have any recommendations or ideas how to best do this at YOUR school?**

I personally have recommended other teachers at my school participate. I think the Arboretium has done an excellent job of notifying educators about this wonderful learning opportunity for their students.

Q13: **How likely would you be to continue Project EXPLORE under the following circumstances:**

Very Likely	With free Arboretum-led guided programs and $100 grant funding, With free Arboretum-led guided programs, Arboretum-led guided programs at cost per student, On your own without the aid of an Arboretum Instructor

Q14: **If you received the $100 grant award, please comment on the amount provided.**	*Respondent skipped this question*

Q15: **Overall, are you satisfied with your experience with Project EXPLORE? Please include any comments/suggestions/criticisms.**

I have had a positive experience with Project EXPLORE and the wonderful support provided by educators from The Arboretum! Participation resulted in an increase in my students interest in science. I will continue to involve my students in this exciting opportunity in the future. Thanks to The Arboretum staff for all you do to make science education so exciting and engaging!