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Teachers as Learners: Outdoor Elementary Science

Sarah J. Carrier
North Carolina State University

M. Nils Peterson
North Carolina State University

Aimee B. Fraulo
North Carolina State University

Laura M. Romeo
North Carolina State University

Kathryn T. Stevenson
North Carolina State University

ABSTRACT

Young learners benefit from learning and engaging in nature, but nature-based outdoor learning impacts on teachers are less understood. The present study examined elementary school teachers' learning experiences with science instruction in outdoor natural settings. An Outdoor Science Education (OSE) program partnered with schools in the southeastern U.S. to provide standards-aligned outdoor science lesson expeditions for fifth-grade students. Teachers reported their participation in expeditions improved their own content knowledge in science and contributed to their confidence teaching science and teaching in the outdoors. In addition, teachers reported their perceptions of students' performance in their science classes and on standardized science tests. The teachers described their perceptions about how the expeditions improved their students' engagement for learning and behavior in outdoor settings when compared to indoor science instruction. They discussed how these changes were most obvious for students who struggled with traditional classroom instruction. Using survey and interview data, we discuss the potential for teacher learning related to outdoor science instruction.

Keywords: outdoors, elementary, science, student engagement

Introduction

Learning science in the outdoors may be particularly effective for young learners, but student success depends on elementary science teachers' instructional practices (National Science Teachers' Association [NSTA], 2020). Outdoor science instruction has shown potential to enhance motivation, behavior, and content mastery for many students (Carrier, 2013; Carrier et al., 2014; Szczytko et al., 2018; Cheng & Monroe, 2012), and outdoor experiences can also support students' critical thinking skills (Ampuero et al., 2015). When science instruction occurs in nature, students can connect directly with science's cross-cutting concepts such as patterns in nature, life cycles, energy flow, and form and function (Cooper, 2015; Fägerstam & Blom, 2013; Next Generation Science Standards [NGSS] Lead States, 2013). Here we define nature as plants, animals, and other objects and organisms in the outdoors not made by people. Further, science instruction in nature supports interdisciplinary learning where students connect science with literacy, mathematics, and social studies (Eick, 2012; Junker & Jacquemin, 2016; McMillan & Vasseur, 2010). Linking science with other subject areas is known to be an effective instructional practice; connects content to students' lives (National Research Council

[NRC], 2000; 2004), motivates students to engage in their learning (Banilower et al., 2010), and prepares students for careers in science (Feinstein et al., 2013). While the benefits of outdoor learning experiences for students are well-documented (Cooper, 2015; Harvey et al., 2020; Rios & Brewer, 2014; Wistoft, 2013), less is known about how outdoor learning experiences impact teachers, particularly K-5 teachers who often have limited science backgrounds (Smith, 2020). Here we examine teachers' participation in one outdoor science education (OSE) program's support of science instruction at elementary schools in the southeastern United States. Our research questions asked:

1. What are the relationships between elementary school teachers' participation in OSE experiences led by naturalists and their perceptions of their own and their students' science content knowledge?
2. What are the relationships between elementary school teachers' participation in OSE experiences led by naturalists and their perceptions of science instruction and outdoor science instruction?
3. What are teachers' perceptions of their students' engagement in science and behaviors following their participation in an OSE program?

We begin with a sociocultural frame, then provide an overview of the documented need to support elementary teachers' science instruction, outdoor learning, and teachers' expectations of student learning. Each of these components positions our study's focus on *teachers as learners.*

Theoretical Framework

The present study is situated in Vygotsky's (1978) sociocultural framework that identifies learning as an interactive phenomenon by which people learn through their social interactions. Humans develop cognitively through social interactions in guided learning, where participants co-construct knowledge with other learners (McLeod, 2014). According to Vygotsky, learning occurs through interactions with others who possess varying degrees of knowledge. Those with a higher level of knowledge are referred to as a "More Knowledgeable Other" (MKO). The MKO may model behavior or vocabulary that guides other learners. The MKO does not necessarily need to be a formal teacher but may be a peer or a tool (in the case of a computer tutorial program or device) that holds more knowledge about a topic than the learner. When members of a group learn and develop together, they enact Vygotsky's concept of MKO (Abtahi, 2017; McLeod, 2014; Moalosi, 2013).

As with young learners, sociocultural experiences also support adult learners (Wang, 2018; Wang et al., 2010). Even though teachers are generally viewed as the MKO relative to their students, they can simultaneously share the role of learners with their students. When teachers possess science content knowledge and explore ways to share this knowledge with their students, teachers' own learning continues as they hone their instructional practices. Further, science instruction reforms note that "learning science involves learning a system of thought, discourse, and practice—all in an interconnected and social context—to accomplish the goal of working with and understanding scientific ideas" (NRC, 2012, p. 252). In this study, we focus on teachers as learners and examine the relationships of their participation in outdoor expeditions with their perceptions of their students and of their own science content knowledge and instruction practices.

Literature Review

The marginalization of science instruction in elementary schools is well-documented and persistent. Data from the *2018 National Survey of Science and Mathematics Education* (Plumley, 2019) suggest that only 18% of primary and 26% of intermediate elementary students receive science instruction on all or most days in a school year. Teachers report challenges that inhibit science instruction beyond time limitations that include elementary teachers' low self-efficacy in science and few opportunities for teacher professional development.

In a recent national survey examining trends in science education (Smith, 2020), only 31% of elementary teachers reported they felt well-prepared to teach science. During their teacher preparation, only 34% of elementary teachers participated in science content coursework in life, physical, and earth science as recommended by NSTA (2012). A comparison of survey data from 2012 to 2018 found that elementary teachers' beliefs about science instruction continue to align with traditional instruction rather than reform-based teaching practices. These data indicate a lack of teacher exposure to professional opportunities to learn and rehearse effective science instructional practices to support their students (Smith, 2020).

While such findings identify a need for teachers' professional development in science, less than 60% of elementary teachers reported participating in science content or science methods professional development in the preceding three years, and 24% had never participated in science-related professional development (Smith, 2020). Such opportunities for professional development in science vary widely and are offered at varying frequencies. When professional development focuses on content knowledge and includes active learning, teachers report positive increases in their knowledge, skills, and changes in their classroom practices (Garet et al., 2001).

As teachers build their content knowledge, their knowledge of teaching practices can also expand beyond traditional instruction to include reform instruction (Feiman-Nemser, 2008). This content knowledge (CK) and the practice of teaching, or pedagogical knowledge (PK), contribute to teachers' pedagogical content knowledge (PCK) (Loughran et al., 2001; Shulman, 1986). Teachers with solid content knowledge are often also pedagogically skilled at incorporating effective instructional practices such as rich questioning during student engagement in science activities (Anderson, 2002; Anderson & Helms, 2001; Kennedy, 1998). Baumert and Kunter's (2013) model of professional competence includes CK, PCK, and PK, as well as teachers' beliefs about and motivation to teach. Park and Oliver (2008) developed an organizational tool of observable components of PCK that includes teachers' "(a) orientations to science teaching, (b) knowledge of students' understanding in science, (c) knowledge of science curriculum, (d) knowledge of instructional strategies and representations for teaching science, and (e) knowledge of assessments of science learning" (p. 264). Their pentagonal model supports the dynamic nature of teacher development of PCK.

Helping teachers shift from traditional teacher-centered instruction to reform-based student-centered teaching demands professional development that provides models and supports ongoing teacher rehearsals with this pedagogy (Desimone et al., 2002). In one study that documented teachers' struggles with this shift, teachers designed outdoor spaces for their students as part of their professional development. These teachers reflected on their challenges in shifting from teacher-centered instruction to student-centered instruction (Catapano, 2005). Desimone (2009) identified features of effective professional development that include active learning, coherence with classroom instruction, content focus, collective participation with PD developers and other teachers, and opportunities to practice. While the OSE in the present study is structured for student learning, we identify features that served as professional development for teachers, including active learning in the outdoors (Glackin, 2016).

Outdoor Learning

Researchers have identified the complexity of learning features that inform best practices for student learning. In *How People Learn II,* the roles of environmental, social, and cultural influences are described:

> Learning is a dynamic, ongoing process that is simultaneously biological and cultural. Attention to both individual factors (such as developmental stage; physical, emotional, and mental health; and interests and motivations), as well as factors external to the individual (such as the environment in which the learner is situated, social and cultural contexts, and opportunities available to learners), is necessary to develop a complete picture of the nature of learning (National Academies of Science, Engineering, and Medicine [NASEM], 2018, p. 9).

Outdoor science instruction has the potential to support students' physical, socio-emotional, and mental health developmental factors, and situating learning in the outdoors can motivate student learning. Researchers have found that outdoor instruction can improve students' science test scores, support their applications of science content to real-world situations, increase student enthusiasm and interest in science, and enhance emotional and cognitive development (Dillon et al., 2006; Lieberman & Hoody, 1998; Kahn & Kellert, 2002; Malone, 2008). Such enhanced cognitive and affective outcomes (Eaton, 2000) have further been found to improve student attitudes and comfort in the outdoors (Carrier, 2009; Cheng & Monroe, 2012) and encourage students' critical thinking skills (Hungerford & Volk, 1990). In an analysis of 18 research articles on outdoor learning, Ayotte-Beaudet et al. (2017) found that "when outdoor teaching and indoor teaching are coordinated to complement one another, a more positive effect on learning can be expected than when compared to indoor teaching alone" (p. 5355). These studies showed that students can make connections beyond the classroom when teachers combine outdoor experiences with indoor science instruction. Such shared social connections enhance students' conceptual knowledge by providing students authentic applications for their new learning.

In addition, students' direct connections to nature have been found to increase their interest in and motivation to learn science (Lindemann-Matthies, 2005; Skinner and Chi, 2012; Zoldosova & Prokop, 2006). Other researchers have found that sustained experiences in nature can impact young children's attitudes about nature that extend into adulthood (Ewert et al., 2005; Wells & Lekies, 2006). By facilitating children's connection to nature, such experiences have potential to enhance students' lasting interest in science.

Despite the affordances that outdoor contexts provide for learning about topics such as weather patterns or life cycles (Glackin, 2016; Rickinson et al., 2004), teachers rarely situate their instruction in the outdoors. Teachers have reported obstacles to outdoor instruction that include their limited awareness of outdoor activities, perceptions of a disconnect with instructional standards, time constraints, lack of administrative support, classroom management concerns, transportation costs, limited resources, and safety risks (Lock, 2010; Palavan et al., 2013). As teachers learn to negotiate these challenges, they can provide young students opportunities to engage with phenomena in outdoor settings and build a strong base for students' future learning.

Elementary Science Instruction

Including authentic science experiences in primary grades helps children learn and are the context for the present study. Decades of research on teaching and learning science have revealed that young children's scientific reasoning skills are more sophisticated than previously thought (NRC, 2007). Teachers can capitalize on these findings by providing students with early and rich science learning opportunities that focus children's scientific reasoning skills and help shape their experiences and prolong their interest in science. While student interest in science can persist through elementary school (DeWitt & Osborne, 2007), studies have found that their interest frequently wanes as they enter middle school (Archer et al., 2010). Children′s early interest in science is a strong indicator of their potential to pursue science studies and careers (Maltese & Tai, 2010), emphasizing the need for teachers to nurture in students an enduring interest and engagement in science. Significantly, teachers' expectations can influence students' motivation and performance (Florea, 2007) and play a critical role in capturing and nurturing their students' interest in science. Because students' K-5 experiences frequently establish a trajectory for their future learning, teachers' expectations and support are critical for all students, including those traditionally underserved in science classrooms and careers. Zargona and colleagues (2017) identified a need for more research on strategies for meeting the needs of all students in inclusion classrooms, and these needs include teachers' positive expectations.

Expectation Bias

Much research has focused on how teachers' expectations of students from academically stereotyped populations may diminish the quality of instruction they deliver to these students (Weinstein et al., 2004). Expectation theories identify the impact of teachers' expectations on student achievement (Cooper, 2000). McKown and Weinstein (2002) found that African American students were more vulnerable to negative teacher expectations than their European American peers. Other studies have identified that teacher expectations related to students′ gender and ethnicity can influence student performance (Retelsdorf, 2015; Rong, 1996; Timmermans et al., 2015). Relatedly, teacher expectations for students identified with learning disabilities have been found to impact their ratings of students' personal attributes and achievements (Rubie-Davies, 2006; Sorhagen, 2013; Woodcock & Vialle, 2011). When teachers' interactions with their students extend beyond the traditional classroom experiences, there is potential to broaden teachers' perceptions of their students' potential. In her work with schoolyard learning, Feille (2013) noted that when instruction expands beyond the classroom walls, teachers and students share direct experiences in the outdoors that can positively impact teacher-student relationships. Situating some science lessons in the outdoors has potential to reach students who may not be well served by traditional instruction. The range of experiences possible in the outdoors offers opportunities for teachers and students to engage in multiple learning modalities making learning accessible to a broad range of students (Eick, 2012; Harris, 2018; Rios & Brewer, 2014).

Methodology

This study is part of a larger examination of an OSE program that focused primarily on student outcomes (Szczytko, 2018; Stevenson, 2021). The present study extends this work to examine the teacher participants' perceptions of the OSE program's impact on their students' science learning and on their own learning of science content and science instruction. A mixed methods embedded design (Creswell, 2014) was employed in this study. All participants were recruited from the OSE program's database (N = 65).

The primary data source presented here is qualitative semi-structured interviews (see Appendix A) with teachers (n = 30) regarding their experiences in the OSE and their perceptions of their students during and after these experiences. In order to supplement the qualitative data, we decided to also include survey data to quantify the response categories and identify patterns and tendencies with the corresponding qualitative data. We sent a survey request the same sample population of the 65 OSE teachers, and to protect teacher identity of those who responded (n = 33), we administered an anonymized five-question targeted quantitative survey (see Appendix B). Embedded designs are appropriate for these analyses as the additional quantitative data supplements the primary qualitative data to provide additional evidence and aid in data interpretation (Creswell & Plano Clark, 2011). This protocol was approved as exempt from the ethics review process by the Institutional Review Board for the Protection of Human Subjects in Research (NC State University IRB # 12084IRB).

Study Context

The context of this study highlights a partnership between one private, non-profit OSE program and participating schools, teachers, and students in a southeastern US state. The partners' mutual goals focused on supplementing fifth-grade teachers' science instruction in the classroom and engaging students in outdoor learning experiences. The teachers' main goals were to enhance their students' science learning, and the OSE program's primary mission was to excite students about the wonders of science in nature situated in outdoor expeditions. These complementary goals positioned the OSE program to guide students and their teachers through a host of outdoor activities directly aligned with the state's science standards.

Schools apply to participate in the OSE program, and once approved, instructors called "naturalists" meet with teachers before their first expedition. During these meetings, the naturalists and teachers schedule multiple expeditions across the school year, and together they collaboratively align their presentation topics with state science standards and teachers' schedules. In the state where the study was conducted, as in many other US states, fifth grade is the only elementary school grade where science is assessed; thus, the emphasis on the state's science standards. The OSE naturalists developed outdoor activities to facilitate students' engagement in outdoor activities while also supporting teachers' goals by addressing the state standards-based science content that is tested. The grade 5 standards include ecosystems, weather, landforms, and life cycles that align well with outdoor learning. The OSE naturalists' science content activities exposed students and teachers to science practices as they asked students to generate and interpret evidence, and they scaffolded students' efforts to form explanations of the natural world (NRC, 2012). Their instructional models further facilitated students' connections to cross-cutting concepts such as patterns, cause and effect, structure and function, and systems (NGSS Lead States, 2013).

The naturalists offer each partner school up to nine expeditions per school year, and most schools average around five expeditions per year. At least one of the expeditions takes place in the schoolyard. More frequently, students and teachers travel to nearby natural areas with the naturalists for a day of science learning and engagement in the outdoors. During the expeditions, the classroom teachers serve in various roles. Sometimes teachers choose to observe the lessons or serve as chaperones to monitor student behaviors, while other times, teachers actively participate in activities along with their students.

Participants

Participants in this study were recruited from the OSE program's participant database. The database consisted of 65 teachers whose schools have engaged in expeditions with the OSE program. Each teacher was individually contacted via email to request their participation in an interview. Thirty teachers agreed to participate in a phone interview (46% response rate); of these 27 respondents identified as female, and three identified as male. The teacher participants had participated in this OSE program for between one to 12 years, with an average of 3.75 years. A separate email with an active link to the survey was sent to the same 65 teachers from the original database to request participation. Of the 65 teachers, 33 teachers anonymously responded to the online survey (50.8% response rate). In an effort to help teachers feel comfortable in honestly sharing their experiences, we prioritized protecting teacher identity; thus, we were not able to align survey data with interview responses. All teacher names are pseudonyms.

Data

Qualitative

We conducted semi-structured interviews with each teacher participant (See Appendix A). Each interview lasted between 25 to 45 minutes, and interviews were audiotaped and transcribed. The interviews were conducted by phone, with the majority administered by the second author, who at that time was a graduate research assistant. Before the start of each interview, the study's aims and the interviewee's rights were reviewed. We obtained informed consent from all participants. The interview process followed a specific sequence of open-ended questions guided by Vygotsky's (1978) sociocultural learning theory that asked the teachers their perceptions about how participating in the OSE programs with the naturalists impacted their learning about science concepts, instructional strategies, comfort in teaching science, and teaching in the outdoors (see Appendix A). The base questions were supplemented with follow-up questions that allowed the teachers to elaborate and clarify their responses.

Quantitative

The online survey (see Appendix B) consisted of response items using a five-point Likert-type scale. The survey questions aligned with research questions to identify patterns and support the qualitative findings. The teachers were asked their perceptions about to what extent the OSE supported their own learning, their comfort teaching science, their comfort teaching science in the outdoors, and their perceptions of their students' science learning and experience in the outdoor expeditions. Additionally, teachers were asked to report on their frequency and levels of participation in OSE expeditions. The findings provided a more holistic view and context for the qualitative descriptions from the semi-structured interviews.

Data Analysis

The interviews were recorded and transcribed, and the transcriptions were coded using a priori coding themes (Creswell & Plano Clark, 2011) derived from the research questions and positioned within Vygotsky's framework of sociocultural learning as teachers participated the OSE along with their students. Additional themes (See Table 1) emerged from the teachers' responses and contributed to the developing theme of teachers as learners.

As recommended by Hsieh & Shannon (2005), interview data were used to construct valid inferences to understand the teachers' perceptions of the OSE experiences. The data analysis occurred in several phases using an inductive process. Three researchers continuously discussed the coding procedures throughout all data analysis phases to assure consistency and provide trustworthiness and reliability of the data to ensure the integrity of the research process (Nadin & Cassell, 2006). The researchers initially read and coded the same four randomly selected transcribed interviews, then compared for coding decisions. The researchers discussed code interpretations and, when necessary, the codes were reviewed and revised until interrater reliability (Krippendorf, 2011) reached 90% agreement. In the next phase of data analysis, the remaining 26 transcribed interviews were randomly assigned to be coded independently by the three researchers. Survey data were analyzed, and descriptive statistics regarding teachers' perceptions of their learning and student learning were calculated using Stata 16 software. Correlation coefficients were calculated using Pearson's R to estimate correlations between teachers' perceptions of their own engagement and learning and that of their students.

Table 1

Coding Themes and Sample Quotes

Coding Themes	Description	Sample Quotes
Science Content Knowledge	Teachers' perceptions of their and their students' science content knowledge	Also, my own knowledge of local botany and wildlife and things like that, I have learned.
Instructional Strategies - Science	Teachers' views about science instruction	I just love the fact that it's a way for our kids to connect hands-on to our environment and to ideas about conservation and things that are going to be lasting impacts...they got to create animals out of natural materials
Outdoor Teaching and Learning	The outdoors as a setting for teaching and learning	It's one thing to read about ecosystems, [but another] to be able to actually be out and see the actual things, roll over dead logs and then find out what's living underneath them
Teachers' Views of Students	Teachers' descriptions of their students in outdoor learning.	They were focused, they were excited. They listened very well. They were willing to do more and participate more outside than versus inside of the everyday paper-pencil.
Teacher as Learner	Teachers' descriptions of their own learning	Science itself I can teach, but being able to connect it to the real world in front of them- that was a little bit harder for me - so I think that improved.

Findings

The teachers' voices from interviews and survey responses are organized around the coding themes that emerged through the inductive analysis process. These findings include teacher interview data and patterns from aggregated survey data.

Teachers' Science Content

The science content of the OSE activities addressed the state's science standards for grade 5. In the interviews, the teachers described OSE lessons on forces and motion, aquatic ecosystems, terrestrial ecosystems, weather, energy and matter, and heat transfer. Despite the fifth-grade teachers' familiarity with the science content topics, 23 of the teachers described their learning or "relearning" science content by the OSE, both within and beyond the standards topics. Darcy felt that her participation in the outdoor program activities built her "own knowledge of local botany and wildlife," and Valerie explained her own learning from the naturalists, "I feel like I learned a lot just from hearing from another science expert." Some teachers referenced elementary teachers' preparation as generalists and their limited backgrounds in science. Alexandra described teachers learning science content from the naturalists' instruction strategies:

> I definitely think it's [OSE] empowering to a lot of teachers. I have a lot of teachers that are on my team that don't know a lot about science. It's been really helpful to them. They've [said], 'I had no idea that heat transfers in that way. I had no idea about all these [concepts], about the plants.'

Abby described connecting the outdoor experiences to her indoor science lessons and her learning along with her students:

> As a teacher and getting outside - and actually participating in the field and the experiments - to me, it gives the students and myself so much more actual hands-on than we can do in the classroom…Then we bring it back into the classroom and even today during science, we were talking about one of our earlier expeditions because we always bring it back. We were talking about fungi and talking about how we saw it on our trip. It keeps bringing everything around and it's interesting and we all learn from it.

In addition to teachers' descriptions of their own learning, many described their perceptions of their students' learning science content.

Teachers' Perceptions of Students' Science Content

Jaden and Darcy used their students' performance on standardized science tests as measures of students' science content knowledge. Both attributed students' strong test scores to their participation in the OSE activities. Jaden explained, "The year that we did [OSE], I had the top 20% highest scores in the state…My kids were all identified in some way with some label [learning or behavior disability]…everyone did well in science." Darcy said, "We noticed that our scores did go up and then we also saw [when] another school in the county dropped it [OSE program], their scores went down and ours were still high."

Data from the teacher surveys (see Table 2) also indicated that while the teachers felt that participation in the OSE program supported students' science learning, it also supported teachers' learning.

There was a significant positive correlation between teachers' perceptions of students' learning and their own learning ($r(29) = .47$, $p < .01$). Approximately half of the teachers (45.5%) stated they learned "a great deal," 30% reported that they felt their learning was "only moderately" impacted by their participation in the OSE, while 6% (two teachers) reported that they felt that the experience did not support their learning at all. During the interviews, teachers who reported learning little from the OSE experience explained their already strong sense of self-efficacy in their science content knowledge and knowledge of science instruction. The teachers' reflections of their students' learning followed clear patterns, with twenty-five (75.8%) of the teachers reporting that the OSE supported their students' learning "a great deal." Only one teacher (3%) reported that the OSE "only moderately" supported their students' learning, and none of the teachers felt that their students failed to learn from the expeditions. In addition to the teachers learning science content, many teachers described learning from watching the naturalists' teaching methods. These methods included OSE naturalists asking students to design and build models, connecting interactive activities to classroom experiences, and extending instruction beyond the four walls of the classroom, as we examine in the next section.

Table 2

Descriptive Data from Surveys

Survey Item	Mean	SD	Variance
How often do you participate in the expeditions with your students?	4.6	0.9	0.8
How comfortable do you feel:			
teaching science to your students?	4.6	0.7	0.6
teaching science through outdoor experiences?	4.2	0.7	0.5
To what degree has OSE supported:			
comfort level in teaching science?	3.7	1.2	1.5
your students' learning?	4.7	0.5	0.3
your learning?	4.0	1.1	1.2

Note: Data were collected in a 5-point Likert-type scale of 1 = "Not at all" to 5 = "A great deal"

Instruction Strategies

The teacher participants described various instruction strategies they learned from observing the naturalists working with their students that aligned with their standards-based science instruction. Valerie said, "I feel like I learned a lot in the way that they presented information and conducted activities. I feel like it gave me maybe just a better love of science and how to engage the students in science." Relatedly, Ellen pointed out that situating instruction in the outdoors helps students connect science to life outside the classroom. "Giving students the opportunity to explore outside, they can see [science] in real-life. Real-life applications." Robert described similar views of science instruction in outdoor settings:

> It's one thing to read about ecosystems, but to be able to actually be out and see the actual things, roll over dead logs and then find out what's living underneath them, and because when we're studying about decomposers, we can actually see them live and experience them. I think it just adds a lot to the learning process and they appreciate that opportunity.

He went on to describe his learning instruction strategies from the naturalists, "Just seeing how they structure it and how they tie in those standards with the activities. It lets you see a model for how it can be."

In addition to student engagement in the outdoor lessons, the teachers described the OSE expeditions as confidence-building experiences for their teaching and learning in the outdoors. Lindsay explained, "Prior to this experience, I had never taken children outside for learning except an occasional field trip...I feel much more confident now taking them on expeditions outside." Bob appreciated that the OSE naturalists capitalized on "teachable moments" when he said:

> When things get pushed by their [students'] wonderings and understandings beyond what is just that objective…they're [naturalists] able to roll with what's interesting to them and pushing that envelope rather than just stopping straight at the content.

Twenty-three of the 30 teachers who were interviewed described how being outside with the naturalists alongside their students influenced their instruction and their learning strategies for authentic science activities and "hands-on" learning. Eight of the teachers valued science instruction that connected science with students' lives and used terms like "real world" and "real life" connections. Fifteen of the teachers described the interdisciplinary instruction potential of outdoor experiences. Ashley explained that the outdoor experiences shed new light for her about "how everything is interconnected."

Learning in the Outdoors

Many of the teachers described learning the benefits of situating instruction in the outdoors. Jamie elaborated:

> I think they see that science is not just in the classroom...I think that's one of the biggest benefits that the students get because they're able to make the connection that you don't have to be in a classroom to learn science or to gain new knowledge about science.

Cassidy's perception of science instruction in the outdoors addressed both cognitive and affective contributions of situating science in the outdoors, saying, "I am just reassured that this [the outdoors] is a good environment to learn. There are learning opportunities that we wouldn't have in the classroom. It definitely sparks their interest and their curiosity."

During the interviews, the teachers often spoke about how the OSE experiences expanded their own cognitive and affective connections to science teaching. Jaden explained that the outdoor experiences positively impacted her feelings about teaching science, "This program has tightened my comfort in teaching science. I love it even more." Darcy also described her learning the critical instruction practice of connecting to students' lives. "Science itself I can teach, but being able to connect it to the real world in front of them, that was a little bit harder for me, so I think that improved." Several of the teachers described their experiences with the naturalists taking on the role of the MKOs in expeditions. Darcy explained:

> When they [OSE program naturalists] teach in the woods, they are not only teaching the curriculum, but they're also bringing in local issues like invasive species that I didn't necessarily know, so that way I can kind of connect it with something around them a little bit better. Then actually applying--like when we did simple machines, and they're [the students] applying it for [designing] the bear bag [with pulleys] to hang food and stuff.

Sharon also described her learning science instruction strategies that connect to students' lives, to nature, and to classroom learning:

> They're [OSE program naturalists] actually tying it back to what the students are learning in the classroom. I just love the fact that it's a way for our kids to connect hands-on to our environment and to ideas about conservation and things that are going to be lasting impacts...they got to create animals out of natural materials that were found in the woods, and then they got to talk about the adaptations that they had from living in that area.

In describing how participation in the OSE program impacted her instruction strategies, Jamie elaborated on her role as *learner*:

> I've gained so much information from them and the activities that they provide as well as just their knowledge base. I guess I'm almost a student to some degree because I'm taking notes and trying to capture their activities that they do so we can recreate them in the classroom.

Relatedly, Lindsay gave a specific example of how participation in the OSE with her students impacted her learning about science instruction.

> It has definitely helped my teaching. I had mentioned to the OSE instructor that I was struggling, and my students were struggling, with understanding motion graphs. When she [naturalist] did her activity, everywhere that we walked that day we paused occasionally, and she had a student collect the data and created a graph and graphed our own motion.

Jamie and Lindsay both described that they learned science instruction practices from the MKO naturalists that tap into students' creative thinking and active learning. While many variables influence teachers' perceptions of their science teaching and outdoor instruction, the teachers' learning expanded beyond their perceived knowledge of science and instruction strategies. In the following section, we document teachers' descriptions of learning more about their students.

Teachers' Perceptions of Their Students' Behaviors and Engagement in Science

In addition to the OSE supporting teachers learning of effective science instruction through connecting to students' lives in the outdoors, the teachers also reported that the experiences altered their perceptions of students' cognitive and affective connections to their learning. Jaden explained how her perception of one student changed following the OSE, "Last year we had a kid who was in an alternate behavior classroom. The deal was that he could go on the expedition on a trial basis. This kid was probably one of the best-behaved kids out there!"

Margo commented on the potential for outdoor experiences to engage all students in science. "I do honestly think that it could encourage students to love science more, especially some of those girls who have started to get away from liking science and math." The teachers often described seeing their students in new and different ways. As Reese explained, "We get to take a step back and view our students in a completely different environment, with a different teacher and we can just learn more about them that way." In addition to seeing their students' interactions with different teachers, Cassidy described the transition of student behaviors in the outdoor settings saying, "Some of the students who don't speak up in class, they were speaking up and were on it. They speak up in the outdoors, but not in the classroom." Lacey had similar observations about her students "They were focused, they were excited. They listened very well. They were willing to do more and participate more outside than inside with the everyday paper and pencil."

Other teachers spoke directly about students who have been identified as learning or behaviorally challenged. Jamie noticed that in the outdoors, her students "who are not able to sit in a classroom setting without a behavior distraction...those students are engaged, they're willing to write...they're willing to attempt more in the participation than they are in the classroom." Similarly, Robert mentioned the positive impact on "students with learning disabilities, again, gets them out of a textbook into the world where they're able to see the concepts instead of struggling through reading about them." Margo noted, "I think that makes it easier for kids that have short attention spans to stay with what's happening." The teachers highlighted their students' affective engagement with science content when learning collaboratively in the outdoors.

Limitations of the Study

One limitation of the study is that the teachers self-selected by volunteering to participate in the interviews. Selection bias may express itself in many ways, but in this study, it seems most likely to occur in a form where the teachers most excited about learning in nature responded. Thus, our findings may provide better inference for contexts with highly engaged teachers. Further, self-reports of the teachers' experiences offer a snapshot of the teachers' perceptions of their science and outdoor instruction. In order to ensure teachers' privacy, we used an anonymous online survey, so we could not determine which of the teachers who responded to the survey were also interviewed, thus inhibiting triangulation of data. While the data presented here are specific to the targeted OSE program participants, it is essential to consider the potential value of teachers' participation in OSEs to inform teacher development and teacher education.

Discussion

While the OSE program in this study was designed to enhance fifth-grade student science learning, our research questions focused on teachers' perceptions of the OSE program's impact on their and their students' science content knowledge, science instructional practices, outdoor instruction, and learning about their students.

Science Content Knowledge

Our first research question asked, "What are the relationships between elementary school teachers' participation in OSE experiences led by naturalists and their perceptions of their own and their students' science content knowledge?"

The teachers' survey responses and interviews were consistent in their perceptions that both their and their students' science content knowledge grew from participation in the OSE expeditions. Alexandra discussed how elementary teachers must learn to teach all subjects and thus can lack specific science content knowledge as documented in national surveys (Plumley, 2019; Smith, 2020). Alexandra described how her content knowledge about heat transfer grew as she learned along with her students. The teachers' survey responses also revealed their critical recognition of how the OSE program activities were directly linked to their grade level science content standards.

Our focus on the teachers' learning connects with research on professional development for teachers. The OSE program featured some core characteristics of effective professional development, such as active learning, content focus, and collective participation (Darling-Hammond, 2005; Desimone, 2009; Desimone et al., 2002; Fischer et al., 2018; Garet et al., 2001; Fishman et al., 2003), but as Kennedy (2016) pointed out in her review of 28 studies on professional development, there are other factors beyond the design of professional development that influence instructional practices. We offer suggestions for addressing other factors in our implications.

The collective participation of naturalists, teachers, and students aligns with Vygotsky's (1978) sociocultural framework to examine the social connections as teachers in this study accompanied their students and participated together in the outdoor expeditions and further aligns with more recent learning sciences research (NASEM, 2018). While the OSE program focused on student learning, both the teachers and students shared the role of learners with OSE naturalists who served as MKOs as they modeled science instruction strategies to facilitate students' science learning in the outdoors. Interestingly, the data provide many examples of ways that the OSE program significantly also supported the teachers learning science content. Lindsay explained that she learned about forces and motion content from the OSE naturalist, and she further gained knowledge about instructional practices from the naturalists' instructional modeling. The OSE naturalists in the present study partnered closely with teachers and also served as MKOs as they presented outdoor learning activities that aligned with the prescribed science standards and supported teachers' indoor science instruction. This critical and participatory design enhanced the experience for the teachers, and the OSE program helped maximize the impact on teachers' perceptions of both student *and* teacher learning (Ayotte-Beaudet et al., 2017).

Science Instruction and Outdoor Science Instruction

The second research question asked, "What are the relationships between elementary school teachers' participation in OSE experiences led by naturalists and their perceptions of science instruction and outdoor science instruction?"

In addition to teachers' perceptions of their increased science content knowledge, the OSE program also supported teachers' science instructional practices, including outdoor instruction. The teachers described how their knowledge of content (CK) and pedagogies (PK) expanded and contributed to their PCK as they learned new and different instruction strategies for communicating science with their students (Park & Oliver, 2008; Shulman, 1986). In addition, this strategic alignment of science content knowledge, science standards, and instructional practices addressed many of the teachers' perceived barriers to outdoor instruction.

Through their participatory collaborations with the naturalists and observations of naturalists' instruction, the teachers in our study described learning how the outdoors can be an authentic setting to teach science standards in ways that apply to students' lives beyond the classroom. The teachers in this study recognized that situating science content and instructional practices in the outdoors connects science with students' lives. For example, one teacher described an activity that challenged students to consider themselves as campers who need to protect their food from potential bears. This lesson moved learning about forces and motion from the teachers' traditional classroom instruction as they asked students to apply these concepts to design a pulley system in tree branches to elevate their food off the ground. Another example of an activity that teachers and students experienced this collaborative learning context reinforced the concept of heat transfer. In this activity, students were asked to apply concepts of heat transfer in their design of a camping stove to make tea out of pine needles.

The teachers' descriptions of their students' engagement in content-focused science revealed the impact of teachers' learning new science instruction practices (Desimone et al., 2002; Glackin, 2016) and the resulting student motivation and interest in science (Dillon et al., 2006; Kahn & Kellert, 2012; Lindemann-Matthies, 2005; Zoldosova & Prokop, 2006). Our findings support research on the effectiveness of outdoor learning as an instructional strategy. Rickinson and colleagues (2004) recommended that programs "use a range of carefully structured (outdoor) learning activities and assessments linked to the school curriculum" (p. 7). They also identified the potential for school grounds and outdoor community projects to impact students' motivation to learn. Importantly, they further describe that, through these outdoor experiences, students may "develop more positive relationships with each other, with their teachers, and with the wider community" (p. 6).

Teachers' Perceptions of Students

The third research question asked, "What are teachers' perceptions of their students' engagement in science and behaviors following their participation in an OSE program?"

Most notably, interview and survey data reveal multiple ways that teachers in this study learned more about their students. Although teachers reported how participating in the OSE with the naturalists helped them learn science content, science instruction strategies, and about using the outdoors as a setting for teaching and learning, the teachers' descriptions of their increased understanding of their students as they learned together in the outdoors may be the most relevant impact of their OSE experience. As Vygotsky's theory suggests, social interaction is a fundamental component of cognitive and social development. Human development and learning are guided by social interactions as participants co-construct knowledge and engage in their environment within a social-ecological system (McLeod, 2014). These experiences provided the teachers an important lens to recognize how outdoor learning can target students' potential and allow students the opportunity to assume the role of the MKO with their peers and their teacher, especially students whose traditional classroom experiences seemed stagnant. Providing teachers with the opportunity to expand learning beyond the classroom exploring outdoor science with their students can motivate both students and their teachers.

The relationship building that can occur during OSE experiences can influence teachers' assumptions about students in ways that have potential to ultimately improve teachers' instruction, improve student outcomes, and challenge teachers' expectation biases (Cooper, 2000; Florea, 2007). Teachers' relationships with their students impact the learning experiences for both. Woodcock and Vaille (2010) explain, "The way in which teachers perceive the students' behaviour can influence their future expectations and responses to students" (p. 178).

Like Jordan, many of the teachers in this study were surprised by some of their students' positive engagement in the science content and learning in the outdoors, especially those students who had previously been identified as having behavioral or learning challenges. Teachers like Reese described their students' positive engagement in the outdoor setting that they had not seen in the indoor science classroom (Dillon et al., 2006; Lieberman & Hoody, 1998; Malone, 2008); these experiences indicate the potential to influence teachers′ expectations and alter bias of students' learning potential (Woodcock & Vialle, 2011). Another teacher, Margo, confronted her expectation biases about girls and science when she said, "I do honestly think that it [outdoor learning] could encourage students to love science more, especially some of those girls who have started to get away from liking science and math."

In this study, as teachers learned science content along with their students, they described an enhanced appreciation of their students' abilities. Two examples where teachers described learning from their students were when OSEs asked students to design a pulley to elevate food to protect it from bears and when their students developed strategies to make their own tea. In addition to seeing the naturalists as MKOs, the teachers in this study were also able to see their students assume MKO roles with their peers and, at times, with their teachers as they shared their learning in the sociocultural context of reciprocal learning (Vygotsky, 1978). This dynamic illustrates the important MKO role as a dynamic interactive/fluid process as the naturalists, students, and teachers take turns as MKO. This fluidity seldomly occurs in traditional interactions with students and teachers in a science classroom and can promote student-centered instruction (Feiman-Nemser, 2008; Smith, 2020).

Shared learning experiences can expand teachers' expectations and attitudes about their students (Rubie-Davies, 2010; Weinstein, 2002). The significance of teachers' increased awareness and appreciation of their students' potential for learning and engagement highlights the benefits of outdoor science experiences to encompass the kinesthetic, cognitive, and affective domains of learning (Honebein & Honebein, 2015). These experiences further support teacher reflection and integration as they build their PCK (Park & Suh, 2019). Though the benefits of OSE for teachers are understudied and arguably underappreciated in practitioner settings, this research suggests how OSE programs can support both teacher development and student outcomes.

Implications

Although this study's findings are specific to this OSE program, these data provide important insights for both teacher and student learning. For decades, elementary science instruction has been marginalized by accountability measures focused on other domains, notably reading and mathematics (Smith, 2020), yet the need for a scientifically literate society is more relevant than ever. Teacher educators and school administrators are responsible for supporting teachers' science instruction and students' science learning. One of the notable implications is that OSE providers can join teacher educators and schools to expand OSE and other science professional development supports for teachers. The school community primarily serves students, so it must maintain a keen interest in and devotion to resources to supporting teachers' professional development in science.

The experience of teachers' participating in OSE presented here have the potential to inform other educators about strategies to access authentic learning opportunities that connect to the natural world and students' lives. Such experiences reinforce sociocultural collaborations with other learners, such as local OSE programs, informal educators in museums or nature centers (Tran & King, 2011), and science specialist teacher leaders (Herbert et al., 2017). Providing teachers with student-focused teaching models in authentic settings has potential to expand teachers' science content knowledge, enhance their instruction strategies that connect to the natural world and to students' lives, build their confidence in science and science teaching, and, importantly, also help teachers learn more about their students. As teachers, students, and collaborators connect with nature and learn together in the outdoors, they begin to build a rich community of learners.

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Sarah J. Carrier (sjcarrie@ncsu.edu) is Professor of Elementary Science Education at North Carolina State University. Her research has focused on teachers' developing identities as science teachers, environmental education, and outdoor learning. As a former elementary school teacher who spent countless hours teaching in the outdoors and learning along with her students, she guides current and future teachers to embrace the outdoors as a setting for teaching and learning.

Aimee B. Fraulo (abfraulo@gmail.com) is a research scientist and outdoor educator. Her research focuses on the neuroscience and socioemotional benefits of outdoor learning strategies in classroom teaching and child development. She has taught in both traditional and Montessori schools and currently works as a researcher in the agricultural and ecological sciences.

Kathryn T. Stevenson (ktate@ncsu.edu) is an associate professor in the Department of Parks, Recreation & Tourism Management at NC State University. Her research and teaching centers on children and nature and environmental education. In particular, she is interested in understanding how time in natural areas provides benefits to young learners as well as how youth-led conversations can lead to community-scale change.

M. Nils Peterson (mnpeters@ncsu.edu) is a Professor of Fisheries, Wildlife, and Conservation Biology at North Carolina State University. His research focuses on unravelling the drivers of environmental behavior in contexts of endangered species conservation, wildlife crime, environmental education, environmental conflict, and environmental policy making.

Laura M. Romeo (lmmmayer@ncsu.edu) is an experienced teacher educator, instructional designer, curriculum specialist, and former elementary teacher. Her passion for working within the education field began as a young girl in her mother's Kindergarten classroom and has grown with each new experience, both professionally and personally. Laura is devoted to providing teachers with more effective instructional practice and contributing to their love and further pursuit of education in her

current work efforts. Her research interests include Universal Design for Learning, Social and Emotional Learning, preservice teachers, instructional design and development, and equitable teaching practices.

References

Abtahi, Y. (2017). The more knowledgeable other: A necessity in the zone of proximal development? *For the Learning of Mathematics*, *37*(1), 35-39. https://doi.org/10.1080/14794802.2017.1390691

Ampuero, D., Miranda, C. E., Delgado, L. E., Goyen, S., & Weaver, S. (2015). Empathy and critical thinking: Primary students solving local environmental problems through outdoor learning. *Journal of Adventure Education & Outdoor Learning*, *15*(1), 64-78. https://doi.org/10.1080/14729679.2013.848817

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education, 13*(1*)*, 1–12. https://doi.org/10.1023/A:1015171124982

Anderson, R. D., & Helms, J. V. (2001). The ideal of standards and the reality of schools: Needed research. *Journal of Research in Science Teaching, 38* (1), 3–16. https://doi.org/10.1002/1098-2736(200101)38:1<3::AID-TEA2>3.0.CO;2-V

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). "Doing" science versus "being" a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education*, *94*(4), 617-639. https://doi.org/10.1002/sce.20399

Ayotte-Beaudet, J. P., Potvin, P., Lapierre, H. G., & Glackin, M. (2017). Teaching and learning science outdoors in schools' immediate surroundings at K-12 levels: A meta-synthesis. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(8), 5343-5363. https://doi.org/10.12973/eurasia.2017.00833a

Banilower, E., Cohen, K., Pasley, J. & Weiss, I. (2010). *Effective science instruction: What does research tell us?* Second edition. RMC Research Corporation, Center on Instruction.

Baumert, J., & Kunter, M. (2013). The COACTIV model of teachers' professional competence. In *Cognitive activation in the mathematics classroom and professional competence of teachers* (pp. 25-48). Springer, Boston, MA.

Bloom, M. A., Holden, M., Sawey, A. T., & Weinburgh, M. H. (2010). Promoting the use of outdoor learning spaces by K-12 in-service science teachers through an outdoor professional development experience. In *The inclusion of environmental education in science teacher education* (pp. 97-110). Springer, Dordrecht.

Carrier, S.J., Thomson, M.M., Tugurian, L.P., & Stevenson, K.T. (2014). Elementary science education in classrooms and outdoors: Stakeholder views, gender, ethnicity, and testing. *International Journal of Science Education*, *36*(13), 2195-2220.

Carrier, S.J., Tugurian, L.P. & Thomson, M.M. (2013). Elementary science indoors and out: Teachers, time, and testing. *Research in Science Education*, *43*(5), 2059-2083.

Carrier, S. (2009). The effects of outdoor science lessons with elementary school students on preservice teachers' self-efficacy. *Journal of Elementary Science Education*, *21*(2), 35-48.

Catapano, S. (2005). Teacher professional development through children's project work. *Early Childhood Education Journal*, *32*(4), 261-267. https://doi.org/10.1007/s10643-004-1428-2

Cheng, J.C.H. & Monroe, M. C. (2012). Connection to nature: Children's affective attitude toward nature. *Environment and Behavior*, *44*(1), 31–49. http://doi.org/10.1177/0013916510385082

Chawla, L. (1998). Significant life experiences revisited: A review of research on sources of environmental sensitivity. *The Journal of Environmental Education*, *29*(3), 11-21. https://doi.org/10.1080/00958969809599114

Christidou, V. (2011). Interest, attitudes, and images related to science: Combining students' voices with the voices of school science, teachers, and popular science. *International Journal of Environmental and Science Education*, *6*(2), 141-159.

Cooper, H. M. (2000). Pygmalion grows up. In P. K. Smith & A. D. Pellegrini (Eds.), *Psychology of education: Major themes* (pp. 338–364). RoutledgeFalmer https://doi.org/10.3102/00346543049003389

Cooper, A. (2015). Nature and the outdoor learning environment: The forgotten resource in early childhood education. *International Journal of Early Childhood Environmental Education*, *3*(1), 85-97. https://files.eric.ed.gov/fulltext/EJ1108430.pdf

Creswell, J. W. 2014. *Research Design: Qualitative, Quantitative, and Mixed Methods*. Approaches. 4th ed. SAGE Publications.

Creswell, J. W., & Plano Clark, V. L. (2011). Choosing a mixed methods design. *Designing and conducting mixed methods research*, *2*, 53-106.

Darling-Hammond, L. (2005). Teaching as a profession: Lessons in teacher preparation and professional development. *Phi Delta Kappan*, *87*(3), 237-240. https://doi.org/10.1177/003172170508700318

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, *38*(3), 181-199.

Desimone, L. M., Porter, A. C., Garet, M. S., Yoon, K. S., & Birman, B. F. (2002). Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Educational Evaluation and Policy Analysis*, *24*(2), 81-112. https://doi.org/10.3102/01623737024002081

DeWitt, J., & Osborne, J. (2007). Supporting teachers on science-focused school trips: Towards an integrated framework of theory and practice. *International Journal of Science Education*, *29*(6), 685-710. https://doi.org/10.1080/09500690600802254

Dillon, J., Rickinson, M., Teamey, K., Morris, M., Choi, M. Y., Sanders, D., & Benefield, P. (2006). The value of outdoor learning: Evidence from research in the UK and elsewhere. *School Science Review*, *7*(320), 107–112.

Eaton, D. (2000). Cognitive and affective learning in outdoor education. *Dissertation Abstracts International - Section A: Humanities and Social Sciences*, *60*(10-A), 3595. https://tspace.library.utoronto.ca/handle/1807/12600

Eick, C. J. (2012). Use of the outdoor classroom and nature-study to support science and literacy learning: A narrative case study of a third-grade classroom. *Journal of Science Teacher Education*, *23*(7), 789-803. https://doi.org/10.1007/s10972-011-9236-1

Ewert, A., Place, G., & Sibthorp, J. (2005). Early-life outdoor experiences and an individual's environmental attitudes. *Leisure Sciences*, *27*(3), 225-239. https://doi.org/10.1080/01490400590930853

Fägerstam, E., & Blom, J. (2013). Learning biology and mathematics outdoors: Effects and attitudes in a Swedish high school context. *Journal of Adventure Education & Outdoor Learning*, *13*(1), 56-75. https://doi.org/10.1080/14729679.2011.647432

Feille, K. (2013). Getting outside: Three teachers' stories of using the schoolyard as an integrated tool for elementary teaching. *Electronic Journal of Science Education*, *17*(3), 1-17. http://files.eric.ed.gov/fulltext/EJ1188358.pdf

Feiman-Nemser, S. (2008). Teacher learning: How do teachers learn to teach?. In *Handbook of research on teacher education* (pp. 696-705). Routledge.

Feinstein, N. W., Allen, S., & Jenkins, E. (2013). Outside the pipeline: Reimagining science education for nonscientists. *Science*, *340*, 314-317. https://doi.org/10.1126/science.1230855

Fischer, C., Fishman, B., Dede, C., Eisenkraft, E., Foster, B., Frumin, K., Lawrenz, F., Levy, A., & McCoy, A. (2018). Investigating relationships between school context, teacher professional development, teaching practices, and student achievement in response to a nationwide science reform. *Teaching and Teacher Education, 72(*1), 107-121. https://doi.org/10.1016/j.tate.2018.02.011

Fishman, B. J., Marx, R. W., Best, S., & Tal, R. T. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and teacher education*, *19*(6), 643-658. https://doi.org/10.1016/s0742-051x(03)00059-3

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, *38*(4), 915-945. https://doi.org/10.3102/00028312038004915

Glackin, M. (2016). 'Risky fun 'or 'Authentic science'? How teachers' beliefs influence their practice during a professional development programme on outdoor learning. *International Journal of Science Education*, *38*(3), 409-433. https://doi.org/10.1080/09500693.2016.1145368

Glesne, C. (2016). *Becoming qualitative researchers: An introduction*. (5th edition). Pearson.

Haider, M., & Yasmin, A. (2015). Significance of scaffolding and peer tutoring in the light of Vygotsky's theory of Zone of Proximal Development. *International Journal of Languages, Literature and Linguistics*, *1*(3), 2015. https://doi.org/10.18178/ijlll.2015.1.3.33

Harris, F. (2018). Outdoor learning spaces: The case of forest school. *Area*, *50*(2), 222–231. https://doi.org/10.1111/area.12360

Harvey, D. J., Montgomery, L. N., Harvey, H., Hall, F., Gange, A. C., & Watling, D. (2020). Psychological benefits of a biodiversity-focused outdoor learning program for primary school children. *Journal of Environmental Psychology*, *67*, 101381.

Herbert, S., Xu, L., & Kelly, L. (2017). The changing roles of science specialists during a capacity building program for primary school science. *Australian Journal of Teacher Education*, *42*(3), 1-21. https://doi.org/10.14221/ajte.2017v42n3.1

Honebein, P. C., & Honebein, C. H. (2015). Effectiveness, efficiency, and appeal: Pick any two? The influence of learning domains and learning outcomes on designer judgments of useful instructional methods. *Educational Technology Research and Development*, *63*(6), 937-955. https://doi.org/10.1007/s11423-015-9396-3

Hoody, L.L. (1996). *The effects of environment-based education on student achievement*. State Education & Environment Roundtable [SEER]. http://www.seer.org/pages/research/educeff.pdf

Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, *15*(9), 1277-1288. https://doi.org/10.1177/1049732305276687

Hungerford, H. R., & Volk, T. L. (1990). Changing learner behavior through environmental education. *The Journal of Environmental Education*, *21*(3), 8-21. https://doi.org/10.1080/00958964.1990.10753743

Junker, C. R., & Jacquemin, S. J. (2016). Bridging the gap: Surveying interdisciplinarity in the environmental literature classroom. *ISLE: Interdisciplinary Studies in Literature and Environment*, *23*(2), 395-411. https://doi.org/10.1093/isle/isw038

Kahn Jr, P. H., & Kellert, S. R. (Eds.). (2002). *Children and nature: Psychological, sociocultural, and evolutionary investigations*. MIT press.

Kennedy, M. M. (1998). Education reform and subject matter knowledge. *Journal of Research in Science Teaching, 35*(3), 249–263. https://doi.org/10.1002/(SICI)1098-2736(199803)35:3<249::AID-TEA2>3.0.CO;2-R

Kennedy, M. M. (2016). How does professional development improve teaching? *Review of Educational Research, 86*(4), 945–980. https://doi.org/10.3102/0034654315626800

Krippendorff, K. (2011). Agreement and information in the reliability of coding. *Communication Methods and Measures, 5*, 93-112.
Lieberman, G. A., & Hoody, L. L. (1998). *Closing the achievement gap: Using the environment as an integrating context for learning*. State Education and Environment Roundtable. https://files.eric.ed.gov/fulltext/ED428943.pdf
Lindemann-Matthies, P. (2005). 'Loveable' mammals and 'lifeless' plants: How children's interest in common local organisms can be enhanced through observation of nature. *International Journal of Science Education*, *27*(6), 655-677. https://doi.org/10.1080/09500690500038116
Lock, R. (2010). Biology fieldwork in schools and colleges in the UK: An analysis of empirical research from 1963 to 2009. *Journal of Biological Education*, *44*(2), 58-64.
Loughran, J., Milroy, P., Berry, A., Gunstone, R., & Mulhall, P. (2001). Documenting science teachers' pedagogical content knowledge through PaP-eRs. *Research in Science Education*, *31*(2), 289-307. https://files.eric.ed.gov/fulltext/ED442631.pdf
Malone, K. (2008). *Every experience matters: An evidence based review of the role of learning outside the classroom on the development of the whole young person*. Farming and Countryside Education.
Maltese, A.V., & Tai, R.H. (2010) Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education, 32*(5), 669-685. https://doi.org/10.1080/09500690902792385
Mannion, G., Fenwick, A., & Lynch, J. (2013). Place-responsive pedagogy: Learning from teachers' experiences of excursions in nature. *Environmental Education Research*, *19*(6), 792-809. https://doi.org/10.1080/13504622.2012.749980
Martin, S.C. (2003). The influence of outdoor schoolyard experiences on students' environmental knowledge, attitudes, behaviors, and comfort levels. *Journal of Elementary Science Education*, *15*(2), p. 51-56.
McKown, C., & Weinstein, R. S. (2002). Modeling the role of child ethnicity and gender in children's differential response to teacher expectations. *Journal of Applied Social Psychology, 32*, 159−184. https://doi.org/10.1111/j.1559-1816.2002.tb01425.x
McLeod, S. (2014). Lev Vygotsky. *Simply psychology*, 1-13. https://pdfs.semanticscholar.org/96ba/471b2677b7ca0b62e778dee40fa1078d5c03.pdf
McMillan, E., & Vasseur, L. (2010). Environmental education: Interdisciplinarity in action. *International Journal of Interdisciplinary Social Sciences*, *5*(3), 435-445 doi:10.18848/1833-1882/CGP/v05i03/51624.
Moalosi, W. T. S. (2013). Assessing Vygotsky's model for students learning. *Educational Research International*, *2*(3), 39-42. http://erint.savap.org.pk/PDF/Vol.2(3)/ERInt.2013(2.3-06).pdf
Nadin, S., & Cassell, C. (2006). The use of a research diary as a tool for reflexive practice: Some reflections from management research. *Qualitative Research in Accounting & Management*.
National Academies of Sciences, Engineering, and Medicine. (2018). *How people learn II: Learners, contexts, and cultures*. The National Academies Press. https://doi.org/10.17226/24783.
National Research Council. (2000). *How people learn*. National Academy Press.
National Research Council. (2004). *How students learn: History, mathematics, and science in the classroom*. National Academy Press.
National Research Council. (2007). *Taking science to school*. National Academies Press.
National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press
National Science Teachers' Association (2020). *NSTA/ASTE Standards for Science Teacher Preparation*. https://static.nsta.org/pdfs/2020NSTAStandards.pdf
NGSS Lead States. 2013. *Next Generation Science Standards: For States, By State*s. Washington, DC: The National Academies Press.

Palavan, O., Cicek, V., & Atabay, M. (2016). Perspectives of elementary school teachers on outdoor education. *Universal Journal of Educational Research*, *4*(8), 1885-1893. https://doi.org/10.13189/ujer.2016.040819

Park, S., & Oliver, J. S. (2008). Revisiting the conceptualisation of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education*, *38*(3), 261-284. https://doi.org/ 10.1007/s11165-007-9049-6

Park, S., & Suh, J. K. (2019). The PCK map approach to capturing the complexity of enacted PCK (ePCK) and pedagogical reasoning in science teaching. In *Repositioning pedagogical content knowledge in teachers' knowledge for teaching science* (pp. 187-199). Springer, Singapore.

Plumley, C. L. (2019). *2018 NSSME+: Status of elementary school science.* Horizon Research, Inc. http://www.horizon-research.com/horizonresearchwp/wp-content/uploads/2020/02/2018-NSSME-Status-of-Elementary-Science.pdf

Posnanski, T. J. (2002). Professional development programs for elementary science teachers: An analysis of teacher self-efficacy beliefs and a professional development model. *Journal of Science Teacher Education*, *13*(3), 189-220. https://doi.org/10.1023/a:1016517100186

Retelsdorf, J., Schwartz, K., & Asbrock, F. (2015). "Michael can't read!" Teachers' gender stereotypes and boys' reading self-concept. *Journal of Educational Psychology*, *107*(1), 186. https://doi.org/10.1037/a0037107

Rickinson, M., Dillon, J., Teamey, K., Morris, M., Choi, M. Y., Sanders, D., & Benefield, P. (2004). *A review of research on outdoor learning.* National Foundation for Educational Research and King's College London.

Rios, J. M., & Brewer, J. (2014). Outdoor education and science achievement. *Applied Environmental Education & Communication*, *13*(4), 234-240. https://doi.org/10.1080/1533015x.2015.975084

Rong, X. L. (1996). Effects of race and gender on teachers' perception of the social behavior of elementary students. *Urban Education*, *31*(3), 261-290. https://doi.org/10.1177/0042085996031003003

Rubie-Davies, C. M. (2010). Teacher expectations and perceptions of student attributes: Is there a relationship?. *British Journal of Educational Psychology*, *80*(1), 121-135. https://doi.org/10.1348/000709909x466334

Rubie-Davies, C. M. (2006). Teacher expectations and student self-perceptions: Exploring relationships. *Psychology in the Schools*, *43*(5), 537-552.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14. https://doi.org/10.3102/0013189x015002004

Sjöblom, P., & Svens, M. (2018). Learning in the Finnish outdoor classroom: Pupils' views. *Journal of Adventure Education and Outdoor Learning*, 1-14. https://doi.org/10.1080/14729679.2018.1531042

Skinner, E. A., Chi, U., & The Learning-Gardens Educational Assessment Group 1. (2012). Intrinsic motivation and engagement as "active ingredients" in garden-based education: Examining models and measures derived from self-determination theory. *The Journal of Environmental Education*, *43*(1), 16-36.

Smith, P. S. (2020). *2108 NSSME+: Trends in U.S. science education from 2012 to 2018*. Horizon Research, Inc. https://files.eric.ed.gov/fulltext/ED611301.pdf

Sorhagen, N. S. (2013). Early teacher expectations disproportionately affect poor children's high school performance. *Journal of Educational Psychology*, *105*(2), 465. https://doi.org/10.1037/a0031754

Stevenson, K.T., Szczytko, R., Carrier, S.J., & Peterson, M.N. (2021). How outdoor science education can help girls stay engaged with science. *International Journal of Science Education*, *43*(7), 1090-1111.

Szczytko, R., Carrier, S., & Stevenson, K.T. (2018). Impacts of outdoor environmental education on attention, behavior, and learning outcomes for students with emotional, cognitive, and behavioral disabilities. *Frontiers*. DOI: 10.3389/feduc.2018.00046.

Thompson, J. J., & Windschitl, M. (2005). "Failing girls": Understanding connections among identity negotiation, personal relevance, and engagement in science learning from underachieving girls. *Journal of Women and Minorities in Science and Engineering*, *11*(1), 1-26. https://doi.org/10.1615/jwomenminorscieneng.v11.i1.10

Timmermans, A. C., Kuyper, H., & van der Werf, G. (2015). Accurate, inaccurate, or biased teacher expectations: Do Dutch teachers differ in their expectations at the end of primary education?. *British Journal of Educational Psychology*, *85*(4), 459-478. https://doi.org/10.1111/bjep.12087

Tran, L. U., & King, H. (2011). Teaching science in informal environments: Pedagogical knowledge for informal educators. In *The professional knowledge base of science teaching* (pp. 279-293). Springer, Dordrecht. https://doi.org/10.1007/978-90-481-3927-9_16

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. (M.Cole, V. J. Steiner, S. Scribner, & E. Sauberman, Eds.). Harvard University Press. (Original work published in 1934)

Wang, J. R., Wang, Y. C., Tai, H. J., & Chen, W. J. (2010). Investigating the effectiveness of inquiry-based instruction on students with different prior knowledge and reading abilities. *International Journal of Science and Mathematics Education*, *8*(5), 801-820. https://doi.org/10.1007/s10763-009-9186-7

Wang, V. C. (2018). Theory and practice of adult and higher education. *International Journal of Information and Communication Technology Education*, *14*(2), 84-87.

Wells, N. M., & Lekies, K. S. (2006). Nature and the life course: Pathways from childhood nature experiences to adult environmentalism. *Children Youth and Environments*, *16*(1), 1-24.

Weinstein, R. S. (2002). *Reaching higher: The power of expectations in schooling*. Harvard University Press. https://doi.org/10.5860/choice.41-0458

Weinstein, R. S., Gregory, A., & Strambler, M. J. (2004). Intractable self-fulfilling prophecies fifty years after Brown v. Board of Education. *American Psychologist, 59*(6), 511−520. https://doi.org/10.1037/0003-066x.59.6.511

Wilson, R. (2018). *Nature and young children: Encouraging creative play and learning in natural environments*. New York, NY: Routledge. https://doi.org/10.4324/9781315148533

Wistoft, K. (2013). The desire to learn as a kind of love: Gardening, cooking, and passion in outdoor education. *Journal of Adventure Education & Outdoor Learning*, *13*(2), 125-141. https://doi.org/10.1080/14729679.2012.738011

Woodcock, S., & Vialle, W. (2011). Are we exacerbating students' learning disabilities? An investigation of preservice teachers' attributions of the educational outcomes of students with learning disabilities. *Annals of Dyslexia, 61*(2), 223-241. https://doi.org/10.1007/s11881-011-0058-9

Woodcock, S., & Vialle, W. (2010) Attributional beliefs of students with learning disabilities. *The International Journal of Learning Annual Review, 17(*7), 177-192.

Zagona, A. L., Kurth, J. A., & MacFarland, S. Z. (2017). Teachers' views of their preparation for inclusive education and collaboration. *Teacher Education and Special Education*, *40*(3), 163-178.

Zoldosova, K., & Prokop, P. (2006). Education in the field influences children's ideas and interest toward science. *Journal of Science Education and Technology*, *15*(3-4), 304-313. https://doi.org/10.1007/s10956-006-9017-3

Appendix A
Interview Questions

1. How many years have you participated in the OSE program including this year? How many expeditions did your students participate in? How many of these were schoolyard vs. field expeditions? Which topics did you choose?

2. Do you attend OSE expeditions? If so, which ones and what was your role during the expeditions? Would you change your role in the future and if so, how?

3. Prior to your participation with OSE, how would you describe your comfort with science instruction?

4. Did this change during or following the OSE experience? If so, how and if not, why not?

5. Prior to your participation with OSE, how would you describe your comfort taking students outdoors for learning?

6. Did this change during or following the OSE experience? If so, how; and if not, why not?

7. What do you feel are the strongest features of the OSE program?

8. What part of the OSE programs did your students most appreciate?

9. What do you feel are the features of the OSE program that need improvement? How?

10. What part of the OSE program did your students least appreciate or fail to connect with? Do you have suggestions for modification?

11. Did you notice OSE' activities connect with some students more than others? Do you have ideas/groupings of students who benefit most from the OSE experience?

12. What did you notice about your students' behaviors in the outdoors compared to the classroom? Did any students surprise you in their reactions to the outdoor instruction?

13. Do you feel that the OSE experience supported your students' understanding of science concepts specific to 5th grade standards/objectives?

14. Do you feel the OSE experience exposed your students to science concepts beyond the standards?

15. Do you feel the OSE experience impacted students' attitudes about science?

16. Do you feel the OSE experience provided opportunities for you and your students to expand beyond science to other disciplines such as mathematics, social studies, language arts, art, or physical education? If so how and if not, can you describe how to expand it to be more interdisciplinary?

17. Do you have any other comments about the experience you would like to share?

Appendix B
Survey Questions

1. How often do you participate in OSE expeditions with your students?

Always Most of the Time About half the time Sometimes Never

2. How comfortable do you feel teaching science to your students?

Extremely comfortable, Moderately comfortable, Comfortable, Neither comfortable nor uncomfortable, Moderately uncomfortably, Extremely uncomfortable

3. How comfortable do you feel teaching science to your students through outdoor experiences?

Extremely comfortable, Moderately comfortable, Comfortable, Neither comfortable nor uncomfortable, Moderately uncomfortably, Extremely uncomfortable

4. To what degree has the OSE supported you in:
   a. Your science learning

A great deal, much, moderately, little, none

   b. Support your students' learning

A great deal, much, moderately, little, none

   a. Comfort level in teaching science

A great deal, much, moderately, little, none