PIERRO, REBEKAH CHACE, Ph.D. What Leads to Effective Science-Teaching Practices in Preschool Classrooms? An Examination of Teachers' Person, Context, and Time Influences on Science Teaching. (2019)
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Science is a natural conduit for children to learn about, and interact with, the natural world (McClure et al., 2017), yet early childhood classrooms are reported as having fewer science learning opportunities, and teachers have more missed teachable moments (Greenfield et al., 2009; Tu, 2006). In an effort to understand the influences of science instruction in early care and education classrooms, four preschool teachers were interviewed about their past and present science-related teaching and learning experiences. Classroom observations also were conducted to capture science-teaching practices and types of science disciplines covered in classroom activities. Using Bronfenbrenner's bioecological theory (Bronfenbrenner & Morris, 2006) as a framework, the person characteristics and the systems of context and the influence of time regarding these teachers' science experiences were considered within their ability to shape current classroom practices. The research questions focused on what past and present formal and informal science learning experiences influenced science-teaching practices and how those experiences affected the facilitation of science in these classrooms. Results indicated that prior science learning experiences and personal characteristics did influence science instruction. The systems of context plus past science learning experiences, as well as science-teaching beliefs, science self-efficacy, and science and math anxiety, were all critical to how these teachers implemented science activities in their classrooms. Links between specific aspects of the interviews and observations

provided evidence to support the importance of past and present science-related learning experiences for teacher development in current science-teaching practices.

WHAT LEADS TO EFFECTIVE SCIENCE-TEACHING PRACTICES

IN PRESCHOOL CLASSROOMS? AN EXAMINATION OF

TEACHERS' PERSON, CONTEXT, AND TIME

INFLUENCES ON SCIENCE TEACHING

by

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To all the moms getting PhDs—
I hope your advisors are as gracious and supportive as Dr. Linda Hestenes,
and know that I believe in you.

To Dr. Deb Cassidy—
Thank you for helping this rock geek feel more at ease among a sea of social scientists.

APPROVAL PAGE

This dissertation written by REBEKAH CHACE PIERRO has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

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CHAPTER I

INTRODUCTION

From an early age, all children can learn science concepts and ideas through their natural inclination to explore, observe, experiment, and discover what exists around them (National Research Council, 2012). In fact, studies have shown that children as young as 3 years old are able to practice the skills of reasoning and inquiry, skills used in critical-thinking and scientific literacy (National Research Council, 2007, 2012). Adults often misjudge and undervalue young children's ability to engage with science learning (National Science Teachers Associate, 2014).

Children are natural investigators and are infinitely curious about the world around them (Gelman & Brenneman, 2004; Jirout & Klahr, 2012). Instructing children in science is most effective when children can connect scientific concepts and ideas with tangible experiences (Counsell et al., 2016). Research indicates that teaching young children science through the process of inquiry (versus a static quantity of knowledge) allows children to acquire their knowledge without solely relying on an authority figure, which supports children's understanding of scientific concepts and ideas (Counsell et al., 2016; Gelman & Brenneman, 2004; McDermott, 1991). This concept of experiential science learning links with Bronfenbrenner's bioecological theory of development, the theoretical framework of this study, and his concept of proximal processes, or the consistent interactions children experience in their immediate environment (Bronfenbrenner & Morris, 1998).

Science instruction is also particularly useful for encouraging children's brains to function at a maximum level for learning (Metz, 2004). Young children can conceptualize the scientific process, ask scientific questions, and observe and investigate their environments and the larger world around them. This brain development leads to the eventual assimilation of the collected data into their own ideas, concepts that continue evolving with further maturation (National Research Council, 1996). The scientific process aligns closely with the development of critical thinking in children. Critical thinking is defined as the unending acquisition of trustworthy knowledge to support our beliefs and behaviors, and it is considered a higher-order skill within the brain, assisting with our executive functioning (Galinsky, 2010). Thus, teaching science to young children may assist them in becoming stronger critical thinkers.

Consistent with critical thinking development through science learning for young children are the benefits that come from STEM-infused play. Research demonstrates teachers critically influence children's engagement in science, technology, engineering, and math (STEM) (McClure et al., 2017). Confident and enthusiastic teachers who facilitate the acquisition of children's emerging knowledge of STEM concepts and practices, transfer their excitement and knowledge to the children in their care (Clements, 2015; McClure et al., 2017). Science instruction, however, is not conducted with young children with much consistency and is viewed as less important than other domains (La Paro et al., 2009; Torquati, Cutler, Gilkerson, & Sarver, 2013).

Many researchers develop teaching interventions with the thought that they may be able to increase the quantity of science that is currently taught in early childhood settings. Often the focus of these interventions is less about teacher fidelity in the long term and more on the intervention's short-term effectiveness (Maier, Greenfield, & Bulotsky-Shearer, 2013). Since teachers' beliefs on instruction and learning influence teaching practices (La Paro, Siepak, & Scott-Little, 2009), interventions need to address teachers' beliefs (Maier et al., 2013). This is difficult to do as teachers' beliefs are difficult to change once established (Nespor, 1987; Ogan-Bekiroglu & Akkoç, 2009). Thus, beliefs teachers hold about specific subject areas can influence their teaching practices and affect student learning outcomes. Therefore, it is critical that we have a greater understanding of the role past science experiences may play in teachers' instructional practices.

To further the field and our understanding of science teaching, it is valuable to consider teacher characteristics linked to science-teaching practices. These characteristics include beliefs, self-efficacy, anxiety, science-content knowledge, and pedagogical-content knowledge. Researchers and policymakers have investigated and established some of the factors of effective teaching, including research on effective science teaching, but little seems to be known about how past and present science-related learning and teaching experiences may influence teachers' science instructional practices. Ultimately, there seems to be a gap of information related to how teachers' past science experiences may influence their current teaching practices. This study seeks to explore what past and present science-related learning experiences (Bronfenbrenner & Morris,

1998) influence teachers’ science instructional practices and how the influence of earlier and current proximal processes may manifest in the classroom during science instruction with preschool age children. In the following chapters, the theoretical framework and methodology planned for the study are introduced. Bronfenbrenner's bioecological theory is discussed as the theoretical basis for the study.

CHAPTER II

THEORY

Different teachers will have diverse views of reality in terms of how they experienced science learning in the past and their methods for implementing science instruction in their classrooms. Understanding that multiple realities exist (rather than a single reality experienced by all of humanity) fits within a contextualist ontology, which aligns with the idea that perceptions of reality are based on the circumstances that influence people's lives (Tudge, 2008). It is important to consider teachers' perceptions of their science instructional practices and the experiences that have shaped these instructional practices. Past interactions with science, both in formal educational settings and informal learning opportunities, assist in shaping teachers' science instructional practices (Bronfenbrenner & Morris, 2006). This study will explore teachers' past science experiences and current science instructional practices while using Bronfenbrenner's bioecological theory as a framework. This will allow for an analysis of how teachers' past proximal processes may affect their science-teaching practices and how those early experiences may influence classroom practices relate to science education. The study will also consider how the proximal processes between teachers and the children in their care may influence teachers' science instructional practices.

Teachers are both the product of, and a primary producer in, proximal processes (Bronfenbrenner, 2000, 2001). In other words, teachers guide children's learning by implementing in their classrooms the lessons learned from their various previous experiences including during childhood and their development as teachers. This theory is described in detail in this chapter, including examples of how it may pertain to teachers learning science as students and implementing science learning in their classrooms.

Description of Bronfenbrenner's Bioecological Theory

Bronfenbrenner posited that an individual's background and biological features influenced the interactions that occur in their immediate environment (Bronfenbrenner, 2000). It is these interactions, or proximal processes, that he believed are the producers of human development (Bronfenbrenner & Morris, 2006). Proximal processes are critical in the development of an individual's beliefs, self-efficacy, and anxiety—factors that may be mirrored in teachers' beliefs, self-efficacy, and anxiety. These factors likely influence classroom practices, specifically, in this case, for science education. Using Bronfenbrenner's bioecological theory (2000, 2001) as a theoretical framework, individual science experiences from teachers' personal histories (including both past formal science education and past informal science-related experiences) may be associated with how teachers currently approach science instruction and science learning their classrooms.

The process-person-context-time (PPCT) model was developed by Bronfenbrenner (1994) to establish a means of testing his bioecological theory. The first letter "P" represents proximal processes. Proximal processes are "mechanisms that produce development" (Bronfenbrenner, 2000, p. 129). In other words, proximal processes may include teacher–child interactions, teacher education (preservice and in-service), and the continuous engagement in various learning activities, either in or out of the classroom or other environments, which may increase in complexity over time (Bronfenbrenner, 2000). Proximal processes are those mechanisms, whether it is interactions, environments, or other experiences, that continue to grow with increased intricacy across the life span. Bronfenbrenner and Morris (2006) discussed the importance of regularity in the PPCT model, specifically in interactions. The microsystems of homes and classrooms are the environments where primary interactions and much development take place. Influential proximal processes may include an individual teacher's experiences as a child or teenager, prior to college education and teacher training. In other words, previous formal and informal proximal processes around science learning may influence how preschool teachers interact with, and implement, current science-content knowledge and pedagogical process in their classrooms. Current proximal processes in their classrooms will also shape not just the learning and outcomes for the children in their classrooms, but also for the teachers themselves. Proximal processes are "the key to the theory, but their nature varies according to aspects of the individual and to the context" (Tudge, 2008, p. 68; see also Bronfenbrenner, 2000, 2001; Bronfenbrenner & Morris, 1998). Past proximal processes then become part of each individual's education and experience that are foundational for who they currently are as a 'person' in Bronfenbrenner's theory.

The second "P" in PPCT is for "person," which is described by Bronfenbrenner and Morris (2006) as the product of "the form, power, content, and direction of the proximal processes" (p. 798), including genetic components. In the case of this study, the teacher is the person in the PPCT model. The person appears twice in the bioecological model—when they are students and when they are teachers (Bronfenbrenner, 2000). Teachers are involved both from the perspective of the student (when the teachers themselves were students) who is having interactions with science and as the teacher who is providing children with scientific activities and instruction. If teachers feel confident in their abilities to understand scientific concepts and problem solving as both students and after, then that confidence may be evident in how they approach teaching scientific concepts and problem solving as teachers of young children. This concept aligns closely with a fuller description of the theory by Bronfenbrenner and Morris (2006) on the three person characteristics: demand, resource, and force characteristics. Demand characteristics are described as those characteristics that evoke an initial and instantaneous response from another person in social situations; therefore, physical traits and perceived personality traits are included within the demand characteristics (Bronfenbrenner & Morris, 2006). Resource characteristics are those that encourage interactions with proximal processes such as knowledge, experience, skill, and ability (Bronfenbrenner & Morris, 2006). In the case of science learning, this could include knowledge and skills acquired through teachers' experiences in camps during summers as children, or participating in Girl Scouts, or having a primary caregiver that enjoyed being outside. Resource characteristics also play a role in teacher–child interactions in terms of teachers communicating knowledge to the children in their care. Force characteristics are distinguished by Bronfenbrenner and Morris as developmentally generative characteristics, or those that "set proximal processes in motion and sustain" (p. 810) an individual's development, and developmentally disruptive characteristics, or those that impede, hinder, or potentially block future development. Developmentally generative characteristics include "differentiated response to, attraction by, and exploration of aspects of the physical and social environment (Bronfenbrenner & Morris, 2006, p. 810). An example of developmentally disruptive characteristics would be poor emotion regulation that disrupts proximal processes and hence negatively impact development (Bronfenbrenner & Morris, 2006). Force characteristics also include disposition, self-efficacy, and self-esteem (Bronfenbrenner & Morris, 2006). These characteristics are aspects of a person's being that influence how an individual may attack, or shy away from, a math problem, for example. In terms of personal agency, the theory represents these three characteristics in a continuum, moving from least dynamic (demand) to more dynamic (resource) to most dynamic (force) (Tudge, 2008).

The next component of the theory is context. Context in the PPCT model in Bronfenbrenner's theory is the "environment—both immediate and more remote—in which the processes are taking place" (2000, p. 130). Considered as a loosely nested model providing context for development, Bronfenbrenner's systems theory includes the following levels within the more holistic bioecological theory: microsystems, mesosystems, exosystems, and macrosystems (Bronfenbrenner, 2000). In this study, aspects of all four contextual systems will be considered for teachers as they develop from childhood to adulthood. The microsystems of interest are the teacher's immediate environs, which include interactions with their current work setting and those that took place in their earlier science-related educational environments. Other microsystems of interest for this study include those related to the teachers' home and school environments from childhood. Mesosystems are the connections between different microsystems, such as family happenings and school happenings. Open-ended interview questions about teachers' previous experiences related to their science education, including classes and workshops as preservice and in-service teachers, will attempt to gain a shared understanding with the participants on their lived experiences with science learning and teaching at both the microsystem and mesosystem levels. There are also questions about past childhood experiences related to science. These questions will be helpful in potentially linking participants' past science educational experiences, or their previous microsystems, to participants' current science-teaching practices.

The next level in the systems theory is exosystems. Exosystems are links between experiences associated with social settings in which the individual (teacher) has no active role yet impact, and are impacted by, the immediate environment. An example of this may be how funding situations change (i.e., salary cuts), which may impede teachers' abilities to provide thoughtful instruction or engage their classes in a new science activity due to a lack of funding or availability of resources. A particular exosystem issue for preschool teachers that would affect the amount of time on science activities is the emphasis on literacy by local program directors and school administrators. With only so many hours in the day, teachers may feel pressure to focus on literacy from forces outside of their classrooms (Saçkes, 2014; Tu, 2006).

Encompassing exosystems, mesosystems, and microsystems, macrosystems incorporate the cultures in which individuals reside. This can include society as a whole, or religious, racial, ethnic, socioeconomic, or regional groups within society, as individuals from these groups typically overlap in their beliefs, values, resources, practices, and share a common identity (Tudge, Merçon-Vargas, Liang, & Payir, 2017). For teachers, macrosystems may assist in defining them over the course of their personal history within the context of their community. An example of how a current macrosystem in our society might influence teachers is, again, the pressure to teach language and literacy that is driven by national or state policy, which may equate to less time for science learning opportunities in classrooms (Greenfield et al., 2009; Saçkes et al., 2011). This example may also overlap with macrotime, as this could be a function of historical time (discussed in more detail in later paragraphs), but it is also a factor of the educational culture that sits within the historical time. The example is different from the exosystem example of pressure by program directors and school administrators to teach literacy because the pressure has two different origins; the macrosystem pressure is a larger scale (i.e., state or national changes in curriculum standards or teaching requirements) than the exosystem drivers, which are more localized to a specific program or corporate childcare structure.

In terms of this study, the microsystem interactions that teachers experience over time regarding science may directly affect the way they teach science today. The mesosystem is critical to consider as well. Bronfenbrenner and Morris (2006) pointed out that an escalating effect is expected when there is instability in the microsystem because "at this higher level of environmental structure, similarly disruptive characteristics of interconnected microsystems tend to reinforce each other" (p. 820). Thus, if issues exist related to science education in the microsystem, then they are amplified in the mesosystem. In other words, if science is minimized through experiences with programs' administration, including center directors and other teachers and staff (administrative microsystems) and the children seem not as interested in science (classroom microsystem), then these mesosystem influences may diminish teachers' beliefs about the importance of science and decrease their science instruction. Finally, the macro-level system dynamic is also salient when considering teachers and science education and instruction. Macrosystems involve the cultural environment in which individuals live (Bronfenbrenner, 2000). If a culture of acceptance of science educational excellence existed during childhood, then this will play a role in how teachers approached science as students (Early Childhood STEM Working Group, 2017) and, in turn, shape their directive beliefs (Bronfenbrenner & Morris, 2006).

Time is the historic period of the person's life. Bronfenbrenner and Morris (2006) described the three levels of time: microtime, mesotime, and macrotime. Microtime is closely related to the proximal processes, and the continuous (or lack thereof) interactions that occur within proximal processes (Bronfenbrenner & Morris, 2006). In terms of this study, microtime may include the interactions that occur during a science activity (Tudge, 2008). Mesotime is the days or weeks that science (or other) learning interactions take place with regularity (Bronfenbrenner & Morris, 2008; Tudge, 2008). This includes teachers covering a unit on weather or forces and motions over the period of several days to several weeks. Macrotime refers to the historical time and the events that occur over the life of the developing individual (Bronfenbrenner & Morris, 2008; Tudge, 2008). In the case of this study, the sociocultural issues related to the lack of women in science (and other STEM fields) influenced how many early care and education teachers, who are predominantly female, may view science during their formal education. Another example is the development of the state level standards as a specific area that would affect teachers and their classroom practices. State standards should, in turn, affect children and their learning over time via proximal processes that occur between the teachers and the children in their care. Another important aspect to consider is the change over time with the increased emphasis on accountability of teachers through assessment of children's learning. Again, the implementation of standards may influence teachers at the exosystem level through program directors and school administrators. It may also influence teachers at the and the macrosystem level through state and or national policy changes concerning curriculum standards or teacher education requirements. It is important to note that the influence of both of these systems of context by the implementation of standards are influenced over historical time, known in the theory as macrotime.

In the context of this paper, macrotime also is considered salient due to changes in instructional practices and attitudes concerning science from a historical perspective. Changes in state standards will affect teachers' classroom practices (both processes and content areas), and potentially impact children's outcomes. In general, Bronfenbrenner's bioecological theory provides the architecture for examining what has influenced teachers and their classroom practices. These four factors—proximal processes, person, context, and time—are interconnected. As mentioned in previous examples, it is possible that aspects of preschool teachers' past and present science learning experiences, person characteristics, context, and time have overlapped to influence the teaching practices of the teachers in this study. Bronfenbrenner's theoretical framework will be used as a foundation in the following review of the literature.

CHAPTER III

LITERATURE REVIEW

Having a scientifically literate society allows for the understanding of science-related concepts and ideas that influence overall knowledge of various aspects of our environment, world, and universe (Chalufour, 2010). Early science experiences and learning encourages children to develop critical thinking skills (Galinsky, 2010) and positively influences brain development to maximize learning (Metz, 2004; Yoon & Onchwari, 2006). Therefore, these critical early experiences with science are important for those who are, and are not, interested in pursuing science employment opportunities as adults.

Multiple professional societies and federal agencies affiliated with science, education, and young children such as the National Science Teachers Association, National Association for the Education of Young Children, National Science Foundation, U. S. Department of Education, and U.S. Department of Health and Human Services, assert the importance of science learning in children's development and suggest that exposure to science concepts and skills will lead to increased school readiness (Brenneman, 2011; Pendergast, Lieberman-Betz, & Vail, 2017). Most states in the U.S. have established science learning guidelines for preschool (Brenneman, Stevenson-Boyd, & Frede, 2009). However, Tu (2006) observed 20 preschool teachers in their classrooms and found formal and informal science instruction was only conducted 4.5%

and 8.8%, respectively. In other words, the teachers in Tu's study favored content areas unconnected to science nearly 87% of time observed (2006). Clearly professionals recognize the importance of science learning in young children; however, commitment to high quality science teaching is lacking.

In this chapter, the concept of scientific inquiry is explained and research surrounding high quality science teaching is introduced. Teacher identity, within the context of science teaching, is reviewed. Research on teachers' Person characteristics, including their science-teaching beliefs, science-teaching self-efficacy, science-teaching anxiety, and personal science educational experiences are outlined. Research around teachers' and young children's science-content knowledge and the types of science taught in early childhood settings are discussed. As framed by the bioecological theory, it is valuable to consider how teacher characteristics and other factors mingle with teachers' past and present proximal processes to shape their classroom science-teaching practices.

Teaching Through Scientific Inquiry

Within the last 25 years, scientific inquiry has become the primary mechanism around which both teaching and learning science is centered and was specifically listed as such in the National Science Education Standards for K-12 students and teachers (National Research Council, 1996). The definition of scientific inquiry by the National Research Council is that it is a multidimensional endeavor involving observing natural phenomenon, asking questions, researching the observed phenomenon; investigating other aspects of the phenomenon, reviewing known information after assessing experimental results, using tools to acquire and interpret data, suggesting explanations and new hypotheses, and discussing results (1996). From this definition of scientific inquiry and the link between the development of critical thinking skills and the scientific process, the building of science processing skills is rooted within the active work involved in scientific inquiry (Shahali, Halim, Treagust, Won, & Chandrasegaran, 2017). This is salient not only for scientists who have developed science processing skills (Meador, 2003), but also critical for students to engage in inquiry to further their understanding of science (Gillies & Nichols, 2014) and to participate as scientifically literate citizens (Walan & McEwen, 2017).

Unfortunately, many beginning teachers (Avraamidou, 2017; Roehrig & Luft, 2004), struggle with a lack of science-specific content knowledge (Greenfield et al., 2009) and a lack of science-specific pedagogical-content knowledge (Chalufour, 2010; Cochran, DeRuiter, & King, 1993). The research for early care and education suggests, like in the K-12 educational system, a lack of preparation in science teaching and the scientific method, leading to feelings of low self-efficacy in science teaching (Gerde, Pierce, Lee, & Van Egeren, 2018; Greenfield et al., 2009; Hamlin & Wisneski, 2012). Feelings of low self-efficacy in science can influence the proximal processes related to teachers' engagement with young children in science inquiry and instruction. This reflects the Person resource and force characteristics and past systems of context teachers experience during their development—as posited in Bronfenbrenner's bioecological theory (Bronfenbrenner & Morris, 1998). These feelings may have specifically been influenced by the microsystems of past classrooms the teachers experienced as students as well as their classrooms as preservice teachers. With this in mind, research associated with exemplary science teaching is discussed next.

Exemplary Science Teaching

Research suggests the primary factors of effective teaching include teacher preparation and knowledge of teaching and learning, teacher beliefs, knowledge of subject matter, experience in classrooms, and the qualifications associated with teacher licensure (Darling-Hammond, 2006; National Council for Accreditation of Teacher Education, 2006). Student factors also play a role in effective teaching such as student beliefs, practices, and knowledge (Bell, Gitomer, McCaffrey, Hamre, & Pianta, 2011; Hamre et al., 2013), as the interactions within classrooms are bidirectional. Only a few studies examine exemplary science teaching practices. Another study conducted by Tobin and Fraser (1990) in Australia found four major trends used by exemplary science teachers in Australia in grades 3, 5, 6, 7, and high school. The major trends included teaching strategies that enabled continued student engagement, the use of teaching strategies intended to facilitate students' increased science understanding, the use of teaching strategies that stimulated students' participation in science learning activities, and the use of teaching strategies that supported a positive classroom learning environment (Tobin & Fraser, 1990). Overall, a commonality among these trends is the quality of the interactions between the teachers and the students and how those high-quality interactions were reflected in the learning environment.

Concerns also center on the need for preservice teachers to develop science-content knowledge, science-specific pedagogical-content knowledge (Brenneman et al., 2011; Kalchman & Kozoll, 2016), and the knowledge of science learning trajectories for young children (McClure et al., 2017). This knowledge is necessary for supporting children's learning and understanding of science and meaningfully engaging with children during their science-learning experiences and is typically developed through proximal processes in the microsystems that teachers experienced at home as children and in school as students. Garbett (2003) investigated how preservice teachers perceived their science-content knowledge and found that most of the preservice teachers held unrealistic views of their level of content knowledge. The teachers also were unaware of how a lack of science-content knowledge might hinder their abilities to enhance children's science learning. These results highlight the importance of reflection, the need to foster confidence in preservice teachers as they learn about science and encouraging preservice teachers to "interact meaningfully with children in the teachable moment rather than provide ready, factual answers to their questions" (Garbett, 2003, p. 478).

Other important factors affiliated with science learning include teacher identity and Person resource and force characteristics of teachers associated with science instructional practices. This includes teachers' beliefs and self-efficacy with science teaching, anxiety teachers may experience related to science, and personal education experiences. All these factors are discussed in the next sections.

Influence of Teachers' Science Identity in Science Teaching

Research conducted on teacher identity as related to science teaching focuses primarily on elementary and secondary education teachers. Although there is a growing awareness in how science teaching and learning in early childhood education can assist in increasing children's scientific literacy, many early care and education teachers are not prepared to foster children's understanding of scientific concepts (Chalufour, 2010). Briefly, teacher identity is defined as how teachers depict themselves in their classrooms through their views, opinions, actions, and knowledge of both content and pedagogy (Avraamidou, 2014), and aligns with the Person resource and force components discussed as part of Bronfenbrenner's bioecological theory (Bronfenbrenner & Morris, 1998). Identity is not static, and is conceptualized as a fluid construct, developing through continuous experience (Akkerman & Meijer, 2011) and influenced by interactions within various social contexts (Avraamidou, 2014). Teacher identity in this study is situated specifically within the context of science teaching and was referred to as science identity. Science identity for this study was defined through a model developed by Carlone and Johnson (2007) that was used to examine the science experiences of 15 women of color throughout their undergraduate and graduate studies in science and into science-related employment. This model incorporated a view of science identity that encompassed both how the women interpreted their science experiences and how society views and structures possible meanings (Carlone & Johnson, 2007). In their model, science identity has three, potentially overlapping, dimensions: performance, recognition, and competence (Carlone & Johnson, 2007). Performance was described by the authors as "social performances of relevant scientific practices" (p. 1191), while recognition was related to being viewed and viewing oneself as a "science person." Competence was connected to one's science-content knowledge and comprehension of science topics and is not as easily witnessed as performance (Carlone & Johnson, 2007).

In this study, when the teacher participants were asked about their science identity, the goal was to understand how the teachers viewed themselves within the overlapping structure involving the three dimensions defined by Carlone and Johnson. Without weighing down the teachers with academic definitions of performance, recognition, and competence, how did the teachers see themselves in terms of science teaching and learning? Were they strong in content knowledge, but lacking in performance? Did they recognize themselves as capable in the world of science knowledge and inquiry? These questions were addressed through asking about the teachers' science identity and inquiring about their feelings regarding their science-content knowledge.

Teacher identity investigated through ethnographic interviews of elementary teachers outlined the biases and contradictions that abound in educational policy and school practices (Carlone, Haun-Frank, & Kimmel, 2010). The prevailing understanding of standards-based science required from National Science Education Standards often places teachers as the unit of analysis when considering the concerns raised about biases and contradictions in current policy and practices, citing issues of teachers' beliefs (Anderson & Helms, 2001) and changes in their roles (Crawford, 2000) as impediments. However, teachers in the study by Carlone and colleagues were committed to standards-based science teaching and worked resourcefully around issues, both technical and otherwise, to give their students their best within the "climate of high-stakes accountability" (2010, p. 942). This is not always the case. Elementary teachers frequently decreased the amount of time for science and lessen their efforts to make science central to their classroom learning experiences in order to increase test scores in reading and math (Carlone et al., 2010; Griffith & Scharmann, 2008; Lee & Houseal, 2003). Early care and education teachers, like their elementary education counterparts, also must deal with the tension between class time limitations and teaching all domains written in early learning standards (Pendergast et al., 2017; Tu, 2006).

For those teachers with a strong science-teaching identity, creative solutions may make it possible for them to continue to offer science-learning opportunities in the face of the obstacles of time constraints and curriculum focusing exclusively on language and literacy. The elementary teachers chose to incorporate science because they "were passionate in their commitment to students and what was best for students. They expressed a moral responsibility to the future of their students, science, and society" (Carlone et al., 2010, p. 952). They wanted to provide their students with the space to acquire scientific knowledge while also conveying that science is about exploration and wonder. The teachers' strong desire to implement science instruction while dealing with time constraints and curriculum limitations is an example of how Person force characteristics from Bronfenbrenner's bioecological theory may influence teacher interactions with students (Bronfenbrenner & Morris, 1998). This concept of science as wonder permeates the literature in early care and education science work (French, 2004; Gelman & Brenneman, 2004), with children being innately curious about their world and how the naturally investigate and inculcate information (Gopnik, 2012; Jirout & Klahr, 2012).

Influence of Person Characteristics in Preparing Effective Science Teachers

All three of the Person characteristics—demand, resource, and force—can influence preservice teachers' learning and teaching experiences as they prepare for becoming professionals. Four Person characteristics to be discussed within this study are teachers' science-teaching beliefs, teachers' science self-efficacy, teachers' science and math anxiety, and teachers' science-education experiences. Teachers' science-teaching beliefs, science self-efficacy, and science and math anxiety are Person force characteristics that influence motivation and can "dramatically affect the proximal processes" in which teachers are engaged (Tudge et al., 2017, p. 49). Collectively, teachers' science-education experiences are a Person resource characteristic that was, in part, influenced by past proximal processes involving science learning when the teachers were children. The teachers' science anxiety discussion will include research involving science and math anxiety since more research exists on math anxiety, both from a student perspective and a teacher perspective. Teachers' science-education experiences are relevant in terms of teacher preparation practices for how teachers are prepared to teach science. Each of these Person characteristics overlap with past proximal processes that the children experienced when they were students and more current proximal processes that the teachers have with children daily to influence current science-teaching practices.

Influence of teacher beliefs about science teaching. Beliefs are critical in considering how teachers approach nearly every aspect of teaching and can surpass teachers' academic knowledge when making classroom decisions (Wallace, 2014). Pajares (1992) defines beliefs as a cognitive process centered on principles and views that teachers have on their work, subject matter, and students, which influences their practices. Research around teacher beliefs is certainly not exclusive to science teaching, but few studies focus on teachers' beliefs about science education. Most of these studies focus on secondary education with a few examining elementary or preschool science education. In the current study, teacher beliefs about science teaching will be defined as teachers' views regarding the process of children's science learning, opinions on scientific inquiry, and thoughts on how teachers may best achieve goals affiliated with science teaching and learning (Avraamidou, 2017).

Studies show preservice and in-service teachers feel discomfort with their lack of science-content knowledge (Cho, Kim, & Choi, 2003; Kim & Tan, 2011), limited conceptual comprehension of science ideas and processes and increased uneasiness and anxiety in teaching science (Garbett, 2003; Saçkes et al., 2011). Research also suggests unease over classroom management and safety issues (Kim & Tan, 2011), and external pressure to focus on language and literacy with minimal time to integrate science (Brenneman et al., 2009; Clements & Sarama, 2014; Duschl, Schweingruber, & Shouse, 2007; Greenfield et al., 2009; Saçkes et al., 2011). From research conducted in the elementary and secondary science education arenas, pre-service teachers also have set beliefs about the definition of what constitutes science (Avraamidou, 2017; Kim & Tan, 2011). Moreover, many early care and education teachers struggle with how to appropriately incorporate science into their classrooms with regards to the needs of the young children in their care (McClure et al., 2017).

To examine how preservice teachers' beliefs change over the duration of a science teaching training program, Ucar (2012) used three different instruments to assess how the teacher training program influenced the preservice elementary teachers' views on science, scientists, and science teaching. The results indicated that the strongest influence of the teacher preparation program related to views on science teaching, namely that views held by the participants on science teaching switched from being teacher-centered to student-centered (Ucar, 2012), a change in the students' Person components. As most science teaching recommendations suggest, most classroom activities and explorations should be child-initiated. This result supports the importance of preservice science teacher training.

Influence of teachers' science self-efficacy. As the theoretical framework of this study is centered on Bronfenbrenner's bioecological theory, it is critical for this study to recognize the importance of proximal processes and context and time, as well as the person, in the development of science self-efficacy for teachers. As mentioned in the theory chapter, self-efficacy is a Person force characteristic within Bronfenbrenner's bioecological theory (Bronfenbrenner & Morris, 2006). Viewing the concept of self-efficacy through the lens of Bronfenbrenner's bioecological theory allows for the development of the teachers' self-efficacy to be examined in its entirety, including constructs of past science-learning experiences and the science-related culture of the teachers' family, as these components may have influenced teachers' science self-efficacy.

Generally, teachers' self-efficacy has been linked to children's learning success (Woolfolk & Hoy, 1990), and high teaching self-efficacy is related to better student outcomes and greater expectations for student academic attainment (Tournaki & Podell, 2005). For early care and education teachers, higher self-efficacy predicted the use of developmentally appropriate practices in classrooms (McMullen, 1999). By comparison, low teaching self-efficacy in preschool classrooms may negatively influence developmentally appropriate practices that result in lower outcomes (Guo, Piasta, Justice, & Kaderavek, 2010). Although these cited studies are not science specific, similar findings were reported when science was considered more explicitly (Gerde et al., 2018; Greenfield et al., 2009).

Although the importance of high teacher self-efficacy is apparent, it can be difficult to build self-efficacy in science within the context that many early care and education teachers are situated (Gerde et al., 2018). The focus on children's language and literacy development within early care and education programs and teacher preparation programs minimizes the time teachers may spend working with children on science activities (Early et al., 2010; Maier et al., 2013; Tu, 2006). Moreover, many early care and education teacher preparation programs do not provide science methods courses and specific science learning opportunities to their students (Brenneman et al., 2009).

In fact, recent work reported by Gerde and colleagues stated that self-efficacy was highest for teachers in the domain of literacy (2018). By comparison, within the same study, teachers' self-efficacy was significantly lower for science and lowest for math. The study also found that although there was some variety across classrooms, most teachers engaged in science with far less frequency than literacy, held few science learning resources, and offered little science instructional assistance and encouragement to children (Gerde et al., 2018). Interestingly, unlike literacy or math, teachers' self-efficacy for science was connected to the amount they engaged in science teaching with children, and education and experience were not predictors of the teachers' science self-efficacy. Higher levels of teacher educational attainment, however, correlated positively with more science instructional support for children. To improve and build children's scientific literacy, this study implies that early care and education preparation programs and in-service professional development for teachers should include more opportunities for learning science content and science-teaching practices "rather than focusing exclusively on literacy" (p. 70). This learning compartmentalization between subject domains comes at the expense of the development of both teachers and children, as both groups have enhanced self-efficacy with integration of science with other subject matter (Harlan & Rivkin, 2000). Overall, teachers reporting high self-efficacy with literacy and low self-efficacy with science may be less inclined to integrate science into their classroom activities (Gerde et al., 2018).

Influence of teachers' science anxiety. Feelings of anxiety around content areas like science or math leads to interference in overall achievement as well as in teaching practices. Math anxiety is described as a negative reaction to situations involving math, mathematics calculations, and, sometimes, numbers alone (Woodard, 2004). This anxiety is "a feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (Richardson & Suinn, 1972, p. 551). Math anxiety is associated negatively with achievement in math (Lee, 2009). Anxiety related to science is not as readily defined, but research indicates that science anxiety connects implicitly to knowledge of science concepts (Watters & Ginns, 1994), and older students in elementary school in the United States report lower science self-efficacy when experiencing greater science anxiety (Britner, 2008; Britner & Pajares, 2006).

Research on anxiety about doing math suggests that the more anxious female first- and second-grade school teachers were about math, the lower some girls' math achievement was by the end of the year (Beilock, Gunderson, Ramirez, & Levine, 2010). The same girls who experienced a drop in their math achievement also were more likely to accept the stereotype formed from traditional gender ability beliefs that "boys are good at math, and girls are good at reading" by the end of the year (Beilock et al., 2010, p. 1860). The levels of math anxiety expressed by the female teachers did not influence the boys. However, the girls who confirmed the stereotype as influenced by the female teachers experiencing high math anxiety exhibited much lower math achievement than girls who did not confirm it (Beilock et al.). Similar to early care and education, teachers in early elementary school are predominantly female. Thus, female teachers who experience math anxiety may create issues of anxiety within the young girls in their classes who believe the long-perpetuated stereotypes regarding girls and math, and boys and reading. These stereotypes related to the marginalization of women and girls in science that have existed for decades are part of the macrosystem and the chronosystem of development influencing teachers and the children in their classrooms. Research also indicates that preservice teachers who have little to no math anxiety are more confident in elementary science and math instruction than those who experienced higher levels of math anxiety (Bursal & Paznokas, 2006).

A study conducted in Turkey by Bekdemir (2010) reported that 53% of elementary preservice teachers expressed moderate math anxiety and a further 6% had high math anxiety. Most of the participants who disclosed that they experienced math anxiety started having such feelings after being students in classrooms in which teachers triggered the initial math anxiety either by their teaching (i.e., instructors' hostility, instructors' ineffective teaching, difficult subject content, etc.) or personal (i.e., test anxiety, negative attitudes toward math, negative peer pressure, student's personality, etc.) behaviors (Bekdemir, 2010). As math-anxious students progress through school, they bring their anxiety with them into high school and college. The result is that when preservice early care and education teachers then finish school and head into their own classrooms, they, once again, bring their math anxiety with them and pass it along to their own students (Bekdemir, 2010).

Considering teachers specifically, Levine (1993) defines math-teaching anxiety as nervousness and apprehension occurring to teachers related to math problem-solving and teaching, specifically math theories, formulas, overall math concepts, and includes memories of math-related disappointments (as cited in Peker, 2009). Pre- and in-service teachers described a few of their math anxiety symptoms as extreme nervousness, sweaty palms, self-talk of a negative tone, a lack of concentration, losing the ability to hear students, and losing the ability to cope with noise (Peker, 2009).

Similar to math anxiety, science anxiety also may be experienced by teachers. As reported in a summary of numerous studies by Ramey-Gassert and Schroyer (1992), the poor self-efficacy related to science teaching experienced by elementary teachers resulted in feelings of science anxiety and negative attitudes related to science and science teaching that has developed into an "unwillingness or hesitancy to spend time teaching science" (Schoon & Boone, 1998, p. 555). Poor science-teaching behaviors established early in teachers' preservice experiences, coupled with negative science-learning experiences when the teachers were students, is considered one of the primary modes of causing science anxiety (Watters & Ginns, 1994), which is discussed more in the next section.

Influence of teachers' science education experiences. Negative past experiences with science from when teachers were students may influence their approach to science instruction in their classrooms as teachers (Edwards & Loveridge, 2011; Gerde et al., 2018). Preservice teachers' prior learning experiences related to learning science may influence their beliefs about their ability to teach science. Specifically, teachers' recollections of their teachers' behaviors and attitudes, the past science-related learning opportunities experienced by teachers when they were students, are related to preservice teachers' development of positive beliefs of teaching self-efficacy (Watters & Ginns, 1994). Thus, being taught by positive and effective teachers may influence becoming a positive and effective teacher. Further, Watters and Ginns reported that those preservice teachers who expressed a positive attitude concerning science attributed their positive feelings to an interest in science activities, practical work related to science, excitement about scientific topics, and enjoying science in terms of the "quest for knowledge" (p. 353) and for social altruism. The same study listed reasons for not liking science that related to modes of learning, such as no discussion, too theoretical, boring, too much writing, and irrelevant content. Many preservice teachers from this study contended that the opportunities for discussion were helpful in improving their science-teaching self-efficacy. This finding indicated that positive science learning experiences during preservice training may assist in ameliorating anxieties and negative feelings about science learning and teaching. The importance of discussing science ideas and questions links to effective science pedagogy for young children as well (Worth & Grollman, 2003).

The Person resource and force characteristics of teachers discussed in this section (science-teaching beliefs, science self-efficacy, science and math anxiety, and science-education experiences) are foundational to the development over time of the preschool teachers. The various pieces of the PPCT model from Bronfenbrenner's bioecological theory provide a map of human development for this study. These Person characteristics influence the proximal processes teachers experienced as students in classrooms. Beliefs, self-efficacy, anxiety, and educational experiences reflect Person demand, resource, and force components, as well as how the systems of context and time, affect the development of teachers, which then influences the types of science content and learning (proximal processes) provided in the classroom with children. In other words, the layering of the teachers' Person characteristics with the children's Person characteristics plus the microsystem of the classroom and its materials plus all the time components (i.e., microtime, mesotime, and macrotime) all influence the proximal processes that teachers have with children.

Types of Science Taught in Early Childhood Settings

Earth and space science, life science, and physical science are the three primary domains of science that may be addressed in curricula that contain science components. Aspects of engineering, the practical applications of science joined with math, might be integrated in some early childhood education curricula, but are not necessarily addressed on its own. In this section, concepts potentially covered in classrooms and brief descriptions of the research within these science domains will be discussed. This summary highlights the lack of work done in some of the domains, while also showing the importance the different domain areas may be in the development of the teachers through past and present interactions and engagement with the science domains themselves.

The research on young children's earth science learning is dated (Saçkes, 2015). In fact, there is a distinct lack of research on earth concepts, such as rocks and minerals and soil science (Saçkes, 2015). This is surprising in that many concepts within geology, defined as the study of the history of the earth and includes rocks, minerals, volcanoes, dinosaurs, fossils, etc., are topics that are of interest to young children. Research commonly centers on young children's understanding of rain and clouds including evaporation and condensation; wind and its effect on clouds; and thunder and lightning (Saçkes, 2015). Other topics within earth science often covered in classrooms includes weather, nature and environmental science.

By comparison to earth science, space science education in early care and education classrooms receives much more attention from researchers. Most studies focus on the shape of the earth; the day and night cycle; seasons; and lunar concepts (Saçkes, 2015). Vosniadou and Brewer (1992) conducted interviews with 6- to 11-year-old children on their understanding of the shape of the earth. The results indicated that children used a small set of mental images of the earth in order to explain the shape of our planet, and that children's presuppositions of concepts such as solidity, gravity, and up and down, will influence their interpretations and beliefs about the earth (Vosniadou & Brewer, 1992, 1994).

Research on children's understanding of life science concepts has been centered on four areas of learning: the distinction between living and non-living things; the growth of living organisms; germs and how they are passed from one being to the next; and plants and animals (Akerson, Weiland, & Fouad, 2015). Trundle, Mollohan, and McCormick Smith (2013) proposed a conceptual model integrating inquiry life science learning: "Play (engage, notice, question, wonder); Explore (predict, observe, record data); and Discuss (share data, reflect, construct explanations, develop new questions, draw conclusions)" (pp. 120–121). As assessment is encouraged throughout, the authors found this model to be an effective blueprint for engaged life science learning.

Physical science concepts often covered during the early childhood years include heat and temperature; forces and motions; float and sink; electricity; light and shadow; and matter. While a broad body of research exists on physical science concepts, there are three helpful implications for science instruction within the physical science domain highlighted in a recent review by Hadzigeorgiou (2015). The first implication is that using children's ideas may assist designing science instruction. The second is the salience of teachers' careful use of language. The third implication is the importance of teachers' awareness in terms of the sequence of science concepts instruction. The three implications listed support effective science learning through proximal processes, like experiential learning, teachers' intentional language use, and teachers' knowledge of science instructional progression, in the microsystem environment.

In general, the research in how children view and understand the different science domains is salient for two reasons. First, the body of work summarized in this section provides a general understanding of how researchers investigate young children's conceptualizations of the science domains and how some of those domains are taught to young children. The science domains are not the same, yet classroom science work is "often taught through isolated, superficial, and overly-planned teacher-centered experiments having no connection to the broader curriculum, void of scientific language" (Pendergast et al., 2017, p. 45). Isolating the science domains minimizes the effect that can be achieved when the science domains are integrated, highlighting the teamwork and wonder of different scientists (or prekindergartners) working together to acquire new knowledge. The second reason is that understanding the difference between earth and space science, life science, and physical science will aid in delineating how teachers may be more confident with one type of science over another. For example, a teacher who grew up in a more rural setting assisting with the family garden may be more confident in teaching about life science over physical science or earth and space science. Exploring these past science experiences with the teachers will assist in answering questions regarding which proximal processes, person characteristics, and contextual systems over time were most influential in their science teaching and how those teachers were affected by these pieces of Bronfenbrenner's bioecological theory.

Historical and Cultural Shifts on Science

Overlaying the previously mentioned domains of science education for young children is the changing views of the importance and appropriateness of science for preschool-aged children. Research indicates that young children's foundational knowledge of science concepts and inquiry skills are underestimated by adults who believe that science information is too abstract and difficult for children to learn (Brenneman, 2011; Metz, 2009). Other issues are the recent changes with increasing the accountability over school readiness and the academic preparation of young children in early care and education classrooms. The change of emphasis of academic instruction links with the macrotime influences in which teachers work and the influences historical time has on their science instructional practices. As the areas of appropriateness and teacher accountability have changed over time within our society, it is salient to consider how they may influence teachers and their science instructional practices.

Another piece to consider in terms of changes with history and culture over time is the view of women in science. Historically, society and communities of practice within science itself have excluded women. This unequal representation hurts the collective power of the scientific community as the diversity of experience, knowledge, perspectives, and skills is lessened (Light & Micari, 2013). Overall the numbers of girls and women in science is growing, but not quickly (James, 2009). Moreover, the workforce for early care and education is predominantly female, and it is possible that teachers' past science experiences may have been adversely affected by macrotime-related views that minimized women's contributions to the scientific community.

Purpose of Study

As major decisions in a study stem from the purpose of the research (Patton, 2015), it is important to clearly state the purpose of this study and how that fits within the study design, data collection and analysis, and result reporting. The purpose of this study is to contribute to the foundational knowledge of what past and present science learning experiences influence preschool teachers' science instruction in their classrooms, and how those experiences influence teachers' classroom practices. This study is based on providing information related to the teachers' science instructional practices in early care and education settings by examining the lived experiences of preschool teachers' past and present science experiences. This involves exploring the lived experiences of teachers through descriptive phenomenology, as this type of strategic inquiry will allow for a deep dive into how individual teachers, who are considered by those around them to be strong science teachers, have developed their science-teaching skills.

Research Questions

This study is intended to provide information, through the lens of Bronfenbrenner's bioecological theory (Bronfenbrenner & Morris, 2006), on the connection between teachers' past science learning experiences and personal assessments of their science-content knowledge and how well they integrate science activities into their classwork with preschool children. This study will examine the lived experiences of in-service teachers through both observing their science instruction in classroom and interviewing them regarding their past science learning experiences, both formal and non-formal, and how they judge their science-content knowledge. Specifically, the following research questions are addressed in this study.

1. What are the past and present science learning experiences that influence teachers' science instruction in preschool classrooms?
2. How do the past and present science learning experiences influence teachers' science instruction in preschool classrooms?

Descriptive phenomenology is a strategy of inquiry useful for acquiring the information considered in this study about preschool teachers because the methodology allows for me to gain insight into how teachers' past and current experiences have influenced their perceptions of, and relationship with, science. By using descriptive phenomenology, the researcher's personal beliefs and biases and suppositions are acknowledged (Gearing, 2004), while also allowing the participants within the study to convey their personal beliefs and biases and suppositions in their own words. The teachers had the opportunity to review the information that they shared with me, which is a beneficial aspect of descriptive phenomenology. Specifically, this investigation into teachers' lived experiences used Moustakas (1994) method associated with descriptive phenomenology through observation and interview (Creswell, 2013) as framed by Bronfenbrenner's theory. The data collection and analytic strategies used in the study are discussed next.

CHAPTER IV

METHOD

Sample

The sample for this study included four preschool teachers from preschool classrooms in Guilford County, North Carolina. This purposeful sample of teachers were asked to participate because of their noted achievement in teaching science in their classrooms. Homogeneous purposeful sampling was used to explore the characteristics that these teachers have in common (Creswell, 2013; Patton, 2015)—the commonalities that have assisted them in developing their skills in science instruction with young children. The teachers were selected from a list of potential programs provided by an early care and education professional development expert in the sample area who was familiar with the study. The expert was asked to think about teachers in child care programs in the sample area that provide high quality, engaging, developmentally appropriate science-learning experiences. The experiences could be indoors or outdoors or both. The professional development expert provided a list of approximately 20 teachers with the names of their programs and directors. From this list, four teachers were chosen at random and contacted to determine their interest in participating in the study. All of the teachers confirmed their interest, and subsequently, the directors of their programs of employment were contacted to approve the teachers' availability to be part of the study and review IRB protocols (discussed in the next paragraph). The sample size was selected to consider information and deliberate bias, as well as a large enough sample to learn about the lived experiences of these teachers who are especially skilled in providing inquiry-based science instruction to children in preschool.

Procedure

Prior to data collection, directors read an IRB information sheet providing research study and participant confidentiality information. Directors received a gift card for completing the program demographic form (see Appendix A) and allowing the study to take place in their centers. The teacher participants completed a consent form for the observations and interviews. After the interview transcriptions were completed, the participants had the opportunity to review the transcriptions for content accuracy. As participants' statements and recollections were quoted, the teachers provided a pseudonym for recording the results of the study. A demographic questionnaire was completed by each teacher related to gender, age, ethnicity, educational level, and years of experience (see Appendix A). A classroom demographic form also was completed by each teacher, which asked about children's age, ethnicity, gender, number of children in the classrooms, and if any children experienced special needs and the degree those needs required services (see Appendix A). Teachers received gift cards for their participation once all the interviews and observations were completed.

Data Collection

Initial in-depth teacher interviews. To understand teachers' past science experiences and current classroom practices, face-to-face interviews were conducted with the preschool teachers, inquiring about their past science experiences and beliefs about their science-content knowledge. Based on previous research and Bronfenbrenner's bioecological theory, teachers were asked questions about how they are supported to teach science, specifics about their past science learning experiences, information regarding their preparation to teach science, and their beliefs and feelings of self-efficacy related to their content knowledge. In the interviewing process, Patton (2015) highlighted the following aspects as important to consider. The first aspect includes an awareness of how the respondent answers questions and the flow of the interview. The second aspect is the necessity of providing the appropriate reinforcement and feedback to the participant (e.g., "thank you for the clarification;" "we are about halfway through the interview, and I think it is going well," etc.). The third and final aspect involves knowing the information you seek and asking questions to gain a relevant response from participants (Patton, 2015). Sandelowski (M. Sandelowski, personal communication, July 25, 2017) also mentioned the importance of asking participants, after observations and interviews, what they thought happened during the observation or interview, and if this observation or interview occurred on a typical instruction day or school day. These important aspects were included in the interviewing protocol. A detailed list of the interview questions is provided below.

1.) What does science learning look like in your classroom?
    a. What materials are you provided, and are used, to facilitate science teaching and learning in your classroom?
2.) Tell me about your past science learning experiences.

a. What was your favorite area of science, or science topic? Can you tell me more about that experience?

b. What was your least favorite area of science, or science topic? Can you tell me more about that experience?

c. What were the views of women in science when you were growing up?

    i. Do you have any examples of how your gender may have influenced your science learning?

d. How does/did your family view science and science learning?

3.) Describe your feelings related to your content knowledge in science.

a. Tell me about the preparation you've received to teach science to young children.

b. Would you say you have a science identity, or how do you see yourself in relation to science?

c. When you are teaching science-related topics, how would you describe your level of confidence or your belief in yourself?

d. In an ideal world, how much should preschool children be engaged in science activities?

e. What kinds of supports and resources do you wish you had to teach science in your classroom?

Again, teachers provided a pseudonym for themselves to protect their confidentiality. The interviews ranged from approximately 45 to 60 minutes, depending on the length of the teachers' responses. The teachers completed in these initial interviews prior to the observations taking place in the classrooms, which is discussed next.

Classroom observations. I requested from each teacher three observation opportunities in which the teachers engaged in typical classroom science learning activities. The participant teachers were audio recorded with a lapel microphone and observed during this instructional time. The teachers also provided an activity or lesson plan with information on the topics covered for the day and materials to be used during each observed instructional time. A running record of classroom happenings captured aspects of the general and science-specific instructional time during each observation. After the completion of each observation, the numbers that correspond to classroom observations were transferred to the appropriate place on the Science Observation Coding Matrix (described below). Additional notes were added to the matrix for clarification of classroom occurrences.

The Science Observation Coding Matrix (see Appendix B) was designed by me for this study to be used for collecting data on science instruction in preschool classrooms. The matrix is not an evaluation measure or assessment device; it was developed purely for capturing science-specific pedagogical- and content-related happenings in the classroom. The Science Observation Coding Matrix was adapted from the *North Carolina Foundations for Early Learning and Development* (2013) and the *Teaching Strategies GOLD* assessment tool (Heroman, Tabors, & Teaching Strategies, Inc., 2010). This tool allowed for the observer to document the science domains covered and how the teachers' actions were engaging the children with the material. The types of science domains included in the coding matrix were earth, life, and physical sciences as well as aspects of engineering, technology and problem solving. There was also space to capture observations about more process-related characteristics of the science instruction, specifically the use of scientific inquiry skills and communication. Interactions that indicated the children's level of engagement but that were not directly related to the science instruction also were coded. Both the interview protocol and the observation matrix were piloted in the fall 2017, and again in the spring of 2018. The interview protocol was tested, in some form, approximately five times, and the observation matrix was piloted approximately six times. For each aspect of the data collection process, different questions or versions of questions were attempted and analyzed in order to acquire the types of responses that would prove most useful in address the research questions. It was an iterative process.

The length of the observation was driven by the amount of time that the teachers thought they might conduct science-related instruction. Science-related instruction was described to the teachers as any opportunities for them to engage with the children in their care about scientific content, including activities or books or general questions about science that the children may pose. This aspect of the classroom observation was discussed during the initial meetings with the teachers and again before each observation. I arrived approximately 30 minutes prior to each observation in order for the novelty of a visitor to dissipate for the children in the classroom. This also allowed me to gather some knowledge as to where the science instruction fit within the overall structure of the classroom for each observation. In addition, I gained familiarity with the teachers and the children in the classrooms. Three of the four teachers were observed continuously throughout the morning, in an effort to collect authentic interactions between teachers and children involving science-related learning. The average amount of time for the observations was 150 to 180 minutes, depending on the classroom. This technique also allowed for the flexibility of emergent curriculum within the morning instructional time. Emergent curriculum and the opportunity to address science learning as it was raised by the children, and the effort involved in capturing those interactions, added time to the length of the observations, sometimes as much as 60 minutes.

After each observation, the teachers met individually with me to discuss aspects of the instructional time. This post-observation interview was a time for reflective commentary for the teachers—time in which they considered why they may have used certain words or engaged specific children in different ways. This also provided me the opportunity to ask why the teacher addressed the subject matter in the manner chosen. In general, I addressed both pedagogical and content questions regarding the science instruction time observed. The post-observation interviews consisted of three questions with potential follow-up questions. The first question asked about the goals for the science instruction and if the instructional time went as expected, while the second focused on the biggest challenge of teaching the science lesson. The third question centered on what the teacher might change when teaching the science lesson in the future, and what would the teacher change if time was rewound and the teacher was to engage the same group of children in the same science-related lesson or activity. I also asked if the teacher had any additional comments or thoughts about the observed science instructional time. Although the post-observation interview questions were set, when time allowed I asked follow-up questions to gain additional clarity regarding classroom operations observed during time spent in the classroom. The post-observation interviews lasted about 15 to 20 minutes and were audio recorded with me taking notes. I kept these interviews brief in respect to the teachers' time constraints. All audio recordings were transcribed and coded.

Analysis Plan

The analysis plan involved two levels of analysis: individual and group analyses. The individual analysis outlined the findings from the initial interviews, highlighting how the teachers answered the questions posed by me. The second level of analysis, the group analysis, included coding the initial interviews for the teachers past and present science learning experiences, person characteristics, and the context that have influenced the teachers' science instruction, and analyzing how those results aligned with the data from the classroom observations and post-observation interviews. The overall analysis plan for the data included these steps: 1) organizing the data, 2) identifying the coding plan, 3) sorting data into the coding plan, 4) using the coded data for descriptive analysis, and 5) conducting second order analysis (Creswell, 2013). First, organizing the data included transcribing all the interviews and observations, labeling the information, and becoming familiar with it. The second step was to identify the coding plan that defined the data. During data sorting into the coding plan, necessary modifications were made to the coding plan. The coding plan was used in the descriptive analysis to assess the range of the responses to interview questions and science teaching methods, as well as identifying reoccurring themes. Many themes of interest were identified prior to the interviews and embedded within the questions, which were guided by the bioecological theory. Finally, with second order analysis, the goals were to identify recurring themes and acknowledging patterns in the data, while building a sequence of events. This type of data analysis was cyclical in nature and iterative (Patton, 2015).

Coding interview data. To explore the influences of preschool teachers science-related classroom instructional practices, the in-depth interviews and post-observation interviews were transcribed to allow for the data to be analyzed using a systematic process of categorical aggregation related to the two research questions (Avraamidou, 2017; Creswell, 2013). Open coding techniques were used to focus first on more narrow units of analysis, then moving to broader units of analysis (Creswell, 2013). The narrow units may be described as "statements of significance, the broader units are considered units of meaning, and both units then lead to individual summaries involving 'what' the individuals have experienced and 'how' they have experienced it" (Creswell, 2013, p. 79; Moustakas, 1994). The narrow units of analysis corresponded closely with the in-depth interview questions, such as past science-learning experiences and preparation to teach science to preschoolers. The broader units of analysis, such as the influences of Person characteristics on science instruction and the influences within systems of context, were used in the group analysis of the four teachers to identify some of the potential developmental mechanisms of the teachers' science-related instructional practices. The open coding involved a line-by-line analysis, assigning codes to the data to categorize the information supplied by the teachers during the interviews.

Using the theory and literature related to teachers' science instructional practices as guides, themes from the interviews were considered in relation to teachers' beliefs about science teaching, teachers' identity in science learning and teaching, and teachers' Person characteristics related to science. The teachers' Person resource and force characteristics included information on teachers' feelings of science-teaching self-efficacy, teachers' anxiety related to science learning and teaching, and teachers' past personal science-education experiences.

Coding the observation data. The data collected from the observations for this study were analyzed using episode profiles within a defined framework or coding plan, specifically asking, "What was learned?" during the observation regarding what science content was taught and how the teachers engaged the children in the science learning, and "Why is it important?" This effort was conducted once for each piece of information collected with the Science Observation Coding Matrix, and then analysis was completed using the "Zooming In & Out" technique (Patton, 2015). This technique allows for zooming in to analyze each characteristic found within the data on the individual teacher unit of analysis, and then zooming out to analyze all the teachers' practices as a whole. Once the zooming in and out was completed, the secondary analysis builds the order of events and identifying all the themes, or the past proximal processes, that may have influenced why these preschool teachers are perceived as stronger science teachers. Identifying the characteristics that assisted with the teachers' development as science teachers attempted to answer the first research question.

To gain some understanding as to what types of science instruction is taking place in preschool classrooms, the types of science covered during the observation was noted. These data were analyzed through quantisizing the data collected regarding the types of science covered during the observations (Sandelowski, Voils, & Knafl, 2009). Once the data were given numerical codes, comparisons between the teachers was conducted, which then related back to the clusters of meaning derived from the interviews of the individual teachers (Tashakkori & Teddlie, 1998). All data was then considered when detailing the essence of the experience of the teachers involved in the study. These data provided information on how the teachers' science learning experience, past and present, have influenced teachers' classroom science practices, answering the second research question.

After the initial interviews were transcribed and analyzed, the major themes including the teachers' responses were sent to the teachers for their assessment on whether the data adequately described their lived experiences. The questions to the teachers were if they felt their responses were accurate and if the interpretations made were appropriate considering the questions asked during the interviews about what and how they teach science to the children in their classrooms. These initial interview analyses were also shared and discussed with a third party familiar with this study, who was also the verification coder for the classroom observation coding. The third-party verification coder who had previous coding experience with several research projects, read and discussed the study proposal with me, and was trained in coding both the interviews and the observations by me. This process of sharing the major themes with both the teachers and the verification coder acted as a triangulation validity check for the data.

Considerations for Analyzing the Quality of this Study

It is important to note that researchers who conduct phenomenological studies strive to have the data they collect represent what happened during their time with the participants (Bogdan & Biklen, 2003; Gearing, 2004). While they recognize that the information they capture is not the only way of collecting data of the empirical world, they do see their work as an "interpretation of reality grounded in the empirical world" and that this interpretation is "useful in understanding the human condition" (Bogdan & Biklen, 2003, p. 24). The quality of the work then may be measured by how well the data represents the participants' remembering of past and current science-related experiences, yet the idea remains that many interpretations may be possible with phenomenon (Gearing, 2004).

Position Statement

It is critical for researchers to acknowledge their personal biases, internal suppositions, and their history, culture, and belief systems (Gearing, 2004). It is also important that researchers use a system for pointing out their judgments and biases, as well as maintaining transparency during the data collection and analysis processes. One such system is bracketing, and while it is effective, acknowledging all personal expectations is impossible (Gearing, 2004).

I have pre-conceived notions around quality of instruction in early care and education classrooms. These biases are centered on quality interactions between teachers and the children in their care, the importance of predominantly child-led educational experiences, as well as using NC Foundations as a framework for what children should be learning. The biases were critical to acknowledge during the data collection and analyses processes of this project. This meant bracketing my thoughts and interpretations in both the interviews and the observations in the data collection notes. Also, it is important to note that many of my views may have been shared by the teachers in the study because there were few teacher–child interactions in which the teachers and I were not of the same mind. Therefore, my biases, which are rooted in the study of assessment of high-quality teaching practices and classrooms, appeared to be aligned with those of the teachers in the study. In terms of the analyses, listening to the interviews and reviewing the classroom observations notes several times allowed me to be mindful of presenting the data in a way that was as authentic to the experiences represented in the classroom as possible.

It must be shared that I have two degrees in earth science. I see science as the essence of wonder and curiosity condensed into its purest forms. From childhood to young adulthood, I spent many days, both sunny and rainy, outside exploring woods and creeks, lakes and rock outcrops. This interest in, and love of, science and nature are inherent parts of me, and it is important to share that this interest and love of science makes completely separating myself from the observations and interviews with the teachers impossible. Although the observations did not assess the skills of the teachers for the purposes of the study, my personal bias was undoubtedly present and was acknowledged as appropriate. This was done through bracketing potential issues that were witnessed. Multiple readings of observation notes and listening to interviews, as well as talking the teachers before, during, and after data collection, afforded me the opportunity to promote these teachers' authentic voices. The use of multiple data points was a purposeful strategy to triangulate findings and minimize my bias.

CHAPTER V

RESULTS AND DISCUSSION

The results and discussion of this study are combined into one chapter to present and discuss the data in a more integrated manner. In order to address the research questions, this chapter is organized into four sections. The first section consists of individual analyses, which includes the summary of the in-depth individual teacher interview and a description of the classroom observation for each teacher. The second section is comprised of group analyses focusing on the influences of the teachers' Person characteristics and the systems of context. The third section is a summary of effective science teaching factors and how the teachers' past and present science experiences have influenced the proximal processes in their classrooms. The fourth and final section is a summation of how Bronfenbrenner's bioecological theory and the synergy between its different components assisted me in trying to understand why teachers have the classroom science practices that they do.

Individual Analyses

Participant 1. Emily is a preschool teacher in her 30s who has worked in early care and education for 11 years. She has a Bachelor of Science in Human Development and Family Studies with a concentration in Early Care and Education, and she is currently working on a Master of Education in Birth-Kindergarten Interdisciplinary

Studies in Education and Development with a concentration in Early Childhood Leadership and Program Administration. She has worked at her current center of employment for 6.3 years. She identifies as Black/African American, and English is her primary and only language. The center where she works has 6 classrooms with 2 full-time co-teachers per room and serves 82 children, and it accepts child care subsidies. The center uses Creative Curriculum and North Carolina Foundations as guides, but the lesson planning is led by child-centered observation-based planning. In other words, teachers are planning for tomorrow based on classroom occurrences that are observed today, while the interests and milestones of a group of children or an individual child are taken into consideration. Emily's class is comprised of 18 children, ranging in age from 4 to 5. Ten of the children are female, eight are male, and one child experiences a moderate, globally-delayed, diagnosed disability.

On science in her classroom. Emily began her interview discussing how her observations of children's interactions with either materials or peers or teachers become learning activities, some of which are science specific. She provided examples of this for both the indoor and the outdoor learning environments. Outdoors, the children noticed that water that was collected on the slides and climber had solidified due to a decrease in temperature. This led to a discussion about solids and liquids and the water cycle. Emily mentioned that she talked with the children about how the water molecules evaporated when the sun came out and warmed the air and the outdoor play equipment. Indoors, Emily tied the spilling of liquids at mealtime to the word of the week, which was hydration. Emily and the children then connected the cleaning of spills with paper towels to the hydration process.

> The paper towel was getting hydrated because it was soaking up the water. Then, we led into another type of experiment where we took celery sticks and we put it in colored water, and we watched the water seep up all the way to the leaves.

Emily continued that the goal is to capture the moments of interest, and then extend those moments of interest to the next level.

In terms of materials that are available for Emily to facilitate science teaching and learning in her classroom, she acknowledged the availability of resources within her classroom and program. Moreover, Emily expressed her positive feelings about being able to make some of their own materials in their classroom. She also highlighted the importance and opportunities of using standard and nonstandard forms of measurement, adding sensory opportunities for the children, and utilizing 21st century skills via photos and researching on the internet. Finally, Emily discussed her strategy of allowing the children to explore and learn through their play.

> Today for an example, they were interested in bubbles. So, I got like some dish detergent and wands, bubble wands, and they made bubbles and they tried it to see how far they could blow their bubbles. Some of them took two wands to see if they can blow one bubble through the next wand. And that was, I mean it just turned into something that they did. It was very open ended. That's another thing we do, like non-conventional materials. We just put them out to see what they're going to do with them, see what their, how they want to explore, what they're going to discover.

On past science learning experiences. A marine biology class that Emily had in high school was her favorite science learning experience, and she said that it had to do with the recognition by the teacher, Mr. Riggs, that Emily would engage more if she had more of a hands-on experience with the aquarium in the hallway adjacent to his classroom. Emily had the job of cleaning this aquarium and thoroughly enjoyed it. She also described her excitement about looking through a microscope at cells on a slide in third grade. “It was really cool to, like, really see the difference in each slide by the organism and, like, talking about the cells. I mean, who talks about cells in third grade and people are excited about it? But, I was!” Clearly, hands-on science learning opportunities are closely connected to Emily’s favorite past science experiences. This opportunity allowed her to engage with learning in a different, more effective way that has stayed with her.

Emily’s least favorite science topic was reptiles. She described being socialized by her mother from a young age to fear the copperhead snakes that were known to prowl around behind the apartment building in which she spent her childhood. On a visit to the Greensboro Science Center, her elementary class was introduced, and encouraged, to handle a boa constrictor during an exhibit experience in which Emily had no interest in participating. She distinctly remembers her teacher at the time redirecting her in a way that was embarrassing. In her classroom, Emily described herself as ready to engage children on the topic of reptiles in terms of researching them with children, but admitted to using phrases like, “that snake makes my eyes big, or you, that snake is a snake that I would probably look at [from] far away” when discussing the snakes with the children in her care.

On gender and past science learning experiences. Emily mentioned in her initial interview that she never felt the same passion from her female teachers regarding science and math that she did with her male teachers. "They [Emily's male science teachers] had a different passion level. They seemed more interested. They seemed more detail oriented with science. I think all of my elementary science teachers were female…. But, I never paid attention in those classes,…." Emily continued this train of thought on gender and science teaching by surmising,

> …it made me generalize a little bit because my math teachers and my social studies teachers were mainly males and they always had fun. So, I was like, oh, well maybe this is their expertise, like, men really have fun teaching math and history and science and female teachers like teaching art, English, and drama. I just felt like my male science teachers were just more interested, they were more in tune. They could answer my questions and they found ways for me to make connections.

Emily also mentioned that many of the experiences that she had with female teachers teaching science in elementary school and after involved learning experiences that were centered on commercialized products. This was different from the male teachers that she had in high school, who would bring in items found in nature, or send the students outside to find items themselves. She equated these less manufactured experiences to "real life, hands-on learning."

On science in her family. Emily said her mother was not necessarily an advocate of academic science pursuits but that she encouraged her children to explore outside and talked to them about science related to their chores. This included involving Emily in cooking and laundry and other types of domesticated work. She said her mother, who was her sole parent, used opportunities, like when Emily accidently turned her white clothing pink, to teach her about clothing dyes and water temperature and detergent. Her mother took advantage of teachable moments, when possible, to share her practical knowledge, rather than focusing on sharing scientific knowledge through reading science books.

On feelings of science-content knowledge. Emily expressed some concern for her science knowledge, saying "I do not feel that I have high content knowledge." She continued, however, "I have a strong willingness to find out, to figure out, to research, to question, to seek, if that makes sense. To extend learning, to prompt questioning, to get observations." Emily connected this openness to her classroom instructional behaviors. "I like to ask a lot of open-ended questions, just to see where their mindset is, and then, however they respond, that kind of gives me my segue of where I can take their learning."

On her preparation to teach science to preschoolers. Emily's undergraduate education and degree prepared her to teach young children. In terms of teaching science to preschoolers, she attended in-service trainings that were not specifically about science but focused on children's learning styles and sensory learning and input. These trainings have increased her abilities to teach science by increasing her awareness of how best to provide learning support to all children, including those with special needs. Emily also mentioned learning about science from a former co-teacher who had grown up in the country and provided developmentally appropriate science learning to the children in their class in such a way that Emily became more interested in science teaching through mimicking her co-teacher's classroom practices.

On her science identity and science-teaching self-efficacy. Emily asked for an example of science identity, and after one was provided, she described her identity as one centered on discovery. She then discussed her science-teaching self-efficacy, stating that she was confident in her abilities because she knew they would ask her questions and be curious. She recognized that she is assisting them with learning to conduct research, saying "…I'm helping them have skills in how to obtain knowledge and how to gather information." Emily also discussed that her interest level and excitement is transferred to the children during science experiments and exploration.

> So, if I'm excited about it, I know that it's definitely going to carry over with the children. And, if I see their eyes beaming, if I see as soon as I put my materials out on the table that they're like, when are you going to call me over to do your activity? That definitely heightens my confidence and I'm like, 'Oh yeah, this is good!' We're going to have fun today! Let's see what happens.

On the frequency of science engagement for preschoolers. Emily expressed that "science should be incorporated everywhere." She tied this assertion to the importance of sensory learning and how it critical it is to acquiring knowledge as children develop from infancy into toddlerhood and continuing through preschool and into early middle childhood. "If you know anything about infants, they learn through their senses. Even in older preschool age, I still have oral learners that are mouthing everything and they're smelling everything." Emily continued about the ubiquitous nature of science in early childhood classrooms by stating, "You can learn so much from science. It can spill over into so many other areas and learning. When we have a good garden….we use that as science, but we incorporate vocabulary, math, nutrition, because we eat what we produce." She also discussed other examples about science learning, including the types of tomatoes and melons that they grew in the garden, and what types of flowers and herbs attract certain insects. She finished by talking about various examples of conversations about food from the garden and the insects that visited there, to hydration that occurs when the class eats fruits and vegetables, to the vitamins and nutrients that help keep the human body healthy.

On supports and resources for teaching science in her classroom. Emily started this reply discussing her interest in training to specifically teach science. She is interested in learning more about how to incorporate different scientific subject matter, "like cause and effect or time." She also expressed an interest in learning more about how to teach science to children with special needs. Another source of potential professional development for Emily was centered on her concern about more family engagement in science activities in an effort to extend the children's science learning into their homes.

In closing out her initial interview, Emily had this to say:

> I think all children have a natural interest in science. They just want to figure things out. They naturally discover and explore and I think it's important for people in our field as educators or those who are trying to get science out and make it more mainstream that... that it is celebrated and that there are moments for children to actually explore and learn through their play. It should be fun. It's okay to be messy. It's okay to get dirty. It's okay to seek information.

Links between observation and science activities. The classroom observations for Emily were conducted in January of 2019 with at least one day between the observations. No notable observations were conducted outside due to weather. Emily chose to conduct rotating small group science activities for the observations, as these are a common occurrence for the children in her class. The themes of the activities, absorb or repel, transferring water, and oil and water mixing, were all conceived due to sustained interest by one or more of the children in an aspect of a previous activity; thus, prior to the absorb or repel activity, the children had a discussion with their teachers about a spill during lunch time. This discussion led Emily to believe that the children would enjoy learning more about how some materials absorb liquid and some repel it. The data from the observations of Emily's classroom support this connection of children's interests in the areas of physical science, specifically the physical properties of objects. All of Emily's observed science-related teaching codes (99 of 124 total codes) fell within physical science or technology and problem-solving, with the majority falling under physical science (see Table 1 in Appendix C for coding data). None of the observed science-related instruction fell into the disciplines of earth science or life science.

Participant 2. Lisa is a preschool teacher in her mid-30s who has worked in early care and education for 10 years. She has a Bachelor of Arts in Christian Education. She has worked at her current center of employment for 7.5 years. She identifies as White/European American, and English is her primary and only language. The center where she works has 6 classrooms with 13 full-time teachers and 4 part-time teachers that serve 71 children. The center is religiously based and accepts child care subsidies. The center uses Creative Curriculum as a framework with emergent curriculum to guide planning. The teaching philosophy behind the science instruction was described as a Reggio-inspired emergent curriculum. Lisa's class is comprised of 17 children, ranging in age from 3 to 4. Ten of the children are male, seven are female, and one child experiences a moderate, diagnosed speech disability.

On science in her classroom. The second participant, Lisa, began the description of science in her classroom focusing on the physical space, talking about the tools available to the children and the items in the science center. This quickly led to the types of conversations that take place between teachers and children and between peers. She discussed how "if a bird passes over, they might ask what kind of bird is that, or if they found on the ground, an acorn or gum ball" that there is always something to gain the attention of the children, specifically outside. Lisa also mentioned using scientific method language (i.e., hypothesis) with the children, which she then explained that "even though it's a big word for a 3- or 4-year old, they can still start to grasp the concept."

On past science learning experiences. Lisa's favorite science learning experience in school was a high school marine biology class. This class took two field trips to the Outer Banks that year, and during one of them, a lighthouse affiliated with Cape Lookout was moved inland because of concerns with erosion, and Lisa's class was there when the lighthouse reopened. In terms of informal learning experiences, Lisa spent much of her childhood on Harker's Island or visiting other coastal, beach areas due to family vacations and grandparents on both sides of her family owning property near the coast. Both her grandfather and her mother were knowledgeable about marine life.

She described them as “two people that always just talked to us about everything they knew about whatever it was we were catching, my brother and I.”

Lisa also discussed a connection with gardening that was cultivated by her grandparents. She helped them throughout her life with their gardens, and now she uses that knowledge with the year-round gardens at the center at which she teaches and her personal gardens at her home. She supports gardening as an interest for her family, too.

Lisa’s least favorite science topic was chemistry. She attributed her difficulty with chemistry to the math involved. Her issues with it were enough to derail her plans to study marine biology in college, since chemistry was a requirement. She specifically declared her distaste of formulas as they “did not appeal to her.”

On gender and past science learning experiences. Lisa described her associations between gender and science through her interest in the marine biologist, Eugenie Clark. Lisa read a book when she was a child about Eugenie Clark, or The Shark Lady, that highlighted the discrimination she encountered from “some men who didn’t think she could [study sharks] or that she wasn’t smart enough.” Other than that, Lisa stated that she rarely considered gender when thinking about science or science learning. Upon further reflection, Lisa believed this lack of awareness with regard to gender and science may have been related to who normally helped her and her brother with their science fair projects: her mother. “My mom was the parent who helped us do our science projects and was all into that type of thing…. We actually won science fairs twice, or placed twice.”

On science in her family. Lisa expressed continued support in science from her mother. "She was very interested in our school work, talking about lots of things." Lisa acknowledged similar behaviors within herself as a mother, stating:

> We have a whole science box in our house with Cicada shells that we've collected and snake skin. I stayed home with my kids for about a year and a half…and we purposely did science things, you know, during the week because I wanted them to appreciate exploring and just trying to figure out things and, in their own little way, researching things that were outside of our house.

Lisa expanded on this description of science engagement with her children. She shared that her middle child, who is 8 years old, who determined to attend North Carolina State University to become a veterinarian due to his keen interest in animals.

On feelings of content knowledge. Lisa expressed her comfort with acquiring unknown information together with the children, both in the classroom and at her home. She stated reasons for this openness, namely that she wants to ensure she is conveying the correct information to children. "As far as my knowledge, I have a bachelor's degree. We did biology and that's all the science I took in college. So, my knowledge is probably not varied."

On her preparation to teach science to preschoolers. Lisa explained that her training was centered on learning how to facilitate the Project Approach within her classroom. She appreciated the Project Approach as it provided the framework to "learning what the children like instead of, they're an empty cup and I'm filling them with knowledge. It's more like we're learning this together and I'm alongside you, and we're figuring this out together." Implementing the Project Approach also allowed for

Lisa and the class to spend months on a fish study due to the continuation of the children's interest.

On her science identity and science-teaching self-efficacy. Lisa stated that her science identity is related to the types of science in which she is considered most knowledgeable at her program, specifically anything related to gardening or nature. "When it comes to something outside, if there's a bug…it's kind of part of my family's life…part of my life." She continued by saying that she will get called into another classroom to deal with insects and spiders, and other teachers will ask her if she wants to keep the insect or spider because they know she will save it and investigate it. "Definitely, here at this school, I'm probably the science nerd of the teachers."

Lisa also made the connection between awareness of, and appreciation for, the natural world and science and her Christianity.

> People just don't pay attention to things…to our world in general…the trees and the plants and the flowers and all this stuff that really matters. I want our kids to grow up appreciating and being aware of it all…. God created this world, and sometimes, as a believer myself [I think] that God puts this amazing stuff in front of us, maybe for us to have fun with, and to be amazed by, this wonderful creation.

Lisa concluded by saying that "the simple little science experiments that we do, like adding vinegar to baking soda, are fun, wow, kinds of things. I think it is a big part of who I am, to be exploring different stuff all the time." She connected her science identity to her interest in nature and science and love of God.

Lisa considered her feelings about her science-teaching self-efficacy to be strongly positive. Although she did not report overwhelming confidence in her science-content knowledge, she expressed a high level of ability with being able to address problems and research in order to assist children in understanding how to acquire answers and "learn the process of learning." Moreover, this philosophy of learning has allowed Lisa to focus more on working with children to "figure it out" versus passing on knowledge, science or otherwise, to the children in the form of didactic instruction.

On the frequency of science engagement for preschoolers. When asked how much preschoolers should be engaged in science activities, Lisa responded "all day long." She expanded on this notion by saying, "It [science] goes with everything. You can always figure out some way to connect it to a book, or even the way they're moving…and stretching and talking about muscle groups and bones." Lisa talked next about how science could be tied to every center in their classroom, including gross motor, dramatic play, blocks, and art centers.

On supports and resources for teaching science in her classroom. Lisa began by talking about the difficulty of attaining funding to acquire materials, and how the timing when asking is important. She recognized that her director attempts to provide the teachers with all the resources they need. Lisa did mention how being able to go on more trips would be beneficial, but the age of the children prohibited field trips. To combat the inability to take the young children in her class on field trips, Lisa talked about bringing in community experts to share with the children in her care, but, again, funding was listed as a problem.

> Our class, it'd be great to be able to do more trips and go places and look at things, which the older class can…. It'd be great to have more people coming in

> to do some things. I'd love to have someone come in from the Natural Science Center, and of course, things can get expensive.

Throughout her interview, Lisa highlighted the importance of appreciating "creation and how everything works." She expressed how she is trying to cultivate this appreciation for the world, as well as teach children skills for how to figure out answers and to observe their surroundings. She shared that she is striving to do this, not just with her own children, but also with the children in her care.

Links between observation and science activities. Lisa's classroom observations took place at the end of January and the beginning of February with an additional observation occurring at the end of February, bringing the total of observations for her to four. This additional observation was proposed to Lisa and her director because of the non-typical happenings during the first observation of Lisa's classroom. During the first observation for this study, Lisa was training a new assistant teacher for another class, continuing to train her relatively new assistant teacher, and being observed by two students from local community colleges. Having four additional adults, plus a relatively new assistant teacher, seemed to be overwhelming for the children. Lisa commented on this several times, both during the observation and in the post-observation interview, stating, "It was an off day."

Two of the four observations involved a period of time in the program's outdoor learning environment. This program's outdoor learning environment is thoughtfully constructed and evolved with considerable effort from the director and Lisa, as well as other teachers from the program. It includes an herb garden, year-round vegetable garden, mud kitchen, pollinator garden, loose parts area, stage, tricycle path, large play structure, swings area, and various other smaller gardens and play areas. This wondrous outdoor learning environment also had picnic tables and other spaces allotted for bringing the classroom-based science learning outside. During the fourth observation, Lisa brought a basket of plastic animals and several animal books and two metal trays outside to continue the lesson on animal predator and prey relationships. Many of the children extended their learning by enacting the animals being discussed and calling themselves either predator or prey.

The program in which Lisa teaches using the Project Approach (Helm & Katz, 2011). While the observations for this study were conducted, the classroom was engaged in a study of animals. The number of codes for life science in Lisa's classroom observations confirmed the science discipline predominantly discussed in her classroom. Seventy-two of the 103 science-related observations were coded as life science or biology-related (see Table 1 in Appendix C for coding data). Very few of the science-related codes were considered either earth or physical science, 2 codes and 7 codes, respectively. The rest of the science-related codes fell under the discipline of technology and problem solving and the majority of those were concerned with the explanation and use of science tools (i.e., balance, microscopes, magnifying glasses, syringes, tongs, etc.).

Participant 3. Candace is a preschool teacher in her late 20s who has worked in early care and education for 5 years. She has an Associate of General Education degree. She has worked at her current center of employment for 5 years and as a mentor teacher at her center for less than 6 months. She identifies as Black/African American, and

English is her primary and only language. The center where she works has 3 classrooms with 8 full-time teachers and serves 60 children. The center uses Creative Curriculum for planning purposes, and accepts child care subsidies. Candace's class is comprised of 21 children, ranging in age from 4 to 5. Fourteen of the children are female, seven are male, and two children experience potential learning/sensory and impulse/sensory issues, but these concerns are undiagnosed.

On science in her classroom. Candace began the interview by discussing the contents of their classroom science center.

> We have our two classroom pets, which are two hermit crabs. We have a beta fish, and we assign jobs to take care of those animals…. Within that center we have different little scientific things that they can explore with, like magnifying glasses. We have a kid-friendly microscope. We have wood, like real wood samples.

Candace moved from the description to her classroom materials to discuss how science learning is implemented in her classroom. "Science definitely happens every day, whether it's a book we're reading and the kids have questions about it, or something they saw at home that they want to talk about, or if they have questions we're researching together." Candace also talked about the science learning that occurs when the class is outside, including walking to and from the outdoor learning environment. She also shared that over the next month the class will be focused on a human body study.

Candace explained that she also encourages the use of less conventional materials by offering the children "simple STEM challenges." With the STEM challenges, children built contraptions with less conventional materials, encouraged by teachers to engage the materials in inventive ways. Small loose pieces, like small wheels, were available to add to the contraptions. Materials used in the past were cut up plastic straws. Some of her materials she has purchased independently.

On past science learning experiences. Candace was in 4-H as a child, and she remembered observing the baby chicks hatch and caring for them. Although she was only in 4-H for about a year and a half during third and fourth grade, her interest was "sparked" by the experience. Another connection she described as influencing her interest in science has been her son, whom she referred to, with a smile, as a "scientific nerd." The two of them have engaged in various science learning activities together, and she shared that she and her son are building a rocket ship at home. She also described an interaction she had with her son the previous evening involving his science lesson from that day. Apparently, her son's fifth grade class dissected a frog, and as a college student, Candace dissected a cat in her anatomy and physiology lab class. Since she still had her notes from her dissecting experience, she and her son compared their experiences dissecting the cat and the frog, respectively.

Another science learning experience that influenced Candace is an exhibit on the human body that she visited at a local natural science museum in a neighboring city. She described herself as "very fascinated." She continued by stating, "…maybe that's a reason why this is my second time around doing the human body theme within my classroom." She summarized that her most influential past science learning experiences were these three opportunities: her time in 4-H, the co-construction of science-related knowledge that she has engaged in with her son, and visiting the bodies exhibit at a local science museum.

It was during this discussion about past science learning experiences that Candace shared that for her first year or so of college, she was a nursing major. This original degree plan provided her with the opportunity to take courses in biology, chemistry, and anatomy and physiology.

In terms of her least favorite science topic, Candace admitted that she disliked learning all the medical terms that were involved in the pursuit of a nursing degree. She also recalled not being especially into science when she was in high school. She tried working out why high school science did not appeal to her, "…when I got in high school, I don't know. I guess the way my teachers, like I said, the way they presented it, it wasn't exciting. It wasn't fun. It was just one of those things I had to do."

On gender and past science learning experiences. Candace had trouble answering this question even after revisiting it at the end of the interview and described herself as "stumped" when discussing it. She brought up female inventors and female doctors finding cures for diseases but felt like she could not articulate more than those concepts. After a period of time, we circled back to gender and science learning, and when she was specifically asked about the views of women in science when she was growing up, Candace mentioned recognizing what a male dominated field it was.

> …the science teacher at my [elementary] school, he was male, and his classroom was marvelous. I mean, he had snakes, he had animals, plants everywhere. It was like a jungle in his classroom. He had an amazing classroom…. I loved Bill Nye, The Science Guy! Loved, loved it. Still remember the song when it came on. He

> was a male. A lot of videos that we would watch in school, you know, there was always a guy, a man, you know, a male figure, teaching that subject.

When it came to the views of women in science and how it may have influenced her past science learning experiences, Candace reflected at the end of her answer that she had never given the idea of gender differences in her science learning experiences much thought until being asked the question.

On science in her family. Raised by a single mother, Candace has three siblings. She did not talk about science much while growing up as many of the adults in her life were working to do "what they had to do." She talked about her love of being in the woods when she was a child, and how she and her sisters and her uncles, who were in the same age range as Candace and her sisters, would play and explore outdoors. They all enjoyed playing outside and exploring in the woods.

On feelings of content knowledge. Candace iterated that if she was unsure about a subject or did not know how the answers to questions posed by the children in her care, she researched either with the children or on her own to find answers. She has enjoyed working with the children to find information to support their science interests.

On her preparation to teach science to preschoolers. Candace stated that she has not been trained specifically on how to teach science to young children. She has attended various trainings and workshops centered on different domains, and, on occasion, that has included science. She mentioned having access to teacher resource books from her program. She talked about having the goal of presenting "science in a natural way in the classrooms and the organic way, where it doesn't seem like it's forced."

On her science identity and science-teaching self-efficacy. After considering the question, Candace decided to refer to herself as a "science late-bloomer." She attributed much of her interest in science as an adult to her son and has enjoyed the expansion of their science knowledge together.

Candace began her discussion of her science-teaching skills by talking about her preparation prior to teaching new science information in her classroom. "I like to prep myself for it, so that I can feel confident whenever I am presenting the information to the kids…. So, definitely going over my notes, going over whatever material it is that I have planned for them." Ensuring her science activities are ready for the children was also mentioned. "We were just talking about the nervous system, and so we did this fun little activity where we all lined up and played 'Telephone,' passing the message to our brain [children as nerves leading to one child, the brain]."

On the frequency of science engagement for preschoolers. Candace stated that she believed science activities should be a part of everyday work with young children. She discussed how vital she thinks that science learning is for children to gain an understanding of their world, both indoors and outdoors. "Science is important, and I think it helps them understand the world and the things around them a little bit better. Gives them a better perspective."

On supports and resources for teaching science in her classroom. Candace discussed that it would be helpful to have more science specific workshops. She pointed out that for a recent conference that there was potentially one science-related workshop for teachers out of the 51 sessions advertised. She also mentioned that it would have been helpful to have had more classes related to teaching science to young children when she was a preservice student. Although she was unsure about how many science-related classes were required for a bachelor's degree in early care and education, she did state that there were no classes focused on teaching science to young children required for her Associate degree. Science material might be found interspersed among other classes required for the Associate degree, but none of them were focused on science. She then compared this notion with the type of education that elementary education majors receive in terms of science education classes, and she mentioned that elementary education preservice teachers have at least one course in science education and that she would have benefited from that type of course. She ended this line of questioning with this statement: "You just can't go wrong with science."

Overall, Candace felt that "science in early childhood education is just one of those things that is overlooked," specifically because of the focus on social-emotional development. "Kids love it, especially when it is presented in a fun way. It makes them feel confident and the capabilities...it like 'I can do this, I can build this, I can invest this, I can discover this.'"

Links between observation and science activities. Classroom observations for Candace were completed the first and second week of February 2019. Prior to the initial interview, the children had expressed keen interest in learning more about the human body, which Candace believed might provide more opportunities for data collection for this study. Over the three observation days that spanned a week, the teachers and children discussed germs and hand-washing, the nervous and digestive systems, and various aspects of nature that arose from outdoor play.

The program where Candace is employed uses Conscious Discipline (Bailey, 2000) as part of their curriculum, specifically for social-emotional learning, and all of the teachers received training on its implementation. The human body project influenced Candace's classroom practices, as evidenced by the number of codes in life science (36 of 45 science codes) (see Table 1 in Appendix C for coding data). The remainder of the science-related observations were earth and physical science with 5 and 4 codes, respectively. None of Candace's observations indicated any work that could be categorizing as technology and problem solving.

Participant 4. Wren is a preschool teacher in their late 30s who has worked in early care and education for 4.3 years. During the interview, Wren shared that she considers herself gender non-binary; therefore, the pronouns used for Wren are "they", "them", and "their" with a singular verb. They has a Master of Arts in English Writing and is currently working on a Master of Arts in Education with a concentration in Nature-Based Early Childhood Education from a university in New Hampshire. They has worked at the current center of employment for 4.3 years. Wren identifies as White/European American, and English is their primary language. Wren is actively learning Spanish and American Sign Language. The center where Wren works has 6 classrooms with 18 full-time and 4 part-time teachers and serves 91 children. The program accepts child care subsidies. The center uses Creative Curriculum in planning. Wren's class is comprised of 17 children, ranging in age from 4 to 5. Nine of the children are female, eight are male, and one child has experienced significant trauma. Although there is not a definitive diagnosis for him, this trauma can influence his ability to regulate his emotions and behaviors. Wren and their co-teacher offer a nature-based classroom learning experience every Friday morning (weather permitting).

On science in their classroom. Wren began the interview stating that "science is an everyday part of life and so it is an everyday part of our classroom. Science instruction happens very organically as things occur, so as children's natural curiosity comes out, we do the best that we can to indulge that curiosity. That is a natural part of early childhood education." Wren and her co-teacher try to support children's curiosity whether it is centered on mechanical phenomena, technological interests, or the natural world. Wren continued by saying that the evidence for children's scientific learning is witnessed in not only the children's increased science knowledge, but also in their increased curiosity of the natural world. The questions that children ask while engaging in science activities are indicators of potential knowledge growth. The children also engage in science learning during group time when sharing items around the circle. Typically, the teachers attempt to include natural items to this sharing time, and the children are encouraged to say these two statements, "I'm noticing this...[about the object]. I'm wondering this…[about the object]." The first statement is a direct connection to scientific observations, while the second statement is linked with scientific inquiry. The teachers also use these open-ended questions/statements in other ways around the classroom and the woods. The most common opportunities to engage the children in open-ended discussions is by asking the children what has changed in the woods since the previous Friday.

On past science learning experiences. Wren's favorite science topic was geology. Their mother was a science teacher, which allowed Wren access to science topics beyond what was taught while they was a student. Wren now uses some items from their mother's rock collection in the classroom. They is also interested in biology and other natural sciences as these subjects were a part of their life growing up on a farm. Wren mentioned a physics professor in college "who made everything make sense. [This physics class] made me feel like physics was the answer to life."

Wren believed at the beginning of college that their future profession was environment science or environmental studies. Wren discussed growing up in West Virginia and witnessing "the horrifying destruction of the natural world…. It's devastating." Struggles in chemistry from a lack of math self-efficacy and lower math skills derailed this planned profession. When sharing about least favorite science experiences, Wren disclosed that their least favorite experience was not science per se, but math. The math issues were related to switching schools twice between the ages of 10 and 12. While acknowledging that science and math are closely intertwined, Wren stated that math, and specifically multiplication tables and other drilled math facts, still causes them some anxiety. During this time of school transition during fourth and fifth grade, Wren also experienced negative interactions with their science teacher that, cumulatively with the math experience that year, negatively influenced Wren's concept of self as a learner for years afterward. Wren stated, "They did damage to me as a learner that did not need to be done."

On gender and past science learning experiences. As Wren considers themselves gender non-binary, they engaged with this question on a different level, acknowledging that others view them as a woman as they has the anatomy and biology of a woman. Wren's mother was a science teacher (they was in preschool while their mother was in college). Wren remembered going on long walks with their mother and collecting flowers for their mother's biology project. Wren associated science with their mother and women in general until they was in middle school and realized that some people had an issue with women in science. Wren stated that their reaction was akin to "What do you mean women don't do science? What? That's ridiculous."

When experiencing a negative bias, Wren admitted to having difficulty processing why that negative bias may have occurred, whether it was from their perceived gender bias or if it was derived from a weight-related bias. As Wren stated earlier in the interview, they was categorized as obese since the age of 5 years old and living with the stigma associated with being overweight since early childhood. Wren wondered if others struggled to see the actual person they is because of either gender or weight and seemed to conclude that it had more to do with weight, saying that "I'm not exactly sure if gender has ever really had anything to do with it." As a student, however, Wren recalled a memory from middle school about a science teacher that made an impact, specifically concerning how others view women in science.

> I remember in my 8th grade class I had this very kooky teacher, who was a chemist, and I loved her to pieces. I thought she was the most amazing thing ever. And, people would make fun of her, and the way that they did it…. There was definitely fodder for her to be made fun of because she was super kooky, but the way they did it made it seem like they were making fun of her gender. I remember being in 8th grade and realizing like, I don't know why you're making fun of her. Is it because she's kooky, or is it because she's a woman and she works in science? I can remember questioning that.

Wren finished this area of discussion by recognizing that nearly all of their science classes in both high school and college were taught by women.

On science in their family. Although Wren grew up on a farm, education was considered the family business. As previously stated, Wren's mother was a science teacher, but their father was a teacher, too. "Science was a part of life, whether we were out cutting wood, or listening to bird songs, or identifying trees and plants and poison ivy," Wren recalled. This knowledge and appreciation of nature extended beyond Wren's parents to include grandparents. Wren's grandfather could identify song birds and trees with acuity, and he could identify trees by nearly any aspect of their biology, including leaf, bark, pulp, and smell; skills that were highly prized by Wren and their family. Wren grew up exploring, and being encouraged to explore, the natural world. As Wren's father believed they would be a doctor and due to their expressed interest in farm happenings and maintenance, this participant was encouraged to assist with various aspects of farm life: birthing calves, tearing the engine out of a tractor, and other examples.

On feelings of content knowledge. "I am the kind of person who knows a little bit about a lot. I believe in learning. I'm a life-long learner." Wren expressed strong beliefs about the co-construction of knowledge with children, addressing and engaging the curiosity of the children in their care. Both Wren and their co-teacher believe in using the resources at their disposal to find out answers to questions posed by the children in their classroom or those questions that themselves are interested in investigating.

Wren feels confident about their knowledge due to their driving curiosity to seek out answers to questions from the children in their care and from themselves, both prior to teaching and during their teaching career. "I feel okay saying to kids, Hey, I don't know but somebody does. Let's find out!" Wren expressed the hope that they communicate this accessibility to acquiring answers and comfort with "not knowing" to the children in their care.

On their preparation to teach science to preschoolers. Prior to teaching young children, Wren was teaching writing at a community college; Wren holds a Masters in writing. Before teaching in the center where they works currently, Wren stated that they received no preparation to teach science to young children. Since beginning work at their current program of employment, Wren described an active pursuit of variables that connect children with nature. Examples of this ongoing pursuit include, but are not limited to, trainings on outdoor learning environments, gardening with children, and a degree in nature-based learning in early childhood education. Wren also commented on the availability of training available for science teaching, stating that these trainings are there but teachers have to pursue them.

On their science identity. Wren explained that they was a person who values inquiry and "following curiosity." After explaining that this question is not about calling oneself a biologist or physicist, but encompassing performance, competence, and recognition within the whole teacher, Wren discussed the mirroring of the scientific process and the learning process. They talked about evaluating variables and assessing what was working and what was not working in both science and learning. This was illustrated with the examples, "If you are looking at a child learning to walk, they are doing the scientific process. They are. If you are looking at a child learning write their name, they are in the midst of the scientific process." Wren continued,

> The idea of I'm testing out a hypothesis. It didn't work. I'm modifying my hypothesis. I'm going to test it again until I have a theory of how I do this the right way. And, maybe, later on in life they realize, Oh, I don't want to write my name THAT way. I'm going to write it a different way. And it starts over again, just like it does in science. I literally mean science is everything. It's everywhere and its everything. It's…it's…it's foundational to who we are as people because it's in our evolutionary roots how we try to explain our world.

On the frequency of science engagement for preschoolers. Wren stated their belief that preschoolers are engaging in science activities all the time, consistently throughout the children's daily lives. Wren also discussed how the use of new classroom tools for the children, such as staplers, or using a familiar tool in a new way, such as using paint with different materials, is science learning. This engagement for preschoolers affords them opportunities to understand how different materials work within their worlds.

On supports and resources for teaching science in their classroom. Wren recognized the freedom that they has in choosing how they can spend the funds budgeted for their classroom. In the past, they has spent their classroom funds on owl pellets for the children to pull apart and examine. Wren described gathering natural materials from the woods, both at school and their neighborhood, but stated that the woods at the center, where they have their forest school on Friday mornings, are immature so there are less loose parts than in more mature wooded areas.

Wren also discussed their wish for items or equipment that the children can take apart. They discussed how we have a notion in our society that when children destroy things, they are learning to break everything, which Wren declared as not true. Instead, Wren believes children do this to experiment with how items or equipment are put together. Wren declared this as an opportunity for experimentation and analysis, not destruction for sake of breaking things indiscriminately.

Links between observation and science activities. Wren's classroom observations occurred towards the end of February and the beginning of March 2019. Wren and their co-teacher provided a forest learning environment for their class on Fridays mornings, weather permitting. These "Forest Fridays" were discussed with enthusiasm by the two teachers and the children. Wren believed outdoor time to be critically important the overall health of children and bundled the children up to go outside for at least 30 minutes despite it feeling like 27 degrees Fahrenheit on one of the observation days. With weather less of an issue, all three of the observations involved at least 30 minutes of outdoor play. The weather during the third observation was clear enough for the class and a father of a child in the class, to go play in the woods adjacent to the program. As evidenced by their enthusiasm for science in the initial interview, Wren was comfortable with any type of science-related activity in which the children may be interested.

Like Candace, the program where Wren is employed uses Conscious Discipline (Bailey, 2000) as part of their curriculum for social-emotional learning. The work in the forest and discussion around weather related to Forest Fridays, as well as the less conventional materials used in the art work in classroom, produced more diversity in the science disciplines covered in Wren's classroom. There were fewer science-related opportunities during the second observation, which brought the overall number of observations down in Wren's classroom. However, the observations in Wren's classroom yielded codes that were more dispersed. Wren had at least 6 codes per science discipline, whereas each of the other participants had at least one discipline with no codes (see Table 1 in Appendix C for coding data).

A discussion of effective science teaching factors and how the teachers in this study exhibited these factors is presented next. This includes the link between the teachers' practices and their person and context influences.

Teachers' Proximal Processes and Effective Science Teaching

The teachers in this study demonstrated how past and present science educational experiences influenced them throughout their observed classroom behaviors. Research suggests additional critical factors in effective science teaching (Tobin & Fraser, 1990) include teaching strategies that support children's consistent and sustained interest, classroom practices that increase children's science knowledge and comprehension, teaching strategies that encourage children's participation in science-related activities, and teachers' behaviors that facilitate a positive learning environment. The teachers observed during this study delivered each of these effective science teaching factors, which when combined with the person characteristics and systems of context, influenced their proximal processes and provided the answers to the second research question. Examples from the classroom observation data of the factors in effective science teaching are presented in conjunction with how the person and context characteristics may have influenced the proximal processes provided by individual teachers.

Children's consistent and sustained interest in science. As part of the continued project study of animals and prior to the observation day (over mesotime), Lisa's class discussed the story of David, the shepherd boy from the bible, and his daring acts of bravery. These acts included defending his sheep from lions and bears, predators that were preying on the sheep. This lesson on David, and its subsequent activities, such as pasture play with sheep, people, and other materials to care for the flock through pretend play and making harps related to David's musical abilities, led to the children asking questions about predators and prey. On the day of the observation, the children were introduced to new vocabulary during group time regarding predator and prey relationships. The vocabulary introduction was multi-faceted. It began at group time with the children with animals on their shirts coming to the front of the carpet and describing the animal or animals on their shirts. At the end of their brief descriptions, Lisa asked them purposeful questions about the animals while also supporting them as the children tried to decide if their animal was a predator or prey. These questions were centered on what the animals ate for food and where they may live. The way that Lisa asked the questions to assist the children in their brief investigation of their animal or animals was derived from her training on how to implement Project Approach. She used her knowledge of the curriculum—a Person resource characteristic—in microtime to provide the children opportunities for proximal processes to support their learning around the relationships between predators and prey within their microsystem. This phase of the lesson continued with Lisa showing pictures of sheep, baby goats, rabbits, lions, wolves, and a bear, and the children choosing whether each picture depicted an animal considered predator or prey. The children discussed their answers together and with Lisa, and once a decision was made whether the animal was predator or prey, Lisa taped the animals to the appropriate poster board with either a 'predator' or 'prey' heading. Additional learning opportunities for learning about predators and prey relationships were offered to the children in three areas of the classroom within their normal centers. Two of the new areas of choice are sorting activities with one being stuffed animals and the other, plastic animals. Although the sorting task of moving the play animals, either stuffed or plastic, to either a 'predator' tray or a 'prey' tray was essentially the same, the two groups consisted of different animals with a few overlaps. The animal diversity between the two groups required the children to think critically about which group the animals belonged. The third area was a scene set out on a relatively raw, slightly-sanded wood disk. On the disk is a plastic male doll that represented David, the shepherd, who, a child from the class shared, was "watching over his sheep because of the big, scary wolf." Hiding next to a rock was another plastic figure, a dark gray wolf. The child who shared David's job duties is using large salad tongs to move jumbo cotton balls from the wood disk to an adjacent bowl. When asked, the child described the activity as "saving the sheep and…helping David take care of them."

As the observation continued, so did the predator and prey work. Another activity that Lisa used to engage the children was to ask them to select different animal predators as they left the classroom to walk outside. She then asked them to act out their predators in the outdoor learning environment. One of the children, a gorilla, begins chases another child, who said she was a shark. Lisa inquired about "who would eat who" between those two animals, and no one responded. Approximately eight of the children sat with Lisa at the picnic table and looked through animal books, sorting plastic animals and continuing to talk about how some animals hunt and where they live. Interest in the picnic table activity was based on child-led small group, and several children stayed for 15 or 20 minutes. After everyone eventually left the picnic table, one child acted like she was climbing the tree, and said to Lisa, "I'm a cougar, Lisa. I'm climbing the tree to get a mouse."

This observation highlighted several positives about Lisa's strategies to teach science and the subsequent positive results, specifically the children's sustained interest in exploration and discussion of predator/prey relationships and their consistent use of the appropriate vocabulary. Lisa's intentional use of questions to aid the children in working through the meanings of the vocabulary rather than simple sharing the definitions of the words aided the children in making their own meaning from the terms. McClure (2017) stated, "The role of a good STEM teacher is often to resist directly *answering* children's questions. Teachers can encourage STEM habits of mind and facilitate learning by *asking* purposeful questions and then supporting children as they investigate for themselves" (p. 86). The multiple and varied opportunities in which the children were able to engage with the physical tasks of sorting and playing with the predator and prey animals allowed for the cognitive processes of learning through practice and repetition that incorporated multiple domains, not only science. Research has found that many early care and education teaching professionals feel overwhelmed by curricular requirements by their programs and local, state, and federal governments, or macrosystem influences, which often leads them to less science engagement in their classrooms (Gelman & Brenneman, 2004; Greenfield et al., 2009; McClure, 2017). Lisa's planning and facilitation on predator and prey relationships demonstrated how integrating various domains with science learning experiences, such as literacy (through the introduction of new vocabulary and the use of books as research tools), attention development (through the sustained investigation into different predators and prey), and physical development (through the fine motor skills required for moving the sheep, or cotton balls, to the bowl from the pasture with the salad tongs and the gross motor skills necessary to act out different predators) allowed the children a richer learning experience across multiple domains. Lisa's ability to implement the integration of the various learning areas across the classroom microsystem comes from her belief that science is critical to children's learning and development, a Person force characteristic, and that it should be part of their daily experiences. Her skills at science integration across centers and locations is also linked to her science-content knowledge and interest in science as a whole, and biology more specifically, which is a Person resource characteristic. As discussed in the individual analysis of Lisa's past science learning experiences, much of her knowledge came from positive and consistent interactions between Lisa and the adults in her family, specifically her grandfathers and mother, throughout her childhood.

Increasing children's science knowledge and comprehension. The day of Candace's second observation, the children had discussed the digestive system for several days (mesotime) and evidence of their work was presented throughout the classroom. During the observation, there were three centers for the children to explore. The first center was cutting and gluing parts of the body, such as brain, heart, stomach, lungs, kidneys, liver, and small and large intestines, onto an outline of a child's body with a picture of each child's face in the class. Near this center were representations of the brain, heart, stomach, and large intestine that Candace made out of modeling clay and painted. The children looked at them several times to figure out the correct orientation of the organs. Candace assisted the children with cutting and gluing, using hand-over-hand support when needed.

The second center was set up for children to draw the digestive system in their human body books that the teachers created for them. In the human body books, each page was titled with a different system within the human body and below the title was a simple outline of a child's body. During this observation, Candace provided varied drawing and coloring materials for the children to use while representing their digestive system on the page in their books. Candace also had a laminated color drawing of the digestive system for the children to reference while completing the digestive system page. One child commented on the colors in this diagram and smiled at her friend, saying that she “hoped her insides were this pretty with colors.”

The third center was dominated by a life-sized outline of a child’s body for collage work. On the outline, children were gluing pictures they found and cut out from magazines to represent the different parts of the face and body. Many of the organs were photocopied and enlarged from the diagrams provided as guides to the children for their body books. This was intentionally done by the teachers to provide some consistency for the children in how the body systems looked across the centers. Once center time ended, this life–sized outline was moved to the front wall of the classroom where it was mounted to the wall. Next, Candace reviewed some of the organs that the class had covered previously with the children, saying the names of the organs slowly and pointing to their location. After this review, she asked what sounds started the individual organ names, and once there was group consensus, the children took turns using alphabet stickers to label the pictures of the organs. Thus, a large black ‘H’ was affixed to the diagram of the heart, while an ‘S’ was stuck to the stomach. Each time a new letter was introduced to the body collage, Candace would focus the children on making the sound with her.

Throughout human body center time within the microsystem of the classroom, Candace supported the children with calming discussion tinged with her enthusiasm for the science of the human body. She would occasionally answer their questions outright, but more often, she would answer their questions with questions, leading them through the investigative process. She would also refer the children to the clay models that she made, or the ones made by the children earlier in the week. When one or more children needed a break from a center, Candace would suggest another center, or if the children's interest was lagging, she would direct them to dramatic play in which friends were spending time at the doctor's office by giving shots to dolls and caring for each other's imaginary cuts and "boo-boos." These proximal processes occurring in the microsystem of the classroom were influenced by Candace's Person resource characteristics (her knowledge of anatomy and how children learn) coupled with her force characteristic (motivation for the children to learn about bodies). Other aspects of the classroom that influenced the proximal processes of this lesson are the materials (i.e., modeling clay organs, materials for cutting and gluing organs, and life-sized body collage) and the sensitivity and calm that Candace used when discussing the different centers work with the children. The children's own Person resource and force characteristics are relevant, too, in that they represent the knowledge built over the previous days or weeks of learning human bodies (resource) and the persistence that the children may exhibit in working in the centers (force).

Candace's science self-efficacy, which, in part, may stem from her science-content knowledge from classes in college, and her fascination with human biology have supplied her with the tools necessary to add to the children's science knowledge and comprehension. Two specific examples of this knowledge acquisition were witnessed during the next observation in Candace's class, during outside learning time. Digging for worms was a favorite activity for outside time for this class, and there were several favorite spots where the children would have success. In one particular spot during the third observation, Candace and seven children found many worms. The teacher and a child with a worm in her hand had the following exchange.

> Candace (to child, who has found a worm): How does it feel in your hand?
>
> Child: It tickles!
>
> Candace: It tickles? Why do you think it tickles?
>
> Child: Because it's wiggly!
>
> Candace: It's wiggly? Why do you think it is wiggling?
>
> Child (thinking and watching the worm with a smile): Because it wants to move.
>
> Candace (smiling at the child): That's right. We've talked about this, haven't we? The worms move because they are looking for dirt in your hand. They want to go back to the dirt because it feels good to them, to their bodies. Sometimes, does dirt feel good to our bodies?

Another example of the children connecting previous discussions with current observations was seen not long after the first, and it is also related to worms. After digging in another favorite worm spot with more moisture, the teacher and the children have this conversation.

> Candace: Why do you think we are finding so many worms here?
>
> Children (many respond with a variation of the same response): Because it is wet.
>
> Child, who is holding the worm: I'm holding it. It is wet!
>
> Candace: You are holding it! You are so brave, [child's name].
>
> Child, who is not holding the worm: Candace! Candace, I see the worm's esophagus!
>
> Candace: [Child's name], where is the worm's esophagus? Can you show me?

> Child points to middle of worm, then playfully acts like he is going to eat it.
>
> Candace, smiling at the child: Did you eat that worm?
>
> Child shakes his head.
>
> Candace: You could eat it. It is good protein, which helps your body stay strong. People eat insects…[lists insects that may be eaten]. There is a place where you can buy insects to eat somewhere here [in Greensboro]. Maybe I will bring some in for us all to try.

These two exchanges show us that previous conversations that Candace's has had with the children about their bodies and, in this case, worms' bodies are taking root and shaping the children's awareness of their biology and the biology of creatures in the natural world.

In the previous examples, the children's interest was supported by Candace's enthusiasm for anatomy and physiology, an interest that she mentioned was initiated by viewing the bodies exhibit in Raleigh and further cultivated in college with nursing classes through microsystem influences. Her early experience with 4-H and being part of a group that "provides experiences where young people learn by doing" ("4-H," n.d.) allowed Candace to connect experiential learning with science in a practical way, which then influenced the proximal processes in her own classroom microsystem. Her local 4-H group was also a microsystem, in which she was encouraged to ask questions and participate in community service learning delivered by a cooperative extension agency near where she grew up. These opportunities (the proximal processes, Person characteristics, and systems of context) gave her the awareness, curiosity, and knowledge that she now shares with her son in the science activities and experiments, or the proximal processes, they conduct at home (another microsystem).

Candace's willingness to let the science experiences unfold both indoors and outdoors through play, rather than through direct teaching, was crafted through her experiences. Research has shown that most teachers recognize that play in kindergarten is critical, but few teachers or administrators can define the interactive relationship between learning and play (Miller & Almon, 2009). Candace's views on how science can be instrumental in building children's confidence and self-efficacy are supported by research (Harlan & Rivkin, 2000). However, research has also indicated that only half of kindergartens had an area devoted to science learning and that kindergarten teachers missed the mark with providing sufficient science learning activities (Tu, 2006). The issue here is that missed opportunities for children's science learning decreases children's participation in science-related activities, which is the next effective science teaching factor discussed.

Children's participation in science-related activities. Within an emergent curriculum, which was practiced at varying levels of implementation at each of the programs in this study, the majority of the topics being covered are derived from the curiosity of the children in the class. This was evident in all of the classrooms observed. In Emily's classroom, the first two observations were closely related. In the first observation, the class tested the ability of different materials to absorb or repel water by moving the water onto the materials with syringes and droppers. The children's Person resource and force characteristics of perceived interest, curiosity, and enjoyment during the first observation led to Emily developing the activity for the second observation. In the second observation, the goal was to transfer water from one container to another using various tools, including syringes, droppers, and different sizes of cotton puff balls. Emily's knowledge of pedagogy and experience teaching children (resource characteristics) within the microsystem of her classroom influenced the proximal processes taking place during these science-learning experiences.

Several times during the course of the activity, children would come over to the small group table where the work was happening and inquire when they would have a chance to do the activity. As previously mentioned in the initial interview, Emily gained confidence from the interest and excitement shown by the children about the activity. She enjoyed the excitement and enthusiasm that the children brought to their learning; it energized her to provide the most engaging science learning activities she could to the children in her care. These interactions between Emily and the children are the proximal processes from which both Emily and the children develop. Both Emily and the children bring their Person resource and force characteristics with them to the microsystem context of the classroom within microtime (during the observed science activites) and mesotime (days and weeks of small group science work prior to the observed science activities) to influence the proximal processes. In Emily's case, she continues to develop her teaching and communication skills with the children, and the children's development is promoted through engaging in science learning.

Emily's ability to carefully observe and note children's interests in certain subjects and translate these observations into high quality science activities was due, in part, to her training within her undergraduate program in child development—a Person resource characteristic. Two other characteristics have influenced Emily's teaching that were mentioned in her initial interview, which were her interests in asking open-ended questions and finding out answers with children. These Person force characteristics may both stem from her persistence and skill in working with children. Contextual factors related to her science teaching abilities were the microsystems of previous classrooms in which she learned from her co-teachers, and microsystems of classes or trainings in which she had participated. All of these environments contributed to her current skill set in providing high quality, interactive science-learning experience for children.

Emily's interest and skill in sensory learning and cause and effect relationships in hands-on learning experiences was evident in the observations. She was also interested in how open-ended questions may be used to find out about children's thinking and comprehension—a force characteristic that influenced how Emily thinks about the proximal processes, or engagement experiences, that she provides to children. These types of proximal processes were an important aspect to her training as an early care and education professional. They were also a representation for how she learned as a student within the microsystem of her science class with Mr. Riggs. Pramling Samuelsson and Asplund Carlsson (2008) found in their research on play and learning that children use repetition and variation in their engagement in activities to attain goals centered on learning. The more opportunities that children have to engage in hands-on science exploration and play with a variety of materials, the more meaning and understanding are built (Bulunuz, 2013).

Although emergent curriculum is powerful in recognizing the children's interest and focusing it in specific areas and is ideal in some ways, a shortcoming may be the lack of diverse science disciplines covered. In general, the teachers in this study exhibited a wide-variety of science-content knowledge and were adept at providing developmentally appropriate science learning opportunities to children. By quantizing the observations, however, it was noticeable how often the teachers went to their areas of strength: a) For Emily, this is hands-on, sensory-rich, science learning experiences, developed from observations of children; b) For Lisa, the areas of strength were biology-based, specifically plants and animals; c) For Candace, this included anatomy and physiology lessons on the human body; and d) For Wren, this was inquiry-based science learning in the woods with a focus on problem-solving. It is understandable that teachers would choose science topics and activities with which they felt the most comfortable. The teachers' feelings of science-teaching self-efficacy, a Person characteristic, led them to focus on the areas of science in which they are most knowledgeable and confident, especially when combating heightened emotional stressors during a live, audio-recorded observation.

Positive science learning environment. During the third observation in Wren's class, the teacher mentioned the coordination of Forest Fridays and the Feeling Faces aspect of Conscious Discipline, the social-emotional curriculum used in their program. At the core of the Feeling Faces within Conscious Discipline are the four emotions of Happy, Sad, Angry, and Scared, each of which is represented with an emoji depicting the emotion. The idea behind the Feeling Faces is that to calm emotions that are limiting children's ability to regulate, children must first recognize the emotions that they are feeling. In terms of how Forest Fridays are aligned Feeling Faces, Wren explained that the emotions felt in Forest Fridays may be more intense than those experienced in the classroom. They suggested that this is because the consequences for actions within situations in which the children may experience fear or frustration are escalated in the less cultivated outdoor settings. The children must regulate their emotions and bodies in order to plan how to address stressful circumstances related to playing in the woods. Wren also commented that children's frustration is more physical in the forest than in the classroom. This may be because there is more room to physically express their frustration.

An example of how the regulation of fear assisted children was observed while out in the forest for the third and final observation of Wren's classroom. During this observation, almost an hour was spent with children exploring a large, downed tree that ranged in height from approximately 3 feet to 4.5 feet from the ground along the trunk. There were three children who stayed at this tree for nearly all the time spent in the woods, while others came and went, depending on their level of interest in continuing their tree exploration. Wren shared in the post-observation interview that many children in the class had investigated the tree and tested themselves with walking along the tree's trunk with Wren's support in previous Forest Fridays, and that the children who spent the time there earlier that day had never climbed up onto the trunk or walked along it. Throughout this time with the downed tree, the children on the tree were comfortable asking for help from Wren. At one point, a child wanted to get down, but two friends were behind her on the tree. She started to get frustrated and panicked about getting down from the tree, flapping her hands in her dismay. Wren asked her to take a few deep breaths and "make a plan to get down from the tree." The child paused, took several deep breaths, asked her friends to back up, and then, with the teacher's help, the child climbed down from the tree. Unfortunately, the circumstances necessitated her climbing down on the opposite side of the tree, so now the child had to figure out how to get around the tree. After a time in which she exhibited more frustration, Wren reminded her to make a plan on how to tackle the problem. The upended root system of the tree blocked one side of her escape, and the other side was blocked by a fence and the large architecture of the limbs of the downed tree. Ultimately, the child declared that her plan was to crawl under the tree, but she acknowledged that there was an issue with her plan—a spiderweb was in the way of her crawling under the tree. She was afraid of the spider climbing on her when she passed through the web. Wren asked how she might deal with that fear, or "what would help keep the spider from getting on your body while you go under the tree?" A discussion between the child, one of the friends on the tree, and the teacher went on for a few minutes. A decision was made that the child would use a stick to clear the path, and once the spiderweb was gone, she would climb through the space. Once the spiderweb was cleared, however, the child was again afraid of crawling under the tree. After a few minutes of sitting on the ground next to the space and a few encouraging words from the teacher, the child said to herself, "You can do this, [child's name]. You are strong!" With that self-boost, the child passed beneath the tree and walked off to her next adventure in the woods. Throughout this child's problem-solving efforts with getting down from the tree, Wren was supportive and sensitive while giving the child the time and space to work through the critical-thinking process to solve her problems; thus, creating a positive science learning environment. Wren was physically available to her, but did not hover, which allowed the child to make the decision to trust herself to figure out how to get down and under the tree. As this was not the only child to attempt walking along this tree trunk and Wren acknowledged supporting many of the children when they attempted this walk, it would seem that Wren's mesotime experiences were resource characteristics used within the microsystem of the woods near this downed tree. The instances of support to the children were proximal processes that may have aided Wren in developing the best methods for coaching children on the tree trunk.

Although this scenario may not look like science, it was an application of the scientific process. The child observed her problems, and then asked the questions of how to get down and on the side of the tree that would allow her to further explore the woods. She gathered information about her problems, formed hypotheses (or plans, as described by the teacher), and tested her hypotheses by talking about the potential issues of her plans with her teacher and a friend. She finally made conclusions by climbing down on the far side of the tree and stating that she could crawl under the tree because she was strong! This real-world application of the scientific method mirrored Wren's own development, a microsystem, in which she would often accompany and assist her father when he was dealing with different farming issues. Also, it is connected to Wren's philosophy and belief system, a Person force characteristic, around science-learning through exploration and problem-solving, especially in the natural world. In the post-observation interview, Wren explained this further,

> There is the adult-world and the kid-world. In adult-world, there are strict social norms, and everything is more structured. Adults do not know how to play. In kid-world, making a mess is making meaning, and there is lack of adult judgements. We need to recognize that that is an adult problem, not a child problem.

Wren ended this thought by reciting the quote from Mr. Rodgers about play being the work of childhood. Wren's skills at offering a positive space for children to learn science created teachable moments that encompassed scientific processes, but also life skills aimed at problem-solving and autonomy development. Wren was not alone in this endeavor of connecting science learning and life skills. The teachers in this study exemplified the ability to provide opportunities and support for science learning, while also giving children a map to navigate the choices in their future through the development of critical thinking and processing skills. The teachers' abilities were created from the science-related experiences and interactions between the teachers in this study, their families, and the teachers in whose classes they participated, and the science learning within their systems of context over time. How those developed skills and abilities influenced the teachers in their science classroom practices in specific ways that reflect their past science learning—their strengths and areas for development.

Group Analyses

In an effort to create clarity, the ideas of what factors have influenced the teachers in this study have been delineated and set apart from each other in terms of their definitions. In reality, these factors, Person demand, resource, and force characteristics and systems of context, are not discrete entities. Instead, they weave together, overlapping and tying around each other, often in intricate patterns, to form the fabric of each teachers' current science-related classroom practices. As such, the examples discussed will influence the teachers in more than one way and interact with multiple components of the theory. The influences of past science-learning experiences may reverberate through many different aspects of these teachers' lives. As an example, negative experiences with science within the microsystem of the classroom when participants were children may influence not only their science self-efficacy, but also their science-teaching beliefs as they grow into professional educators. The following sections provide analyses concerning how the teachers' Person characteristics and systems of context influence their current science-teaching practices.

Influence of person characteristics on science instruction. Science-teaching beliefs, science self-efficacy, science and math anxiety, and science education experiences, both formal and informal, are Person resource and force characteristics that have influenced the teachers within this study in how they approach and facilitate science-learning experiences with the preschool children in their care. All four of these teachers have a strong commitment to providing high quality science-learning experiences to young children. When asked how often science experiences should occur in preschool classrooms, all four teachers said all the time or consistently throughout the day. Their past experiences—created by the synergy between the teachers' Person characteristics when they were children and the different microsystems in which they learned and engaged with science, as well as the proximal processes afforded to them during times of science learning throughout their development—have influenced their ideas of the role that science should play in young children's exploration of their worlds. These experiences undergird the teachers' strong beliefs in the importance of science learning opportunities and those beliefs are apparent in their classroom practices.

Evidence of the influence of the teachers' science self-efficacy development was found throughout the interviews and observed in the classrooms. Lisa's and Wren's feelings of self-efficacy with outdoor learning environments came from science-learning experiences they had across their lifespan, first as children with their families and later as college students studying marine biology and environmental science (although it should be noted that both teachers changed their majors due to math anxiety and fears associated with the math classes they would need to take to complete their original majors). This learning continued on for both of them as Lisa continues to work with cooperative extension experts on bees and the program's pollinator garden, and Wren pursues another graduate degree in nature-based learning in early childhood education.

Although all four of these teachers are recognized as highly capable with science instruction, science anxiety was still considered an issue for at least one of the teachers. The nature of science learning in formal contexts often involves math, and two science disciplines, chemistry and physics, require math work with formulas and computation even at their more elementary levels. Thus, if students develop math anxiety, it can influence how they view their self-efficacy about science, too. As an example, Lisa visibly cringed as she said the word chemistry when I asked about her least favorite science topic. She then began saying how she was not a math person and did not have a math brain. This fear of math influenced her feelings about chemistry, even as she continued to state her love of marine biology. Strong positive feelings about one or more types of science does not equal strong positive feelings about ALL types of science.

In terms of past science education experiences, each teacher discussed previous science-related learning experiences. Candace's nursing classes in college and her interest in those classes provided her with the content knowledge to support the children's science learning with respect to the human body study. It also supplied her with the knowledge of how to make, and the feelings of self-efficacy that she could make, various body parts (heart, brain, stomach, and large intestine) from modelling clay. Through Emily's experiences in both her undergraduate and graduate programs and additional trainings, she has gained knowledge on how to incorporate experiential and sensory learning into her daily classroom activities. These types of science-related educational experiences have created Person resource characteristics related to the knowledge that these teachers bring with them when they enter the classroom.

Influences within systems of context. Exploring through outdoor play offered all of the participants informal science learning opportunities within their microsystems for growing their resource characteristics. For Emily and Candace, this involved playing with siblings and other family members outdoors. Candace spoke about she and her sisters playing in the woods with her uncles, who were close in age to her and her sisters. Both Lisa and Wren talked about learning from their families about the natural world and being encouraged to investigate it independently and with other family members. For

Lisa, who spent many vacations at the beach, this inspired an interest in marine biology. For Wren, this manifested as curiosity with the multidisciplinary area of environmental science. Although both Lisa and Wren were interested in pursuing careers in marine biology and environmental science, respectively, math anxiety—cultivated within formal classroom, or microsystem, settings—moved them onto different career paths.

Microsystems within school settings also influenced how Emily saw science, positively and negatively. Although Emily admitted to being less excited about science through most of her K-12 schooling, she did speak with enthusiasm about her high school science teacher, Mr. Riggs. His recognition of Emily's need for experiential learning opportunities sparked an interest that flashed again when Emily began working with young children and acquiring more knowledge about their learning styles, which is a Person resource characteristic.

A result from the data that should be considered is if the teachers have the autonomy to follow ideas regarding how to teach science to the young children in their care. Within this study, all four teachers were observed and spoke about having the affordance within their microsystems to use different materials and resources in order to provide engaging and developmentally appropriate science-related learning opportunities to children. With Emily, it was apparent by the various types of materials used in her observed science activities, as well as the project output found in the classroom, that she and her co-teacher had flexibility from the director to make observations concerning children's interests then create learning activities that would stimulate their knowledge acquisition. This was found in each of the observed classrooms. Lisa's director took more of a direct approach to assisting her with additional science tools, such as a new balance and two new age-appropriate microscopes. Wren's director allowed for lumber and other construction materials to be used during a parent work day to build structures for sitting, balancing, and playing in the woods. Although much of this work was organized by the teachers, the flexibility that the teachers had within the program allowed for them to exercise their agency in providing rich science-related learning experiences for the children in their care.

Another system that influenced the science instruction of the teachers' in this study was the chronosystem, or time. All of the teachers in this study are within a decade of each other in terms of age. All of the teachers talked about the ease of acquiring information, or science facts, through technology via internet or cell phone to assist them in providing correct details to curious children. Another system influenced that was not mentioned as an issue with the teachers in this study, but has been consistently reported in the literature, was the macrosystem and teachers' concerns with having time to integrate science within their daily classroom work (Gerde et al., 2018). McClure and colleagues (2017) have discussed that teachers with high self-efficacy with regards to science have fewer issues integrating science with literacy and math and other domains because they are of the belief that science exploration is foundational for children's learning. The teachers in this study have high science–teaching self-efficacy, and they feel confident when presented with the quandaries associated with linking science with other cognitive areas, including less traditionally academic skills like attention and problem-solving. The directors of the programs involved in this study may recognize these teachers' high science-teaching self-efficacy and offer them the autonomy to implement the curricula as the teachers see fit, which in turns aids the teachers in their ability to provide engaging science-learning activities.

Another concept of the macrosystem that may also be influenced by macrotime is the teachers' responses in their initial interviews that indicated gender as less of an issue for them than pilot studies of this data collection protocol indicated. The macrosystem of our society's uptake of women into science career fields is also a function of macrotime in that the values and beliefs of our Western, heteronormative, patriarchal society (macrosystem) is slowly evolving over time to be more inclusive towards women's employment in STEM fields. Previous studies provided information that resulted in the general notion that the teachers' gender might influence their past science-learning experiences. This was not the case with the teachers' in this study. Additional work may be needed to tease apart whether this is more of a cultural influence or a time influence, or both.

Influence of teachers' self-reflections and their timing. All observations were completed in the morning. Each participant was interviewed in the late morning or early afternoon on the day the observation was conducted. As each participant was asked to reflect after each observation and then verbally report on those reflections within the microtime of the observation, all of them identified additional opportunities to add science or other instructional support to the children in their care. Interestingly, some of these teacher reflections also involved mesotime as they included issues occurring over days, weeks, or months. Emily discussed the need to engage more of the senses in each of her observed activities. She also recognized that during the third observation it was hard for her to stop when the children were satisfied, as she felt there was more to explore with them regarding the mixing (or lack thereof) of oil and water. She mentioned that it was difficult to reign in her expectations as to where the lesson should go versus the children's interest.

The other teachers also talked in their post-observation interviews about how they might change their classroom practices to better facilitate science learning in their classrooms. Lisa discussed focusing on being more intentional through more organized small group work. She also talked about moving more of their science learning extension activities outside as the weather continued to warm, which involves mesotime as it will occur with regularity once weather permits. Candace realized during her first post-observation interview that she and her co-teacher were not setting and listing goals in their activity plans over days and weeks (mesotime), and she reflected that it would be helpful to share objectives or goals so that both teachers were aware of the goals of the activity. This was especially important in Candace's classroom as she and her co-teacher split the class equally during large portions of the day.

Another reflection that occurred within mesotime is Wren's statement that this study encouraged them to think critically about how the children engage with the science center in their room and how the teachers can improve the overall science center for the children. This critique of the science center led to the co-teacher and her husband building a light table for the classroom. Wren also realized that although visual aids to provide support for various activities and routines were located throughout the indoor classroom, aspects of the children's outdoor environment that they had spent time exploring and discussing had no such visual aids or supports. An example Wren provided was that there were words and pictures posted above the enclosure for the class pet, a rabbit named Alfalfa, on how to feed and care for it. However, there were no pictures or words posted around the enclosed outdoor play area on the three types of dirt that Wren and the children had explored and discussed multiple times. As these examples indicate, the teachers recognized the importance of reflecting on their classroom science activities and the processes and materials within their classrooms that support science learning and were able to consider both the present concerns within microtime and the more long-term issues in the past in mesotime. These group analyses provided evidence of how the layers of development of the teachers' science teaching was influenced by their Person characteristics and systems of context from Bronfenbrenner's bioecological theory.

Bronfenbrenner's Bioecological Theory and Teachers' Classroom Practices

Bronfenbrenner's bioecological theory encompasses four components: proximal processes, person, context, and time. This study conceptualized proximal processes as those regularly occurring science teaching and learning interaction between teachers and children, and although it is typically seen through the lens of how they influence children's development, this study considered how the proximal processes may influence interactions from the teachers' perspective. The Person characteristics of resource and force were used to describe science-teaching beliefs, science self-efficacy, science and math anxiety, and science-education experience. The Person demand characteristic was that all the teachers were women. The systems of context that were considered in the study were the microsystem (the classroom), exosystem (example is local or state professional development classes offered with few science options), mesosystem (more than one microsystem such as the classroom and a teacher's home environment), and macrosystem (the culture within the early care and education field). In terms of time, the study considered microtime as the present time, or the unit of time in which the observation was being conducted. Mesotime was viewed as the day or weeks or months of time leading up to the observation, which included learning times that were referenced by the teachers about previously discussed topics. Macrotime was conceptualized within the study as historical time and may have referred to an earlier time in the teachers' personal development. All these parts are interesting on their own, but together, they overlap and combine and synergistically influence the development of the teachers that were in this study.

The study attempted to capture much of the nuance and detail of the teachers' past science learning experiences and how those experiences were demonstrated in the teachers' proximal processes. Implications for practice, strengths and weaknesses with the study, and future work and conclusions will be discussed next.

CHAPTER VI

CONCLUSION

This chapter contains the implications for practice, limitations to the study, future work to pursue for this line of inquiry into teachers' past and present science-learning experiences and their influence on their current classroom practices, and concluding words on the study.

Implications for Practice

This study has several implications related to the practice of caring and educating young children. This includes both preservice and in-service teachers. As early care and education preservice teachers are preparing to enter the professional workforce, it is critical that they are ready to engage children in activities to support the development of the many domains involved in the growth of children's minds and bodies. Within the area of science learning, recognition of preservice teachers' different levels of science self-efficacy seems to be particularly important based on these results. This may be best done through considering teachers' past science-learning experiences.

In the professional development environment, consideration for in-service teachers' past science-learning experiences may also pave the way for more effective science instruction training. It is conceptually interesting to postulate that for both preservice and in-service teachers' classwork and professional development, respectively, teachers grouped based on their science self-efficacy may be an effective method for expanding and refining teachers' science instructional practices. This would allow for differentiated instruction in a setting created to minimize science and math anxiety when appropriate. A benefit for grouping teachers based on their science self-efficacy is that if teachers who have higher science self-efficacy in one or more types of science (i.e., biology or geology), but less self-efficacy in one or more types of another science (i.e., chemistry or physics), those particular science areas can be addressed in order to grow the teachers' science self-efficacy.

Another implication to consider in training both preservice and in-service teachers is that it is not critical for teachers to love science or for them to be considered "sciency." Instead, teachers must be open to knowledge co-construction with young children and willing to develop strategies centered on the four factors of effective science teaching: children's consistent and sustained interest in science, increasing children's science knowledge and comprehension, children's participation in science–related activities, and positive science learning environment (Tobin & Fraser, 1990). It is also important for teacher preparation and professional development around science instruction to provide teachers with strategies to promote these four factors of effective science teaching. Focusing on the application the four factors through practical strategies will assist those teachers who struggle with effective science instruction.

Other implications related to this study are the importance of outdoor play in engaging young children in science learning, science education through experiential learning and play, and the connections for the teachers in this study between science learning and autonomy in their respective programs. All three of these implications are important on their own, but also may overlap in how they manifest. As an example, two of the teachers in this study focused in interviews and observations on the importance of children acquiring knowledge through outdoor experiential learning and exploration, and both mentioned that their directors were not only supportive of their outdoor learning endeavors but allowed them the freedom to direct the cultivation of their respective outdoor learning environments. They were given the autonomy to provide the children in their care with the opportunities and environment to learn about science in the way the teachers deemed most effective. In addition to essential elements of outdoor play, experiential learning, and teacher autonomy, this study also indicated that acknowledging where preservice and in-service teachers reside in terms of their science self-efficacy and past science-learning experiences, as well as promoting an openness to acquiring science knowledge with children, were important for preschool teachers' science-teaching practices.

Limitations

This study provides the opportunity to connect preschool teachers' past and present science-learning experiences to their classroom practices, and, thus, contributes to the knowledge of what may influence science teaching in preschool settings. However, the study is not without its limitations. Several limitations, ranging from study design changes to coding framework revisions, are addressed next.

First, to gain more information on how program directors/administrators affected the science education classroom practices, it would have been helpful to have asked the program directors/administrators about their views on science education in their programs' preschool classrooms. The influences of the program administrators/directors within the broader microsystem of centers about science instruction may be either direct or indirect and intentional and unintentional. McClure (2017) highlighted the need for program directors to provide space and flexibility to support teachers' experimentation with investigating science with young children. Without this flexibility from administrators, additional opportunities for inquiry-based science exploration may be limited for teachers who feel burdened by the amount of school readiness-specific curriculum they are encouraged to cover. As a macrosystem influence among the early care and education field, school readiness as a construct is that it is relatively narrow in its definition, focusing on reading and writing and math, instead of broader and more difficult to measure skills in critical-thinking, problem-solving, attention, memory, self-regulation, executive functioning, and others. In fact, a meta-analysis of 73 studies selected through randomized control trial of professional development opportunities offered between 1995 and 2012, the number of opportunities available centered on language or literacy was 39 (Schachter, 2015). In contrast, there was only one professional development opportunity available for teachers interested in improving their science-pedagogy or -content knowledge (Schachter, 2015). This exosystem contextual influence may have implications for the proximal processes being experienced in classrooms. It needs to be said again—science education through exploration and inquiry can support the development of these broader, fundamental skills that are important, not only for early childhood academic achievement, but for success in life (Gerde et al., 2018). Gathering data from administrators would help determine how teachers' practices are connected to broader center-based philosophies and views on school readiness and science teaching more specifically.

Second, more variability within the teacher participant group in terms of Person demand characteristics may have resulted in additional information related to gender differences in science. Perhaps, if one of the participants would have been at least a decade older, there would have been at least one different perception on women in science. It also may have been interesting to examine the perceptions of a younger female teacher. The range of age of the teachers was from 29 to 39, so it would have helpful to have a participant who was in her 50s or 60s to have a different perspective.

Third, it might be valuable, at both an exosystem level and a macrosystem level, to gather additional information on how science exploration may be influenced by the policies and rules advanced by the quality rating and improvement systems (QRIS) and the Environmental Rating Scales (ERS) being used for assessments of quality across the states. This would potentially incorporate looking at the local/state and federal government regulations. Considering the ubiquitous nature of QRIS procedures in place across the country, within the macrosystem, and the common use of ERS, examining restrictions such as the time limits involved in outdoor play or regulations on hand-washing may be beneficial to the understanding of the lack of science-learning opportunities lost in lieu of risk management in many preschool classrooms.

Fourth, the coding framework may have limited how many of the observations were counted in terms of the science being covered by the teachers. This is because the current coding system only coded each of the observations one time, using the code that best fit the overall observation. The problem with this method was that it seemed to me and the second verification coder that some opportunities for acknowledging rich science experiences were missed because they were coded in a different science domain because that domain was the majority of the interaction. In other words, the interaction between the children and the teacher involved more than one science discipline, but only one was coded because of the current coding framework. Unfortunately, this shortfall was discovered during a discussion between the second verification coder and me regarding how well the coding framework was accurately capturing the science-related proximal processes observed. Although the Science Observation and Coding Matrix was piloted in several classrooms, the tallying of the codes was completed to a smaller scale than that which was necessary for the study and the limitation was not discovered.

Finally, another potential shortcoming of the study is that teachers knew ahead of time when the observation would occur and likely focused on their strengths for the classroom observation pieces of the research project. What this means is that every teacher was focused on providing their strongest activities and ideas to the children for the observations in order to ensure good data for the research project. Unfortunately, this can be limiting in terms of offering diverse science learning opportunities to the children in their care. It can also limit our understanding of what takes place in classrooms around science instruction because it may not represent what children are experiencing on a daily basis. Instituting a greater number of observations over a range of seasons would paint a stronger picture of the children’s promixal processes with science over mesotime.

Future Work and Conclusions

In terms of future work, it would be interesting to revisit teachers in this study and observe if they are implementing any of their post-observation interview ideas into their classroom practices. All of the participants mentioned that the nature of the study caused them to think about their science classroom practices and served as a teaching and learning opportunity for them. For Emily, her reflection included wanting to provide more engagement of sensory learning opportunities for the children and reinforcing her awareness of her expectations for science activities versus the children's learning needs. Lisa's reflection initiated the recognition for more intentional science learning opportunities with more organized small group work and taking advantage of the warming weather to engage in additional science learning outside in a different microsystem. For Candace, the post-observation interview registered a need for explicitly sharing objectives or goals with her co-teacher. Finally, Wren acknowledged the need for stronger engagement opportunities in the classroom's science center to encourage its use, and the need to provide visual learning supports outside like those inside the classroom. Follow-up questions regarding what specifically about the new ideas have been most helpful in their classroom practices, and why they have been the most helpful, might be worthy of exploring. This type of follow-up on the reflective process could be thought of as a potential intervention and may shed light on strategies to support improvements in teaching practices.

Additional work around the coding of the observations might be beneficial. In order to accrue more information about science learning in classrooms, it is important to ensure that the data captured is accurate across all the areas of science learning occurring in classrooms. Thus, revising the current coding system to more precisely reflect all of the science-related learning occurring across activities would add to the validity of the data collected. This may be accomplished by recoding the data for all of the potential science-related proximal processes and checking to ensure the results are replicable across coders. Further analysis would assist in understanding if the revisions to the coding framework were valuable in attempting to accurately capture the daily experiences of preschool teachers as they teach science.

In conclusion, the teachers in this study had science-related experiences that predated their time as teachers, as well as science-related experiences after becoming teachers and during their everyday lives that impacted their current science-teaching practices. Including the influences that these experiences have on teachers' science-instruction practices is germane to the overall discussion of science education in early childhood. Using Bronfenbrenner's bioecological theory (2000, 2001) as a theoretical framework, individual science experiences from teachers' personal histories (including both past formal science education and past informal science-related experiences) were examined for their influence on how teachers currently approach science instruction and science learning in their classrooms. The research questions centered on the past and present science-learning experiences that influenced teachers' science instruction in preschool classrooms, and how these learning experiences influenced their instruction.

This study demonstrated that teachers' past and present science-related learning experiences can influence their current science-teaching practices through a variety of factors, specifically past formal and informal science learning experiences as well as other Person resource and force characteristics—science-teaching beliefs, science self-efficacy, and science and math anxiety. This study also illustrated how these influences were critical in the development of these teachers' science-related teaching practices as observed in the microsystems of their classrooms. The teachers in this study recognize that science affords opportunities for young children to learn about their world through integrating various aspects of their environment. With science, literacy and math, the opportunities are much more "both/and" rather than an 'either/or' in terms of children's learning. Teaching children how to think through problems scientifically is critical for preparing them for their futures, whether or not they pursue careers related to science.

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APPENDIX A

DEMOGRAPHIC FORMS

Program Name:______________________________

Program Demographic Questionnaire

Please answer all the questions below. This information is confidential and will be used for research purposes only. Please have this form completed prior to the first classroom observation.

1. **Total number of classrooms in your program:** __________

Please complete the table below by telling us how many classrooms you have in each of the age categories. Please make sure that your number of classrooms equals the total number of classrooms; do not count a classroom twice if it includes children across age categories, consider the ages of the majority of children to identify the classroom.

Only use mixed age if there is not a majority of children in one of the age groups defined below

	Number of classrooms
Infant (up to 15 months old)	________ classrooms
Toddler (15 months – 35 months)	________ classrooms
Preschool (36 months – 5 years old)	________ classrooms
School age (K – 5^{th} grade)	________ classrooms
Mixed age	________ classrooms
Total Number of Classrooms	

2. **Total number of teachers who work in your program:** ____ full-time ____ part-time
3. **Does your program currently take Child Care Subsidies?** ☐Yes ☐No
4. **Total number of children enrolled in the program:** __________
5. **Please list languages, other than English, that staff speak when working directly with children. If only English is spoken when working directly with children, please check Not Applicable.** ☐ Not Applicable

   Language 1. __________________ Language 2. __________________ Language 3. __________________
6. **What curriculum is used in the preschool classroom(s)? If no set curriculum is used, please write "NA".**

   ____
7. **If no set curriculum is used, please explain the teaching philosophy behind the science instruction conducted in the preschool classroom(s). Please use the back of this sheet if needed.**

   ____

Teacher Demographic Form

Please answer all of the questions below.
This information is confidential and will be used for research purposes only.

1. Name: ____________________

2. Position: ____________________

3. Sex: ☐ Male ☐ Female

4. Age in Years: ____________________

5. Ethnicity:
   ☐ Hispanic or Latino
   ☐ Not Hispanic or Latino

6. Race:
   ☐ American Indian or Alaska Native
   ☐ Asian/Pacific Islander
   ☐ Black/African American
   ☐ Multiracial
   ☐ White/European American
   ☐ Not listed above: __________

7. Primary Language:
   ☐ English
   ☐ Other: ____________________

8. Other languages spoken: ____

9. Highest education level completed: ____
   (Please list degree and area of concentration.)

10. Year highest degree earned: __________

11. Number of college credit hours in special education: ________________ hours

12. How long have you worked in this school (current and previous positions)? ________ years ________ months

13. How long have you worked in your current position? ________ years ________ months

14. How long have you worked in this classroom (with these children or a majority of these children)? ________ years ________ months

15. How long have you worked in the early childhood field (professional paid positions only)? ________ years ________ months

Classroom Information Form

Teachers: Please provide the following information by printing legibly.

We will collect this form from you at your interview. Thank you!

Teacher Name: ____

Number of children enrolled: _______ Maximum number of children allowed by licensing: _______

Youngest child's birth date: _____/_____/_____ Oldest child's birth date: _____/_____/_____

Please indicate the number of children in your classroom for each demographic item below:

0-12 Months Old	
1 Year Olds	
2 Year Olds	
3 Year Olds	
4 Year Olds	
5 Year Olds	
6 Year Olds	

Asian/Pacific Islander	
Black/African American	
Multiracial	
Native American	
White/European American	
Not Listed	

Hispanic or Latino	
Not Hispanic or Latino	

ESL	
Diagnosed Disability	

Male	
Female	

Please indicate the number of children in your classroom for each demographic item below:

Type of disability	How would you describe the disability?	Check if the child has IFSP or IEP
1.	☐ Mild ☐ Moderate ☐ Severe	☐
2.	☐ Mild ☐ Moderate ☐ Severe	☐
3.	☐ Mild ☐ Moderate ☐ Severe	☐
4.	☐ Mild ☐ Moderate ☐ Severe	☐
5.	☐ Mild ☐ Moderate ☐ Severe	☐
6.	☐ Mild ☐ Moderate ☐ Severe	☐
7.	☐ Mild ☐ Moderate ☐ Severe	☐
8.	☐ Mild ☐ Moderate ☐ Severe	☐

APPENDIX B

SCIENCE OBSERVATION CODING MATRIX

		SCIENCE OBSERVATION CODING MATRIX				
		NAME OF TEACHER:			**NUMBER OF STUDENTS:**	
		NAME OF PROGRAM:			**DATE AND TIME OF OBSERVATION:**	
			Types of Science Content			
			Earth Science (geology, geosystems, climate, weather, environmental science and anthropomorphic influences, geomorphology)	**Life Science** (biology including plants and animals)	**Physical Science** (physics, forces and motions, rockets, physical properties of objects, physical change, object movement, engineering)	**Technology & Problem-Solving** (use of tools and other technology to solve problems and perform tasks)
Process (from NC Foundations for Early Learning and Development)	**Children explore the world by observing, manipulating objects, asking questions, making predictions, and developing generalizations.**	Represent what they learn during scientific exploration through drawing, modeling, building, movement, or other methods. **SCIENTIFIC PROCESS/ COMMUNICATION**				
		Ask questions and identify ways to find answers (look in a book, use the computer, try something and watch what happens). **PROBLEM SOLVING/ TECHNOLOGY SCIENCE INQUIRY SKILLS**				
		Compare objects, materials, and phenomena by observing and describing their physical characteristics. **EARTH, LIFE, AND PHYSICAL SCIENCE/SCIENCE INQUIRY SKILLS**				
		Use an increasing variety of tools to investigate the world around them (measuring tools, balance, prism, droppers). **SCIENCE INQUIRY SKILLS/ PHYSICAL SCIENCE**				
		Make and check predictions through observation and experimentation, with adult support and guidance. **SCIENTIFIC PROCESS**				
		Manipulate the environment to produce desired effects and invent solutions to problems (attach a piece of string to the light switch so they can independently turn off the lights). **ENGINEERING/ PHYSICAL SCIENCE**				

APPENDIX C

TABLES

Table 1. Number of Codes Per Participant for Earth Science, Life Science, Physical Science, and Technology and Problem Solving.

	Participant 1 Emily	Participant 2 Lisa	Participant 3 Candace	Participant 4 Wren	Total Science Codes per Discipline
Earth Science	0	2	5	6	13
Life Science	0	72	36	24	132
Physical Science	77	7	4	6	94
Technology and Problem Solving	22	22	0	10	54
Total Science Codes per Participant	99	103	45	46	293