HEAD START TEACHERS' UNDERSTANDING OF SCIENCE AND HOW IT RELATES TO CLASSROOM SCIENCE PRACTICES

By

Arianna Pikus

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Human Development and Family Studies - Doctor of Philosophy

2023

ABSTRACT

The development of scientific thinking and an understanding of science ideas is essential for all people. Not only do children deserve to have experiences that help them learn about and make sense of their world, but these experiences set the foundation for later science skills (NASEM, 2022). These understands are vital to living life, to participating in society, and for STEM (science, technology, engineering, and math) related careers (which the U.S. Bureau of Labor Statistics predicts will increase by 8% over the next ten years (2021)). One attempt to address this need is to begin science instruction earlier, specifically, there has been a recent push in early childhood education to incorporate high-quality science experiences into the preschool classroom (NASEM, 2022). While the field has produced resources to help teachers meet this need (e.g., science curriculum), it has skipped a critical first step in determining what ideas teachers already bring into their classroom about science. Teachers' ideas about science are an important area of study because research has shown teachers' ideas can influence their implementation of curriculum and classroom practices. Yet this characteristic has been found to be malleable and is an advantageous area to target through professional development. The current study takes an asset-based approach to determine early childhood teachers' ideas about science for young children and how these ideas relate to their classroom science practices. In this study, teachers' open-ended responses to these questions were analyzed qualitatively using thematic analysis (Braun & Clark, 2006). This approach provided a rich and deep understanding of the range of ideas teachers have related to science. Overall, these ideas were shown to be more positive than previously found. A weak, but positive correlation was found between these ideas and other measures of teachers' attributes related to science (e.g., attitudes and beliefs about science and science self-efficacy). However, teachers' attributes about science were not shown to

predict classroom science practices. This disconnect between early childhood teachers' idea about science and their classroom science practice, highlights a need to figure out how to better support teachers in engaging children in science practices and the role that beliefs, contexts, practices, and other dimensions play in the process. In addition, further measurement work is needed to ensure researchers are accurately capturing the relationship between teachers' ideas about science and their classroom science practices. Implications for professional learning for early childhood teachers on science topics and pedagogy are discussed

ACKNOWLEDGEMENTS

This dissertation would not have been possible without the support of so many individuals. First and foremost, I would like to thank the members of my dissertation committee, all of whom I have been working with throughout graduate school. I am in awe of amount of guidance and support you have all provided to me as I navigated this experience. You all have helped shape me into the scholar I am today, and I cannot thank you enough for that. You will always be little voices in my head, continuing to guide me as I navigate my next steps. Dr. Hope Gerde, thank you for being my teacher, mentor, and friend. You have gone above and beyond as my advisor, and I cannot put into words how grateful I am for you. You always made me feel more like a colleague than a student and that I had a meaningful voice to contribute to the field. If I am half as good of a mentor as you, I will consider myself lucky. Dr. Lori Skibbe, you were the first person to believe in and tell me I had what it takes to get a PhD. I truly would not be where I am today without you. Thank you for guiding me through my Masters, helping me banish my imposter syndrome, providing tough love (when needed), celebrating my successes, supporting my work, and continuing to be a source of guidance for me throughout my PhD. Dr. Ryan Bowles, thank you for always being willing to answer a question or talk through a stats problem. Your ability to meet your students where they are and your belief that there are no “silly questions” created a safe space for me to really understand complex statistical techniques. Because of you I am able to use my statistical toolbox to better answer my research questions. You have made me and my scholarship stronger. Dr. Christina Schwarz, thank you for sharing your expertise in early science and pushing me to consider other factors when studying teachers and classrooms.

Thank you to all the members of the ELLI lab, past and present! You were always my first pass at a research idea, sometimes the idea worked. . .other times the idea needed some work, but your feedback, questions, and suggestions helped to strengthen my program of research. Thank you for the laughs, hugs, writing dates, and encouragement at every stage of this process. I would also like to thank the HDFS department as a whole, including all the faculty, staff, and fellow graduate students who provided support, encouragement, opportunities, and mentorship.

To Dr. Tanya Wright, Dr. Amelia Gotwals, and the SOLID Start team, thank you for being my honorary home through my PhD. Working with all of you and being a part of this project has extended my thinking on early childhood science and professional learning. Thanks for letting me share my stats knowledge with you all.

I would like to thank the PIs on the *Head Start on Science* project, specifically Dr. Laurie Van Egeren. Thank you for welcoming me to the team and letting me use your data to better answer my research questions.

Finally, I would like to thank my family and friends. Thank you for your love and encouragement throughout this entire process. It has been a rollercoaster, but you all kept me ground and reminded me what I was working for when times got tough. To my parents and my sister, thank you for believing in me from day 1. You have always told me I could be anything I want to be. Thank you for helping me achieve my dreams.

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

Overview

This study examines Head Start teachers' ideas about science and how these ideas are related to their classroom science practices. Specifically, I take an asset-based approach to determine what early childhood teachers already know about science by analyzing their open-ended responses to questions on what science is for young children and how science should be taught to children. I then examine to what extent teachers' ideas about science align or deviate from current science standards and how these open-ended responses relate to more formal measures of teachers' attitudes and beliefs about science and their science self-efficacy. Finally, I examine the relationship between the characteristics Head Start teachers possess related to science (i.e., ideas and self-efficacy) and their science classroom practices.

Rationale

Young children are inherently curious about the world around them (NASEM, 2022). Experiences with science allow children opportunities to make sense of their world (Larimore, 2020; NASEM, 2022). Not only do early science experiences set the foundation for later science learning (NASEM, 2022), they support children's development of other skills (e.g., language and literacy, Brenneman, 2011; NASEM, 2022; and social-emotional skills, French, 2004). In addition, there is a growing need for a more scientifically literate population within the United States, with scholars arguing the need to begin science education as early as possible (Morgan et al., 2016). In particular, children from marginalized communities have less exposure to science, which results in lower science readiness scores at the start of kindergarten (Greenfield et al., 2009). This difference in science skills starts early and remains throughout formal schooling

(Morgan et al., 2016). One way to address these concerns is through early childhood science interventions (Morgan et al., 2016).

Current early science interventions focus on the development and implementation of science curriculum (Gropen et al., 2017); however, it is unclear if this is the most effective place for early interventions to focus. Studies with elementary school teachers found that the effects of content-based interventions were strengthened when they also addressed other ideas and understandings teachers possessed about science (Heller et al., 2012). Interventions designed to develop and build on early childhood teachers' ideas about science could be more advantageous than those focused on enhancing content knowledge alone because they provide teachers opportunities to build on and expand their current knowledge or beliefs that can help to develop skills that can be applied to multiple science content areas. However, the field is currently lacking empirical evidence about early childhood teachers' ideas about science in order to design effective professional learning.

Teachers' ideas about science are an important area for study because characteristics teachers possess are shown to influence the way teachers implement curriculum, the instructional strategies they use, and the quality of instruction they provide in classrooms (Bingham & Hall-Kenyon, 2013). Teachers' ideas about science captures a general body of knowledge and skills teachers utilize when engaging in classroom science practices. Not only do teachers' ideas impact the way curriculum is implemented in the classroom (NASEM, 2022), but also student achievement (McCutchen et al., 2002). However, is it unclear in the literature how teachers' ideas directly and indirectly impact classroom practices (Lee, 2009; Liu, 2011; Wilkins, 2008). Some work has shown a bi-directional relationship has been shown between other elements which contribute to teachers' understanding of science, such as their knowledge and their science self-efficacy. Greater content knowledge has been shown to be related to higher science self-efficacy (Maier et al., 2013) and science self-efficacy has been shown to increase as teachers' science content knowledge increases (Menon & Sadler, 2016). Other work examining beliefs and practices more generally have found teachers' beliefs to be misaligned or inconsistent with their classroom practices (Jorgensen et al., 2010; Lim & Chai, 2008; Liu, 2011). Teacher characteristics have additional impacts on classroom practices. For example, science self-efficacy and attitudes and beliefs about science, have been shown to be related to the frequency in which early childhood teachers provide science activities (Erden & Sonmez, 2011; Gerde et al., 2018). Most importantly, these characteristics are malleable and current recommendations for professional learning argue for programs that enhance teachers' ideas of science (Gropen et al., 2017; Park et al., 2017). However, before effective interventions can be designed and implemented, the field needs to understand what ideas and beliefs teachers currently possess related to science in order to build on this in professional learning.

Guiding Theoretical Frameworks

Broadly, the study of science education is guided by sociocultural and constructivist learning theories, which emphasize that learning occurs through experiences (Dewey, 1938; Piaget, 1973; Vygotsky, 1986). Early exploration of the world around them allows children to begin to develop concepts about science phenomena (National Research Council, 2012). When children have repeated experiences with a specific science phenomenon, they begin to make sense of their ideas about the world and apply these ideas to other areas (Dewey, 1938). In addition, opportunities to engage with science phenomenon through hands-on experiences allow children to integrate new knowledge into their existing schemas (Driver & Erickson, 1983; Howe, 1996; Piaget, 1973).

Young children need the help of an adult in order to make sense of their science experiences. Vygotsky's social constructivist theory highlights the importance of a knowledgeable other when children are constructing their own knowledge (Vygotsky, 1986). This learning occurs through the Zone of Proximal Development (ZPD), in which a knowledgeable adult helps children to understand and master skills they would not be able to on their own. Additionally, Vygotsky argues that learning should occur collaboratively between children and the more knowledgeable other. While student learning is complex, this study focuses on specific factors relevant to teachers approaches to learning. Drawing from adult learning theories, teachers bring their own experiences and characteristics (e.g., attitudes, beliefs, and knowledge) that informs their classroom practices (Wallace & Loughran, 2012). However, the characteristics teachers possess related to science impacts the ways in which they are able to support children's science learning and are thus the focus of this study.

CHAPTER 2: LITERATURE REVIEW

Children are naturally curious about the world around them. Even from infancy, children resemble scientists in the ways in which they interact with their world. For example, infants have been shown to engage with their surroundings using strategies that resemble hypothesis testing (Gopnik, 2012). There has been a recent push in early childhood education to incorporate high-quality science experiences into the preschool classroom, shown through an increase in early childhood science curriculum (e.g., *Preschool Pathways to Science* Gelman & Brenneman, 2004; *A Head Start on Science* Ritz, 2007; *A Head Start on Life Science* Straits, 2018), standards (e.g., Head Start Early Learning Outcomes Framework, U.S. Department of Health and Human Services, 2015; High/Scope, Schweinhart et al., 1993), and professional development (Hong et al., 2013; Piasta et al., 2015). Some scholars argue that science should be at the heart of early childhood curriculum because it provides a natural guiding theme in which children can engage a range of skills across developmental domains (Gelman & Brenneman, 2004; Gerde & Wasik, 2021; Pentimonti et al., 2020).

While the recognized importance of science education and the development of high-quality resources for teachers is encouraging, the creation of these resources has skipped a critical first step. Studies on improving early childhood science practice focus primarily on adherence to a specific curriculum (e.g., Gropen et al., 2017), however we know very little regarding early childhood teachers' understandings of science and the ideas on science pedagogy that they bring into their classrooms. Teachers' ideas about science for young children and how it should be taught to young children is an important area of study because research has shown teachers' ideas influence their implementation of curriculum and classroom practices in other academic areas such literacy (Bingham & Kenyon-Hall, 2013), yet these ideas have been found to be able to be built on through professional development. In addition, previous research examining what early childhood teachers know about science for young children and how to teach it, have only studied ideas about specific science phenomenon (e.g., force/motion; Gropen et al., 2017). This constricts our knowledge of the ideas early childhood teachers may possess. In response, the present study analyzes early childhood teachers' open-ended responses regarding their ideas about what science is for young children and how science should be taught to young children. Such data will provide a potentially more accurate, broad, and complete account of teachers' funds of knowledge related to early childhood science than previous work – and illustrate the resources that curriculum designers, researchers, and policy makers can build on. The current study then examines how teachers' ideas about science relate to formal measures of teachers' beliefs about science and self-efficacy for teaching science and how these attributes (i.e., ideas, beliefs, and self-efficacy) translate into their classroom science practices.

Importance of Science Education

The development of scientific thinking and a thorough understanding of science concepts is essential for all people. Not only do children deserve to have experiences that help them learn about and make sense of their world, but these experiences set the foundation for later science skills (NASEM, 2022). These skills are vital to those entering STEM (science, technology, engineering, and math) related careers (which the U.S. Bureau of Labor Statistics predicts will increase by 8% over the next ten years (2021)), but it is also necessary for the general population to understand and effectively respond to complex science-based problems affecting them like climate change and the COVID-19 pandemic (Osborne et al., 2003). In fact, a new report from the National Academies of Sciences, Engineering, and Medicine (NASEM, 2022) argues for the need for investment now in improving science learning for all to meet the challenges of the future.

Despite the need for a scientifically literate population, students in the United States have not shown any significant improvement in science assessment scores in the past 20 years (TIMSS, 2019). Even more worrisome, the Trends in International Mathematics and Science Study (2019) found that the previously large gap in science scores between the top- and bottom-performing students in both 4th and 8th grade is increasing. In addition, research from Morgan and colleagues (2016) found this discrepancy began as early as kindergarten, with children from low-income families entering kindergarten with significantly lower science school readiness scores than their peers (Greenfield et al., 2009). This effect has been shown to persist through until at least eighth grade (Morgan et al., 2016). This may be due to limited opportunities to engage in quality science experiences, which is supported by evidence that children living in low-income environments have fewer opportunities to engage with science phenomenon (Greenfield et al., 2009; Tao et al., 2012; Tu, 2006). One way hypothesized to address this lack of opportunity is through early intervention, specifically interventions implemented before the start of elementary school (Morgan et al., 2016).

Early experiences with science help to set the foundation for children when they enter "formal" science education in K-12 classrooms (NASEM, 2022). A joint statement by the National Association for the Education of Young Children (NAEYC) and the National Science Teachers Association (NSTA) states that "learning science and engineering practices in the early years can foster children's curiosity and enjoyment in exploring the world around them and lay the foundation for a progression of science learning in K-12 settings and throughout their entire lives" (p. 1, NSTA, 2014). Fostering young children's natural curiosity for the world around them is especially beneficial as early science interests are a strong predictor of later opportunities to engage in science learning (Alexander et al. 2012). In addition, early science experiences have been shown to help develop positive attitudes about science (Zimmerman, 2007) and reasoning skills in children (Morris et al., 2012). Early childhood science education is especially advantageous for children living in low socioeconomic communities and provides an opportunity for children to access more ways of knowing which are culturally relevant to their daily lives. Thus, in order to prepare students for the challenges of the world and foster science learning for children, there is a need to facilitate high-quality science experiences in early childhood classrooms that support children's development of science understanding and skills.

Early Science Development

Children are commonly referred to as "little scientists" in the ways in which they explore their world (Gopnik, 2012). Piaget believed that children actively construct knowledge about the world through experiments (1973) and research shows that children act purposefully to gain new knowledge about their world (Wilkening & Sodian, 2005). In addition, young children have the ability to reason, use inquiry skills, and should be encouraged to observe, explore, and discover the world around them (NSTA, 2014). While there is extensive work on how science develops during formal schooling, this section focuses specifically on young children.

Children begin gaining science skills in infancy. Gopnik and Meltzoff (1997) have put forth the "theory theory" which argues that infants and children inherently think and learn in ways similar to that of science. This theory states that most of children's learning comes from informal experiments and gathering data by watching and listening to others. Children then use this knowledge to generate predictions, interpret evidence, and provide explanations (Gopnik, 1996). In addition, by the time children are three and four, they are able to test hypotheses against data and make causal inferences about their findings (Gopnik, 2012). While some scholars argue that Gopnik's comparisons between children's cognitive development and the ways of science overreach in the similarities (e.g., Fuller, 2013), it is widely believed that young children can and should engage in science learning experiences (Larimore, 2020; NASEM, 2022; NSTA, 2014).

While children are naturally curious and eager to explore the world around them, this exploration can initially be limited because children need to learn the skills to manipulate and control variables (a strategy required for formal hypothesis-testing; Klahr, 2002). Children enhance their reasoning skills by developing strategies to help them achieve a goal (Morris et al., 2012) and develop new strategies for problem solving through individual discovery, formal instruction, and other social interactions (Gauvain, 2001). In addition, children can learn these new strategies by being explicitly taught a strategy, imitating a strategy, or by collaborating in problem solving with more knowledgeable others (Gauvain, 2001). While children are capable of developing these skills, they need high-quality experiences conducive to science exploration. These high-quality experiences can be enhanced through the intentional set-up of the classroom environments for science, active and repeated experiences with science phenomena, and guidance from a knowledgeable adult to engage children in sensemaking around science.

Setting-up the Classroom Environment for Science

The classroom environment plays a critical role in children's science learning opportunities. Structuring the classroom environment to provide opportunities for science engagement can promote learning and scientific thinking (Curtis & Carter, 2003; Gopnik, 2012). Children need a stimulating environment with opportunities for active exploration (Shonkoff & Phillips, 2000). Learning theorists, such as Maria Montessori, encourage teachers to be intentional in how their classroom is set-up with materials organized and readily available for children to engage with (Montessori, 1917).

When setting-up an environment for science exploration, teachers need to create a space that allows children to observe, be active, and experiment (Judy, 2001). Teachers should include materials that help children learn about their world and capitalize on their interests (e.g., flowers and leaves collected from the playground), tools to explore phenomena (e.g., magnifying glasses), and materials for children to communicate their thinking (e.g., science journals or data collection sheets). These materials should be available in different areas of the classroom to ensure science can be supported through formal and informal learning activities. For example, a designated science center in the classroom can include materials associated with a specific science phenomena and science tools so children are able to explore these materials independently.

In addition to having materials available, children need opportunities to interact with the materials in a variety of ways. Zacharia and colleagues (2012) found that children needed to physically interact with and manipulate stimuli in order to understand science phenomena. Hands-on experiences allow children to use their senses to integrate new information into their existing ideas (Driver & Erickson, 1983; Howe, 1996; Piaget, 1973). While formal science activities, such as in a teacher-directed lesson during large group, can be impactful for introducing children to new science concepts or practices (Nayfield et al., 2011), research shows that spontaneous play for young children can involve a form of intuitive experimentation (Gopnik, 2012). Proponents of the experiential learning cycle (that is, the theory that individuals learn from first having an experience, reflecting on that experience, and then applying those ideas to the world around them) frequently argue for the importance of hands-on learning experiences, which children can later reflect on to form a new idea or modify their existing understanding (Kolb, 1984). Early childhood theorists also argue children need to be engaging with hands-on learning experiences (Dewey, 1938; Montessori, 1917; Piaget, 1973), which has been supported by empirical research (Osborne & Brady, 2001; Pramling et al., 2006).

Play is one way in which children explore their environment and have meaningful learning experiences (Bergen, 2009; Pramling et al., 2006). Children use play to understand how the natural world works (Mantzicopoulos et al., 2009; Nayfield et al., 2011). Through play, children can explore science phenomena by engaging with different materials, learning about properties of objects, and making observations about how things work. Materials such as science tools (e.g., magnifying glass, rulers, or measuring cups) provide children opportunities to engage in science practices (such as analyzing data and constructing explanations) while playing. Experiences through play provide children the ability to use their reasoning skills to help conceptualize their daily experiences about science (Vosniadou & Brewer, 1992). Everyday experiences (e.g., kicking a ball at the park) provide children opportunities to engage in scientific activities and discourse about science phenomena (Callahan et al., 2013), which can lead to sensemaking for science.

Active and Repeated Experiences with Science Content and Practices

For children to be able to make sense of the world, they need consistent opportunities to explore and have meaningful experiences with the science phenomena around them. Many scholars, including Dewey (1938), Kolb (1984), and Vygotsky (1986) argue that learning occurs through experiences. When children explore the world around them, they begin to develop concepts about science phenomena (NASEM, 2022; National Research Council, 2012). Repeated experiences with a science phenomenon allow children to work/progress through the experiential learning cycle (Kolb, 1984) and begin to conceptualize their ideas about the world around them and can then apply those ideas to other areas (Dewey, 1938). These repeated experiences allow children to further their ideas about science and begin to notice similarities across different areas of science learning, such as patterns or cause and effect. For example, a child notices a bird at a bird feeder in their backyard. The child might remember when they saw a bird pick-up a worm from the ground and eat it. This experience helps the child to understand that birds can eat different kinds of food to survive. It then may lead the child to wonder, "What other animals need food to survive?"

Once children have reflected on and conceptualized an experience, they are then able to apply what they learned to other areas, another component for children's science understanding. When a problem occurs, children can refer to previous experiences to gather information and form new ideas for problem solving. These new ideas then act as a foundation for further exploration (Dewey, 1938). When children explore science materials, they develop background knowledge that can be retrieved later during formal science instruction (Bulunuz, 2013), showing that the experiential learning cycle (Kolb, 1984) continues to flow as children learn more about complex science concepts. Science practices (i.e., the behaviors scientists engage with as they investigate the world), highlight the importance of evaluating explanations, assessing alternative explanations, and applying explanations to other topics (National Research Council, 2012). This happens when an individual or a group draws conclusions based on evidence (Kuhn et al., 2000). The formation of explanations allows children to develop reasoning and scientific thinking skills that help create an understanding of science ideas (Metz, 2004).

Not only does the experiential learning cycle allow children to create meaning out of their experiences (Kolb, 1984), it also resembles the ways in which scientists conduct science, a key aspect of scientific literacy (National Research Council, 2012). By cycling through the experiential learning cycle, children gain experiences with science practices by learning how to gather information, test hypotheses, and draw conclusions. They are also able to gain other learning and scientific inquiry skills by distinguishing between types of evidence (Schulz & Bonawitz, 2007). When children actively engage in the work of scientists, they develop a foundational understanding of inquiry (Mantzicopoulos et al., 2013) and make sense of phenomenon instead of just memorizing facts (Larimore, 2020), which could promote positive science outcomes and understanding.

Adult Support for Scientific Sensemaking

Children need adults to guide and build on their interests to support science learning. Vygotsky (1978) highlights the important role adults play in supporting children's construction of knowledge broadly. Social constructivist theory states that children are active participants in the creation of their own knowledge and they construct this knowledge through interactions with more knowledgeable others, which can include peers or adults (Vygotsky, 1978). This theory highlights the need for collaborative learning between children and teachers or family members (Vygotsky, 1978). This learning occurs through the Zone of Proximal Development (ZPD), in which a knowledgeable adult helps children to understand and master knowledge and skills they would not be able to on their own (Vygotsky, 1978). This is especially important for children trying to make sense of science phenomena.

Many scholars support the idea that adult guidance is needed for science learning, specifically in early childhood (Kontos & Wilcox-Herzog, 1997; Nayfield et al., 2011; Tu & Hsiao, 2008). While children explore their world like scientists, they need guidance to connect ideas and engage in sensemaking. Young children are more likely to explore tools and materials in the science area if the teacher has previously demonstrated how to use a material (Nayfield et al., 2011). Children engage in some science practices independently (e.g., asking questions), but need strategies modeled or scaffolded for them to deepen their science understanding. For example, a child could guess if and how a block will roll down a hill. However, through scaffolding the child could be encouraged to make a prediction based on previous experiences they have had with blocks and evidence gathered as they reflect on these experiences with an adult.

While children naturally explore the world in ways that resemble hypothesis testing, some experiences need to be scaffolded for children to make sense of science phenomena. For preschoolers, children who worked with parents, or other adults, on a hypothesis testing task were more likely to identify causal variables than children who worked alone (Schauble & Gleason, 2000). Teachers also play a critical role in scaffolding children's scientific reasoning skills. Teachers can provide direct guidance when children are testing variables to help facilitate their learning and help children develop the skills to apply their knowledge to new contexts in the future (Klahr & Nigam, 2004; Strand-Cary & Klahr, 2008). Scaffolding science learning experiences is also effective for inquiry learning, in which the teacher helps children make to real-world connections through exploration and developing problem-solving skills (Alfieri et al., 2011; Hmelo-Silver et al., 2007).

It is clear that teachers' ability to set-up the classroom environment, plan active learning experiences and scaffold these learning experiences helps to support children's science understanding. However, we still do not know what ideas about science early childhood teachers possess that help them offer guidance and support for children's science experiences.

Teacher Attributes Related to Science Practice

Due to the importance of a knowledgeable adult for high-quality science experiences, it is fundamental to examine what characteristics early childhood teachers possess that contribute to their understanding of science concepts and how these characteristics are associated with the materials, environments, and supports they provide for science. It is well known that teachers' ideas, funds of knowledge, and experiences impact their classroom practices in general (Bingham & Hall-Kenyon, 2013; McCutchen et al., 2002; McMullen, 1999). However, the field is just starting to explore what these characteristics look like in regards to science for early childhood teachers.

While these characteristics have been shown to be malleable and can be learned or enhanced through professional development (Gropen et al., 2017), most of the work in early childhood science takes a deficit perspective and begins with the assumption that teachers are low on these skills. For example, Gropen and colleagues (2017) created a professional development program to support teachers' understanding of early childhood science and quality of science teaching around two physical science topics. This professional development program required extensive energy and time from teachers in order to participate, with coursework, curriculum guidance, classroom-based assignments, and individual and small-group coaching sessions all required as part of the program. While this program has shown positive effects on teachers' quality of teaching and knowledge around two specific topics (Gropen et al., 2017), it assumes teachers start the program with little to no prior experience with science. In addition, this program focuses only on two physical science topics (i.e., sink/float and balls/ramps) and it is unclear if, or to what extent, teachers can transfer the skills developed as part of this professional learning program to other science topics.

It is potentially more advantageous to first determine *what* ideas teachers have regarding early childhood science and how these characteristics are associated with each other, so future professional learning opportunities can capitalize and build on teachers' existing funds of knowledge and experiences. This would not only make professional learning less intensive, and therefore more approachable to a greater number of teachers, but also help teachers generalize the skills developed through professional learning to additional science topics based on children's interest. However, first we need to examine what ideas about science and other characteristics related to science early childhood teachers are already bringing into their classrooms.

Conceptualizing Teachers' Ideas About Science

Broadly, teachers' ideas have been shown to influence classroom science practices and student achievement (McCutchen et al., 2002). Teacher ideas commonly refers to the funds of knowledge, skills, and experiences that are needed to function successfully in the classroom (Darling-Hammond, 2000). Numerous conceptual frameworks have been used to understand teachers' ideas (see Fernandez, 2014 for a review), however there is a lack of consensus in the field on how best to conceptualize, model, and assess the funds of knowledge teachers bring to their classrooms (Ferdandex, 2014; Kind, 2009). The origin of defining funds of knowledge is credited to Moll and colleagues (2009) who initially proposed drawing on the knowledge and skills families to develop home-school connections and improve classroom quality. Development of these fund of knowledge allows teachers to find multiple ways to represent information, adapt material to children's developmental levels, prior knowledge, and misconceptions, and it allows teachers to tailor learning activities based on children's curiosity and interests (Shulman, 1986). More complex models have been created to conceptualize teachers' funds of knowledge related to science and their classroom practices (Fernandez, 2014). However, it's important to note that when these models were developed and empirically tested, studies primarily focused on secondary science educators who tend to "specialize" in one science content area, have received formal education in that content area, and teach science in a fundamentally different context than in an early childhood classroom.

There currently is a lack of empirical findings regarding early childhood teachers' funds of knowledge related to science but examining research on other content-specific skills early childhood teachers possess can highlight the relations between ideas and practice in early childhood classrooms. For example, preschool teachers' math pedagogical content knowledge has been shown to predict the instructional quality of math activities in the classroom and has shown positive gains in children's math learning (McCray & Chen, 2012). In addition, greater math knowledge allowed teachers to recognize math content in children's everyday play (Oppermann et al., 2016) and was associated with teachers' planning more mathematical learning opportunities in the classroom (Dunekacke et al., 2015). In light of these findings, current recommendations argue for professional development that enhances teacher's funds of knowledge and experiences with science (Park et al., 2017).

One reason for a lack of empirical evidence for early childhood teachers' ideas about science could be due to a lack of valid and reliable ways to measure teachers' attributes related to science. Most of the measures for teachers' ideas about science have been study specific and it's unclear to what extent the results are generalizable (Barenthein et al., 2018; Gropen et al., 2017). For example, Gropen and colleagues (2017) created performance tasks to measure teachers' pedagogical content knowledge for science. These tasks required teachers to respond to a hypothetical scenario of classroom science learning around the two content areas (Gropen et al., 2017). Barenthein and colleagues (2018) developed a paper-and-pencil test to measure preschool teachers' science knowledge. However, similar to Gropen's work (2017) this test focused on four content areas (i.e., sinking/floating, material, state of matter, and magnetism). While measures like these are useful in determining what teachers know about and how to teach a specific science concept, this knowledge may not be transferable to other science content. Conclusions from these measures are potentially limited because they only assess teachers' ideas on physical science topics, and completely ignore other science content areas such as life science, Earth/space science, and engineering. For example, the ideas about science teachers may have of how to best teach a unit on sinking/floating may differ from the funds of knowledge they pull from in order to teach a science unit on trees. By asking teachers about specific content, we may be missing the general ideas and skills teachers are bringing into their classroom for science activities. Thus, the present study is the first to ask general, open-ended questions to elicit early childhood teachers' ideas about science regardless of specific content area.

Current Standards. It is also necessary to examine early childhood teachers' ideas about science in the context of current science standards due to the influence standards have on the content and skills teachers choose to focus on in their classrooms (NASEM, 2022; Smith & Kovacs, 2011). Current early childhood standards show a mix of content-specific knowledge and science practice skills children are supposed to develop. However, there is substantial variation depending on which standards a program has adopted. For example, Teaching Strategies GOLD (Heroman et al., 2010) has five items related to science and technology. These items include observing children using scientific inquiry skills, demonstrating knowledge of characteristics of living things, demonstrating knowledge of physical properties of objects and materials, demonstrating knowledge of Earth's environment, and using tools and other technology to perform tasks (Heroman et al., 2010). High/Scope's Child Observation Record (COR; Schweinhart et al., 1993) includes eight items for preschoolers related to science and technology, including items related to observing and classifying, experimenting, predicting, and drawing conclusions, the natural and physical world, and tools and technology. The Head Start Early Learning Outcomes Framework includes six items related to science learning (US Department of Health and Human Services, 2015). These items include having children observe and describe phenomena, engage in science talk, comparing and categorizing observable phenomena, asking questions, gathering information, and making predictions, planning and conducting investigations, and analyzing results, drawing conclusions, and communicating results (US Department of Health and Human Services, 2015). However, it can take time and also be challenging for teachers to align with new science standards (Banilower, et al., 2013; Davis, et al., 2006; Tekkumru & Stein, 2015). Due to the adoption of the Head Start Early Learning Outcomes Framework (US Department of Health and Human Services, 2015) by the participants in the current study, I examine to what extent teachers' science ideas align or deviate from these science standards and how these ideas relate to their classroom science practices. In addition to current early childhood science standards, changes in national K-12 science standards may also impact classroom practices.

Science standards in K-12 classrooms have undergone an extensive shift in the way teachers and schools are thinking about science learning (National Research Council, 2012). Based on *A Framework for K-12 Science Education*, published by a committee of recognized scientists, cognitive scientists, science education researchers, and education policy experts, the Next Generation Science Standards (NGSS) were released in 2013 (NGSS Lead States, 2013). These changes proposed that instead of simply learning about a topic, students should be encouraged to "figure out" about a phenomenon (Schwarz et al., 2017). This is done through the three dimensions of the framework: disciplinary core ideas, science practices, and crosscutting concepts (National Research Council, 2012). Disciplinary core ideas refer to the content that is being taught or domain specific knowledge. The disciplinary core ideas are grouped into four domains of science: physical science, life science, earth and space science, and engineering, technology, and applications of science (National Research Council, 2012). Science practices, or domain general knowledge, refers to the skills scientists (and engineers) use as they investigate phenomena (or design solutions). The science and engineering practices include: asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using math and computational thinking, constructing explanations and designing solutions, engaging in arguments from evidence, and obtaining, evaluating, and communicating information (National Research Council, 2012). Crosscutting concepts refers to the ideas/concepts that are applicable across all domains of science. Crosscutting concepts include: patterns, cause and effect, scale, proportion, and quantity, systems and system models, energy and matter, structure and function, and stability and change (National Research Council, 2012). In order to facilitate children's science understanding and skills, these three dimensions should be integrated to investigate and explain phenomena in the standards (NGSS Lead States, 2013).

While not officially adopted for preschool aged children, the NGSS has been making its way into early childhood classrooms. Researchers have begun to work on NGSS-based assessments (Greenfield, 2015; Kaderavek et al., 2015), curriculum (John et al., 2018), and professional development (DeJarnette, 2018; Tuttle et al., 2016) for preschool aged children. However, it is still unclear if all, or what specific aspects, of the NGSS are applicable for young children. One possible source of insight into this is by examining what ideas experts (i.e., early childhood teachers) possess about early science and how these ideas align or deviate from the current standards. By taking a strengths-based approach, this dissertation examines how early childhood teachers' ideas about science are related to the three dimensions of the framework and how this alignment or deviation influences classroom science practices.

Attitudes and Beliefs for Science

Another attribute teachers possess that influences their classroom practices are their attitudes and beliefs. Attitudes and beliefs are viewed as complex, multidimensional constructs that help to guide human behavior (Osborne et al., 2003). Attitudes are defined as a person’s “feeling” towards an object or concept, while beliefs refer to information a person has about an object or concept, regardless of if that information is factual (Fishbein & Ajzen, 1975; Koballa, 1988). These two constructs influence each other (Koballa, 1988), for example a teacher's belief about science determines how that teacher feels about science (Shrigley et al., 1988). There is currently debate in the field on how teachers’ beliefs influence their classroom practices (Brown, 2005; Lee, 2009; Liu, 2011; Richardson, 2003; Wilkins, 2008). For example, Brown (2005) found teachers’ mathematical beliefs to be uncorrelated with standards-based mathematics instructional practices. However, other scholars hypothesized teachers’ attitudes and beliefs to be one set of characteristics that influence science teaching in early childhood classrooms (Maier et al., 2013).

Most of the current research in this area focuses on elementary school teachers’ attitudes and beliefs toward science teaching. Various studies have shown that elementary teachers generally have negative attitudes towards science and these negative attitudes often originate from negative experiences within their own K-12 science education (Palmer, 2001; Palmer, 2004; Tosun, 2000). These attitudes have been shown to impact the learning opportunities and instructional practices teachers provide (Jones & Carter, 2007). When teachers have positive attitudes and beliefs, they spend more time teaching science and incorporate more hands-on materials in their science teaching (McDevitt et al., 1999).

When looking at early childhood teachers, teachers were found to have more positive attitudes and beliefs about science than previously hypothesized. For example, in a study looking at Turkish preschool teachers self-reported attitudes towards science, teachers were shown to have more positive than average attitudes towards science teaching (Erden & Sonmez, 2011). These attitudes were shown to predict the frequency in which teachers provided science activities in their classrooms (Erden & Sonmez, 2011). However, this association, while significant, was rather weak, indicating that teachers' attitudes toward science play a role in explaining classroom practices, but not a substantial one (Erden & Sonmez, 2011). Pendergast and colleagues (2017) found similar results when using a different self-report measure with 112 preschool teachers in Georgia. However, they reported that teachers felt anxiety about their own science knowledge and ability to support children's scientific learning (Pendergast et al., 2017). In addition, teachers' attitudes and beliefs have been shown to influence how they interpret and later implement what they learn in professional development (van Aalderen-Smeets & Walma van der Molen, 2015). However, the studies previously mentioned (i.e., Erden & Sonmez, 2011 and Pendergast et al., 2017) examine teachers' attitudes and beliefs in isolation and do not take into account the full range of characteristics towards science teachers possess and contribute to their classroom practices. Thus, it is necessary to analyze the relations between teachers' attitudes and beliefs and other teacher attributes related to science (such as ideas and self-efficacy) to determine how these attributes are related to one another and how they influence classroom science practices.

Science Self-efficacy

Teachers' science self-efficacy is another characteristic that has been shown to impact classroom practices (Gerde et al., 2018). Self-efficacy for teachers is an individual's belief about their own abilities to perform specific teacher and learning related tasks within the context of their own classrooms (Bandura, 1977). In general, teachers with higher self-efficacy are shown to use more developmentally appropriate teaching practices with young children (McMullen, 1999) and higher self-efficacy has been associated with better student outcomes (Tournaki & Podell, 2005). When looking at academic subjects, teachers need domain-specific self-efficacy, that is, they need to feel confident in their own ability before they become confident in teaching specific content (Vartuli, 2005).

However, the way in which science self-efficacy influences classroom practices is still unclear. In general, domain-specific self-efficacy has repeatedly been shown to influence teachers' classroom practices and child outcomes (Guo et al., 2010; Spektor-Levy et al., 2013). This may be due to higher levels of child engagement that have been shown to be correlated with higher levels of self-efficacy, but it is unclear if higher self-efficacy is predictive of child engagement (Guo et al., 2011). Another study found that self-efficacy mediates the relationship between professional development and frequency of science occurring with a preschool classroom (Oppermann et al., 2019). Gerde and colleagues (2018) found preschool teachers' science self-efficacy to be related to how often they engaged children in science instruction. However, these studies only looked at self-efficacy and did not examine a richer model that included other teacher attributes for science.

Some work has suggested that there is a relationship between teachers' science self-efficacy and ideas about science. For example, it is hypothesized that professional development designed to build on teachers existing science ideas could also impact teachers' science self-efficacy as self-efficacy increases with teachers' science content knowledge (Menon & Sadler, 2016). However, to date, the relationship between early childhood teachers' ideas, attitudes and beliefs, and self-efficacy towards science has yet to be examined. Previous studies have shown the importance of each of these characteristics individually, but the field has yet to test a complete model that examines the unique variance each of these characteristics contributes to science classroom practices.

The Current Study

This study took an asset-based approach in deciphering early childhood teachers' ideas about science and determining how these ideas align or deviate from current science standards. This study then examined how these ideas relate to validated measures of teachers' beliefs about science and self-efficacy for teaching science and how these attributes (i.e., ideas, beliefs, and self-efficacy) influence teachers classroom science practices. This study was guided by four research questions.

RQ1) How do Head Start teachers describe their understanding of science?

Hypothesis: I expect teachers' ideas about science will vary greatly, with some teachers thinking science is not appropriate for young children and others identifying extensive views on what science should entail for young children.

RQ2) How do teachers' ideas about science align or deviate from current early childhood standards (Head Start Early Learning Outcomes Framework; US Department of Health and

Human Services, 2015) and the three-dimensional framework for K-12 students (National Research Council, 2012)?

Hypothesis: I predict teachers' ideas about science will refer to some aspects of the Head Start (HS) standards. I also predict teachers will refer to some aspects of the NGSS framework (e.g., by listing science practices children can engage in or by naming specific topics) but few will integrate all three dimensions.

RQ3) How do teachers' ideas about science relate to their attitudes and beliefs and their science self-efficacy?

Hypothesis: I expect teachers' ideas about science to be significantly, and positively correlated with their beliefs about science and their science self-efficacy.

RQ4) How do teacher's characteristics about science (i.e., their ideas, beliefs, and self-efficacy) relate to their science teaching practices?

Hypothesis: I expect teachers' ideas will account for a significant portion of the variance in models predicting the amount of science materials, the frequency in which science occurs, the quality of science lessons within the classroom, and their use of science practices during a science lesson.

CHAPTER 3: METHODS

Participants

Seventy-three lead teachers were recruited from eight Head Start programs across one Midwestern state to participate in this study. Programs were located in rural, urban and suburban environments. Teacher demographic information can be found in Table 1. On average, teachers had approximately 11 years of preschool teaching experience (*SD* = 7.38; Range: 2 – 31 years), and over 6 years in their current position (*SD* = 6.17; Range: 0 – 25 years). Teachers reported their highest level of education, with 1.4% (*n* = 1) having obtained a high school diploma or GED, 22.2% (*n* = 16) with an Associate's degree, 69.4% (*n* = 50) with a Bachelor's degree, and 6.9% (*n* = 5) with a Master's degree. One teacher did not report their highest education level and was excluded from the education percentages presented. Additionally, teachers listed any certifications they had obtained: 24 had a ZA early childhood endorsement, 16 had a CDA, and 22 had an elementary school teaching certificate. All but one of the teachers identified as female. Approximately 83.3% of the teachers in this study self-identified as White (*n* = 60), while 12.5% (*n* = 9) identified as African-American/Black, 1.4% (*n* = 1) identified as American Indian/Native American, 2.8% (*n* = 2) identified as other, and one did not report their race. Two teachers identified as Hispanic.

Due to eligibility requirements for attending Head Start classrooms, children in these classrooms lived in families identifying as low-income. The children in the classrooms observed were approximately 47 months old (*SD* = 6.1 months) at the start of the study. Primary caregivers were asked to report children's race; a majority of children in the classrooms observed were Caucasian/White (approximately 62%), however classrooms showed racial diversity with approximately 19% of children being African-American, 10% biracial, and 9% identifying as other. A majority of families reported their primary home language as English (82%), with 16% reporting Spanish and 2% reporting other. In addition, approximately half of primary caregivers reported their highest level of education as completing high school or less. Approximately, 30% of caregivers reported their highest level of education as some college, while 9% had obtained an Associate's degree, 7% had obtained a Bachelor's degree and 2% had obtained a post-Bachelor's or graduate degree.

Procedures

This study utilized data from a larger intervention study designed to examine the effects of a science curriculum on preschool teachers' practices and developmental outcomes for low-income children. Data were collected over two academic years for two cohorts of participants. In order to utilize the full range of teachers' ideas about science, baseline classroom and teacher data was pooled across both cohorts prior to conducting analysis. As the data being utilized were collected before the intervention was implemented, this study examines teachers' beliefs and practices outside of intervention supports and does not address intervention effects. Data collected included a teacher survey with questions about their demographic information, science-specific self-efficacy, attitudes and beliefs about science, comfortability in teaching science, and two open-ended questions, "What is your definition of science for young children?" and "How should science be taught to young children?" In addition to the survey, a classroom observation was conducted to assess the quality of a science lesson, the observed use of science practices within a science lesson, and science materials present in the classroom.

Classroom observations were scheduled with teachers one week in advance to ensure data collectors were observing a typical school day (e.g., no field trips). Trained research assistants video recorded teachers' implementing a science activity within their classroom. Teachers were randomly assigned one science activity to teach focused on either sink/float, force and motion, or waves. The sink/float activity focused on investigating which types of objects sank or floated by encouraging teachers to fill a tub with water and providing objects that children could test. The force and motion activity provided children with a variety of small objects (e.g., toy car and marbles) to explore the relationship between the objects and motion. Lastly, the waves activity gave children the opportunity to create a disturbance while playing with objects in a tub of water and observing when the waves occurred and what they looked like. The present study captured whichever lesson was randomly assigned to each teacher at their first observation point. Teachers were provided with minimal directions on how to conduct the activities which allowed researchers to observe teachers' typical approaches to early science education. For each activity, researchers provided teachers with activity materials and a one-page summary sheet describing the goal of the activity, a materials list, and a brief explanation of the science content. The summary sheet did not identify specific learning standards or vocabulary. The goals were written to encourage sense-making versus learning isolated facts; for example, the force and motion activity goal was to "help children understand the relationship between the force exerted on an object and the resulting movement of the object." Teachers were also asked to conduct the activity in whatever manner they chose, with the intent of observing how teachers enacted science lessons as part of their regular classroom practice. To accommodate real-world contexts, teachers were asked to conduct activities when they felt it most appropriate in their daily schedule. Most teachers (79%) conducted the activity with a small group of children (i.e., 2-8 children), while a few (21%) chose to conduct the activity in a whole group. Recorded videos were transcribed and assessed on classroom quality and practices by CLASS trained research assistants (see "Quality of Science Lessons" in Measures) and were coded on teachers observed use of science practices using the SciTOP-P (Larimore et al., 2018; Larimore et al., *under review)*. In addition to video recording classroom practices, data collectors observed the classroom and live coded science materials available throughout the day using the Preschool Classroom Science Materials/Equipment checklist (Gerde et al., 2018; Tu, 2006).

Measures

Teacher Resources Related to Science

Science Understanding. As part of the survey, teachers wrote their responses to two open-ended questions to gather their ideas about early childhood science. The questions asked were, "What is your definition of science for young children?" and "How should science be taught to young children?" Responses were transcribed verbatim into an excel database. On average, teachers' responses to "What is your definition of science for young children?" contained 25 words (SD = 18.58; Range: 2 – 96 words) and to "How should science be taught to young children?" contained 27 words (SD = 24.34; Range: 2 – 114 words). Analysis was conducted by pooling together each teacher's response to both questions; this was done to ensure the teachers' complete ideas were accurately captured.

This data was coded using the widely utilized qualitative analytic method of thematic analysis. Thematic analysis is a method used for identifying, analyzing, and reporting patterns or themes within data (Braun & Clarke, 2006). This analysis was chosen due to its flexibility and ability to provide a rich and detailed, yet complex, account of the data (Braun & Clarke, 2006). Thematic analysis is a recursive, ongoing process that includes six phases (Braun & Clarke, 2006). The phases are: familiarizing with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing a final report. In order to *familiarize myself with the data,* I read and re-read the transcriptions, jotting down initial ideas.

Next, I *generated initial codes* by documenting where and how patterns occurred in teachers' responses (Braun & Clark, 2006; 2012). Teachers' responses were coded by idea unit and therefore, were coded into as many codes as were relevant and present in each response. This decision to code at the idea unit allowed for the coding of highly varied responses, including very brief statements, and ensured we did not integrate ideas too early in the process. For example, Teacher 5 response, "At the preschool level, science is exploration and observation of living and no[n] living things to help students make sense of the world around them." This response generated the initial codes of exploration, observation, living/non-living, sensemaking, world around them. These initial codes represent reoccurring and unique ideas that were present across teachers' responses. This initial step focuses on the ideas present in the data thus reflecting the ideas of early educators themselves, an important and unique contribution to the field. Subsequent analyses applied theories and general ideas/conceptualizations of science from the field. Tables 2 and 3 show initial codes reflecting teachers' ideas generated from this step. These codes were further synthesized as I answered research question 1 and 2 by following the remaining steps proposed by Braun and Clark (2006). Further description of these steps can be found in the Data Analysis section below.

Attitudes and Beliefs about Science. The Preschool Teacher Attitudes and Beliefs Toward Science (P-TABS; Maier et al., 2013) was used to measure Head Start teachers' attitudes and beliefs towards teaching science. The P-TABS has teachers indicate the degree to which they agree or disagree with items using a 5-point Likert scale, with 1 indicating strongly disagree and 5 indicating strongly agree. Higher scores are associated with more positive attitudes and beliefs about science. The P-TABS contains 35 items related to early childhood science, which form three factors encompasing Teacher Comfort, Child Benefit, and Challenges. Eleven of the items were negatively worded to avoid agreement bias and reverse coded for analysis. The P-TABS has shown strong evidence of concurrent and predictive validity (Maier et al., 2013).

Science Self-efficacy. A revised version of the Attitudes Toward Science instrument (Van Egeren et al., 2007; Von Blume, 1998) was used to measure teacher's science self-efficacy. This measure contained five items to assess teacher's perceptions of their ability and enjoyment of science. Each item was rated using a 5-point Likert response format: 1 (strongly disagree), 2 (disagree), 3 (not sure), 4 (agree), or 5 (strongly agree). Composite scores were calculated by summing the responses, with higher scores indicating greater self-efficacy for science. The scale showed high composite reliability of .79 (95% CI [.70, .86]; Gerde et al., 2018).

Classroom Practices

Science Environment. An adapted version of the Preschool Classroom Science Materials and Equipment Checklist (PCSMEC, Gerde et al., 2018; Tu, 2006) was created for this study to assess the amount of science materials and equipment present in the preschool classroom. This new instrument included two new science material items (science learning computer games and science magazines) and removed three items with low face validity (puzzles, candles, and latches). The final checklist contained 53 items, divided into three categories: science materials (20 items), science equipment (24 items) and natural materials (9 items). Trained observers scored the classrooms based on the presence (given a score of 1) or absence of materials (given a score of 0). Items were scored as present if they were available at any time during the day, such as during free play or during a teacher-directed activity. Total scores were summed with higher scores indicating a richer science environment. Green and Yang's (2009) reliability coefficient for this measure is $\widehat{\rho}_X$= .92 (95% CI [.89, .94]), and interrater agreement for trained observers was .95.

Quality of Science Lessons. The Classroom Assessment Scoring System-Instructional Support domain (CLASS-IS; Pianta et al., 2008) was used to examine the quality of instruction in teachers' science lessons. The Instructional Support domain was calculated from three dimensions of the CLASS, which measure concept development, quality of feedback, and language modeling, as indicated in the CLASS manual (Pianta et al, 2008). Coders were first trained to the CLASS developers' standards of reliability (i.e., 85% of codes with 1 point of the expert ratings), before scoring video-recordings of the teachers engaging in science activities with children. Possible scores range from 1 to 7 with higher scores indicating higher quality of science instruction. CLASS-IS has evidence of high internal consistency and predictive validity (Pianta et al. 2008). In this sample, Krippendorff's alpha (2013) was used for interrater reliability and found to be .66 (95% CI [.45, .83]). A one-way ANOVA showed there were no significant differences in CLASS-IS scores based on assigned science activity, $F(2, 51) = 1.131$, $p = .33$.

Observed Use of Science Practices. To assess teachers' use of science practices within the classroom, the Science Teacher Observation Protocol for Preschool (SciTOP-P; Larimore et al., 2018; Larimore et al., *under review)* was used. This is a frequency-based coding system designed to capture teachers' modeling and facilitation of science practices (Larimore et al., 2018). This tool captures both NGSS science practices (e.g., analyzing data) as well as early childhood science process skills (e.g., observing). In addition, it captures teachers' modeling, facilitation, and classroom management related to science. Codes include: eliciting background knowledge, generating explanations (what and how), generating explanations (why), exploring, investigating, observing, predicting, introducing science vocabulary, recording information, categorizing, managing, and reflecting. Interrater reliability between coders was high, with Krippendorff alpha's ranging from .91-.99 (Larimore et al., *under review)*. Final scores were calculated as the number of codes observed per minute of activity to control for the differences in the duration of activities. A one-way ANOVA showed there were no significant differences in Sci-TOP-P scores based on assigned science activity, $F(2, 48) = .753$, $p = .48$.

Engagement in Science. To assess engagement in science, teachers were asked, "In this classroom, how often do teachers interact together with children on science activities." Teachers selected from five possible responses: (1) 3-4 times a week, (2) 2 times a week, (3) 1 time a week, (4) 2 times a month, (5) 1 time a month. Responses were part of the larger survey about the general classroom environment.

Data Analysis

For clarity purposes, I have divided this section by research question and subsequent analysis.

Research Question 1

In order to answer my first research question, *how do Head Start teachers describe their science understanding*, I continue following the steps of thematic analysis (Braun & Clarke, 2006; 2012). I have chosen to use this approach in order to provide a richer and deeper understanding of teachers' ideas about science than previous work which required teachers to respond to researcher-generated ideas about science rather than asking for teachers' ideas. It is important that we first understand what resources and ideas teachers are bringing into the classroom and how these resources are related to science. Therefore, an inductive coding process (Charmaz, 2014; Linneberg & Korsgaard, 2019; Saldana, 2015) was chosen to ensure the codes stay as close to the data as possible and allowed me to extract the full range of ideas teachers possess related to science. I continued to *search for themes* by searching the entire data set to collate initial codes (Step 2) into themes. One important aspect to consider during this process is what qualifies as a theme. Braun and Clark (2006) argue that the importance of a theme does not need to be dependent on a quantifiable measure, but instead on the extent it captures something important in relation to the research question. I created a thematic map to help identify themes present in the data. Once the initial search was completed, I *reviewed the themes* with my primary advisor to determine if the themes adequately capture the nuance of teacher responses and to examine the validity of individual themes in relation to the data and whether the thematic map accurately reflects the meanings evident in the data set as a whole (Braun & Clark, 2006). Analysis was an interactive and ongoing process through continued discussion with my dissertation advisor and refining of the major themes present in the data. After the themes were agreed upon, I *defined and named the themes* with examples extracted from the data to help tell the story of each theme (Braun & Clark, 2006). Once this process was complete, I *produced a final report* summarizing the themes present in teachers' responses.

Research Question 2

In addition to coding teacher responses inductively as part of research question 1, I also coded responses theoretically to answer my second research question, *how does teachers' understanding of science align or deviate from current early childhood standards and the three-dimensional framework for K-12 students?* While my first research question generated themes based on the data, I also coded responses with specific questions, or theory, in mind (Braun & Clark, 2006; Saldana, 2015), particularly how do teachers' responses correspond to Head Start (HS) standards and NGSS standards for early science education.

For the HS standards, I identified the number of teachers who discussed the science components of the Head Start on Early Learning Framework and also how many components of the framework each individual teacher refers to. Teachers received a score of 0 – 6 depending on how many components of the framework they mention in their responses.

I also identified the number of teachers who discussed each of the three dimensions of the NGSS framework and the number of teachers who identified multiple dimensions of the framework. This information was then used to create a continuous variable reflecting teachers' alignment with NGSS; possible scores range from 0 to 3. Conceptually, the NGSS dimension of science and engineering practices includes many, but not all, of the components of the HS standards, meaning a teacher who scores 1 – 6 on those standards was likely to score at least a 1 for knowledge related to the NGSS framework. At least 20% of teachers' open-ended responses were double-coded using the coding system developed for HS standards and NGSS, with interrater agreement at 90%.

Research Question 3

To answer my third research question, *how do teachers' understanding about science relate to their attitudes and beliefs and their science self-efficacy,* I used Spearman correlations between the variables created to represent teachers' ideas related to HS standards and the NGSS framework, separately, and teachers' attitudes and beliefs (P-TABS) and science self-efficacy. I also created additional groups of teachers based on themes discovered as part of the analysis associated with research question 1 to examine how these groups were related to teachers' attitudes and beliefs about science and their science self-efficacy. Teachers were coded dichotomously into groups based on the presence/absence of a particular code (i.e., 1 = teacher mentioned variable, 0 = teacher did not mention variable).

Research Question 4

To answer my final research question, *how do teacher's characteristics about science (i.e., their understanding, and self-efficacy) relate to their science teaching practices,* I used hierarchical linear regressions to determine to what extent does each representation of teachers' understanding (i.e., alignment to HS standards and/or NGSS framework) predict the amount of science materials in the classroom, the quality of the science lessons taught as measured by the CLASS-IS, observed use of science practices with a science lesson, and the reported frequency in which science lessons are taught. A three-step hierarchical regression was run for each classroom science practice. Step one contained teachers' science self-efficacy to control for teachers' beliefs in their ability to teach science to young children. Teachers' understanding aligned with HS standards was entered in step two, while teachers' understanding aligned with the NGSS framework was entered in step three to determine if teachers' understanding of science above and beyond their current guiding science standards predicted their implementation of high-quality science practices.

CHAPTER 4: RESULTS

This study utilized a mixed methods approach to explore early childhood teachers' ideas about science and how these ideas relate to other attributes teachers possess related to science and their classroom science practices. Findings are organized by research question.

Head Start Teachers Science Understanding

Using the process of thematic analysis (Braun & Clarke, 2006), I analyzed teachers' written responses to two open-ended questions: 1) *What is your definition of science for young children?* and 2) *How should science be taught to young children?* Through this qualitative analysis technique, six themes emerged from teachers' responses: appropriate for young children, purpose of science, how children learn, what children learn, location of science, and the role of teacher/child.

Appropriate for Young Children

All Head Start teachers (n = 73 teachers) in this study believed science was appropriate and important for young children. For example, Teacher 56 wrote, "Children should be exposed to science at a very early age to help them learn." Teacher 69 responded, "The earlier [science is taught] the better and the more hands on the more interested children will stay." Another note of interest was that no teacher mentioned science was inappropriate for children or they were too young to understand scientific concepts. However, some cautioned that teachers should ensure that science does not "go over [children's] heads" (Teacher 42).

In addition to the appropriateness of science for young children, approximately 14% of teachers (n = 10 teachers) mentioned the frequency in which science should occur for young children. When teachers did mention the frequency for science, they typically advocated for daily science occurrences. For example, Teacher 8 said, "...[science should be taught] Every day all day." Some teachers emphasized the role of the teacher in making science happen daily, "Science is around us daily and we as teachers should take the opportunity to teach our children about our environment." While other teachers discussed the importance of providing materials for daily science to occur. For example, Teacher 44 said, "Providing science materials and activities on a daily basis." Teacher 37 mentioned, "Materials available daily for children to explore, investigate and experiment."

Purpose of Science

Another theme teachers discussed related to science for young children was the purpose of science. Broadly, this theme describes the *why* of science engagement and captures teachers describing the benefits to young children when they engage in science learning. Within this theme, sub-themes emerged including exploring/making sense of the world, developing or expanding knowledge, developing a sense of wonder/promoting curiosity, and preparing children for life or creating life-long learners.

Over half of the teachers in this study (n = 39 teachers) mentioned that science experiences allowed young children to explore and begin to make sense of the world around them. Within this sub-theme, teachers ranged in how they described this purpose of science. Some teachers described this in general terms, for example Teacher 34 said, "Learning about the world around them and how it affects them." However, other teachers offered more nuanced descriptions, such as Teacher 65 who said, "Science to young children is learning about the world around them. All of the how, what, and why questions that make them curious about how things work." Or Teacher 59 who said, "Science is when children are allowed to experiment with the world around them and to see how things work. It teaches cause and effect. It allows them to incorporate what they know and use it to figure something else."

In addition, approximately 25% of teachers (*n* = 18 teachers) described early science experiences as helping to develop or expand knowledge in young children. Some teachers mentioned this explicitly, for example Teacher 60 said, “Science is when young children learn new knowledge and expand their existing knowledge through exploration.” Or Teacher 61, who said, “Science should be taught to children based on their interests. Building on what they know and learning what they want to know...” Other teachers described this as figuring out the unknown, such as Teacher 11 who said, “...Asking and finding out about questions to which the answer is unknown.”

Another sub-theme that emerged within purpose of science, was the discussion of science as a way to develop a sense of wonder or promote curiosity in children. Approximately, 8.2% of teachers mentioned this (*n* = 6 teachers). For example, Teacher 55 said, “[Science is] discovery/curiosity and answering “I wonder” questions...” Another teacher discussed how adults can support this process, for example “...Adults should model the posing of questions and the development of a sense of wonder...” (Teacher 52).

Lastly, approximately 4% of teachers (*n* = 3) mentioned that science for young children helped to prepare them for life or create lifelong learners. For example, Teacher 8 said, “...The more students explore and learn the more prepared they will be for life.” Or Teacher 60 who said, “...When young children have experiences, such as with science, they will become lifelong learners.”

How Children Learn Science

Broadly, many teachers brought up how children engage with and learn science. Almost 73% of teachers (*n* = 53) stated that science learning for young children should be hands-on and/or involve the five senses. Some teacher responses were general, such as Teacher 25, "hands-on experiences," Teacher 31, "hands-on," and Teacher 3, "anything hands-on." Other teachers expanded on this theme, for example Teacher 2 who said, "Any activity where the children are able to guess what is going to happen, then do a hands-on experiment to see if they were correct." Or Teacher 36 who described science as:

> *Learning and exploring how things work, how things work when mixed with another item. This is accomplished by hands-on, visual, sensory, trial and error, question, question, question…Science is not just about mixing things together. There is also finding answers through various means and watching/exploring the world around you*.

Other teachers mentioned hands-on activities in relation to teacher support, for example Teacher 27 said, "I think science should have some explanation to children but be more hands-on than anything." Or Teacher 42 who said, "...I feel hands-on learning is the most appropriate to learning science, along with teacher guidance to scaffold them to higher learning and understanding of what is being taught."

In addition to hands-on/sensory learning, another sub-theme to emerge within *how children learn science* was the use of science processes or practices. Approximately 63% of teachers in this study discussed science practices in their responses (n = 46 teachers). Within this sub-theme, teachers discussed science practices in many different ways. Some teachers listed a few science practices children should engage with in preschool in their responses, such as Teacher 71, "through exploration, experiments, hypothesizing, etc." Other teachers, such as Teacher 62, discussed that early science should teach children how to engage in science practices, "Science should teach young children how to observe, ask questions, make predictions, use tools to find answers, and communicate their findings."

Finally, approximately 42% of teachers (n = 31 teachers) discussed the types of materials needed to facilitate science instruction. Some teachers described materials that should be present in the classroom for science learning, such as Teacher 72 who said, "...like using sensory objects and things that they can explore and use their imagination like shaving cream, play-dough, etc." Or Teacher 26 who said, "...The materials should be safe, posing no threat or harm while they are participating…in an activity." Other teachers discussed materials more broadly, stating that a variety of items needed to be present for children to engage with, such as Teacher 59 "...children should be given a great amount of items they can experiment with." Or described how materials engage children with science, such as Teacher 7 who said, "...Having hands on materials available to help peak a child's curiosity to learn more about science." Or Teacher 53 who said:

> *...[Children] should be able to learn by exploring materials and asking questions about those materials. Materials should be provided from the teacher to get the children interested and get them to use problem solving skills to figure out what they can do with the materials that are provided.*

In addition, some teachers shared their beliefs that children will naturally gravitate to and explore science materials, such as Teacher 55 who said, "Teachers can set out items, but children should be allowed to freely discover the materials." Teacher 63 who said, "...I also believe that many times if materials are available science will just happen." Or Teacher 44 who said, "...We [teachers] should provide materials to be out with young ones so that they can discover on their own." Finally, of this group of teachers who discussed materials, 12% (n = 4 teachers) explicitly mentioned tools necessary for science. For example, Teacher 52 said:

> *...Children are encouraged to make observations of the world around them, and use tools to perform simple investigations.*

Or teacher 51 who said, "A classroom for young children should have a science center with materials used to explore and investigate, to find out what happens and why things work the way they do. Also, teachers can direct a science activity to introduce tools and vocabulary terms that relate to the activities provided."

Role of Teacher

While similar to teachers' ideas about how children should learn about science, some teachers described the ways in which a teacher could support young children in their science learning. Teachers' responses varied widely with some saying science learning should be child-led with guidance from the teachers, while others said science learning should be entirely teacher-led, and a range of responses in between.

Approximately 32% of teachers (n = 23 teachers) described their role as providing guidance through child-initiated science experiences. For example, Teacher 23 said, "Exploring, observing, and hands-on experiences with adults making suggestions and asking questions to guide the children's learning." Another example is Teacher 61 who said, "Children should be given opportunities to freely explore with some teacher direction as needed."

Some teachers discussed their role as learning with children (15% of teachers or n = 11). For example, Teacher 52 said:

> *Adults and children should together explore phenomena…Together adults and children can develop research questions and investigations, to make sense of the natural world.*

In addition, 5% of those teachers' responses (n = 4) mentioned the importance of teachers modeling science experiences for children. When teachers discussed modeling, it was usually about engaging with science practices, like with Teacher 8 who said, "Teachers should model the science experiment and then allow time for students to experience the experiment themselves."

Finally, approximately 10% of teachers (n = 7) mentioned the importance of teacher-directed science experiences. For example, Teacher 51 said, "Teachers can direct a science activity to introduce tools and vocabulary terms that relate to the activities provided."

What Children Learn

Another theme to emerge was *what* young children should learn about science. Approximately 58% (*n* = 42) of teachers, mentioned what children should learn in broad context, such as Teacher 34 who said, “Learning about the world around them and how it affects them.” Or Teacher 26 who said, “I feel that science is the opportunity to explore the unknown…” Of these 42 responses, 4 teachers mentioned the importance of science content being age appropriate. For example, Teacher 13 said, “Information should be age appropriate and interesting.”

In addition to discussing science content broadly, 23 teachers (i.e., 31.5%) mentioned specific subjects of science young children should learn about. For example, Teacher 72 said:

> *To me the definition of science for young children is learning about natural things such as the five senses, weather, live animals, maybe [a] classroom pet, plants, outdoor activities, and experiments.*

While other teachers discussed overarching concepts children should learn, such as Teacher 54:

> *Science in PreK is hands-on exploration of materials which show change or growth. Weather changing, environmental materials, color changing, health, plants and animals and how they grow/live – humans too.*

When discussing specific science topics young children should learn, approximately 33% of teachers (*n* = 24 teachers) mentioned children should learn about nature or the natural environment. For example, Teacher 64 said, “Science to me is exploring nature, and the process of nature around us.” Or Teacher 56 who said, “...A deep respect for nature should be developed.”

Approximately 8% of teachers (*n* = 6 teachers), said science topics should be based on children’s interests. For example, Teacher 61 said, “Science should be taught to children based on their interests. Building on what they know and learning what they want to know.” Or

Teacher 17 said, "[I] think it is important to take science ideas from the children, so they are interested in the activities and want to learn the material."

Finally, 8% of teachers (n = 6) discussed how science learning was connected to other developmental domains. For example, Teacher 52 said:

> *Science should be taught to young children through different modalities (literature, gross motor activity, aesthetics)...*

Or Teacher 55 who said, "Science is part of every interest area (i.e., dramatic play, math, language arts, pet care, outdoor time, etc."

Location of Science

A final theme to emerge in teachers' responses was *where* science learning occurs. Approximately 26% or teachers (n = 19 teachers) responses contained this theme. Some teachers mentioned that science occurs during free play, for example Teacher 10 said, "[Science should occur] during play in [a] fun way." Others mentioned group times as when science should occur. For example, Teacher 32 said, "…whole or small group." And Teacher 24 said, "Throughout the classroom day structured lessons/direct instruction & free exploration"

While not an abundant response, two teachers mentioned science outside of the traditional classroom. One teacher discussed the importance of field trips for children's science learning. Teacher 18 said:

> *Science should be taught by introducing them to the natural and physical world through field trips where they can be exposed to new plants, animals, and nature.*

While another teacher mentioned science learning within the home environment. Teacher 28 said, "...Interacting with science at home."

Teachers' Understanding of Science Related to Current Standards

To answer my second research question, I developed a coding system based on specific questions and theory to determine how teachers' responses aligned or deviated with current science standards. A different coding system was created for HS standards for science and for the NGSS framework for K-12 students.

Head Start (HS) Standards for Science

The classrooms in this study all used the Head Start Early Learning Outcomes Framework (US Department of Health and Human Services, 2015) as their guiding standards for instruction. This framework contains six items related to science learning and was the basis of the coding system developed to answer this question. These items include having children:

1. Observe and describe phenomena
2. Engage in science talk
3. Comparing and categorizing observable phenomena
4. Asking questions, gathering information, and making predictions
5. Planning and conducting investigations
6. Analyzing results, drawing conclusions, and communicating results

Approximately 79.5% of teachers' (*n* = 58) shared ideas that aligned with the HS standards. On average, teachers' ideas about science aligned with 1.59 of the Head Start Early Learning Outcomes (*SD* = 1.25). Teachers' responses ranged from discussing zero of the learning goals (*n* = 15) to five learning goals (*n* = 1), however no teachers' responses discussed all six of the learning goals. The most frequent learning goal mentioned was planning and conducting investigations (*n* = 39), followed by, asking questions, gathering information, and making predictions (*n* = 28), observe and describe phenomenon (*n* = 23), analyzing results, drawing conclusions, and communicating results (*n* = 17), engaging in science talk (*n* = 7), and the least mentioned standard was comparing and categorizing observable phenomena (*n* = 2).

Next Generation Science Standards (NGSS)

In order to determine to what extent teachers' ideas about science aligned or deviated from the Next Generation Science Standards (NGSS Lead States, 2013), responses were coded based on the three-dimensions of the framework (i.e., disciplinary core ideas, crosscutting concepts, and science and engineering practices; NRC, 2012). Of teachers' responses, 47.9% related to disciplinary core ideas (*n* = 35), 11% related to crosscutting concepts (*n* = 8), and 83.6% related to science and engineering practices (*n* = 61). When teachers did discuss the science and engineering practices, most teachers only referred to one practice (49.3%; *n* = 36). However, 24.7% of teachers mentioned two practices (*n* = 18), 8.2% mentioned three practices (*n* = 6), and 1.4% mentioned four practices (*n* = 1). While discussion of each of the three dimensions is informative, the NGSS highlights the importance of integrating the three dimensions to investigate and explain phenomena (NGSS Lead States, 2013). In this sample, 2.7% of teachers' responses included all three dimensions (*n* = 2), showing most teachers' ideas about science did not align with all components of current K-12 science standards. However, 45.2% of responses included two dimensions (*n* = 33), while 43.8% discussed one dimension (*n* = 32), and 8.2% did not mention any of the dimensions (*n* = 6).

Teachers' Understanding of Science and Other Science Attributes

Means, standard deviations, and ranges for all study variables are presented in Table 4. A visual examination of the histogram for each variable suggested the data was not normally distributed. The Kolmogorov-Smirnov test was used to test normality for the HS standards, NGSS, and science self-efficacy variables. Due to the amount of missing data for the attitudes and beliefs variables (i.e., comfort, child benefit, and challenges), a Shapiro-Wilk test was run to assess normality to account for the smaller sample size. While teachers' comfort ($W(38) = .956$, $p = .145$) and challenges ($W(38) = .986$, $p = .919$) scores were shown to be normally distributed, early learning ($D(65) = .219$, $p < .001$), NGSS ($D(65) = .291$, $p < .001$), science self-efficacy ($D(65) = .124$, $p = .014$), and child benefit ($W(38) = .878$, $p < .001$) were shown to not follow a normal distribution. Therefore, Spearman's rho was chosen to assess the relationship between teacher characteristic variables.

Table 4 shows the correlation table for all teacher characteristic variables. Teachers' understanding of science that was more aligned with HS standards showed a weak, positive correlation with responses aligned with the NGSS framework ($r_s = .27$, $p = .023$) and their science self-efficacy ($r_s = .29$, $p = .019$). There was also a moderate, positive correlation with responses aligned with HS standards and their comfort teaching science ($r_s = .43$, $p = .007$). Finally, there was a moderate, negative correlation between teachers' responses aligned with HS standards and perceived challenges in teaching science ($r_s = -.43$, $p = .007$). Therefore, teachers with responses that were more aligned with HS standards were more likely to have responses aligned with the NGSS framework, more positive beliefs in their ability to teach science, their perceived comfortability teaching science, and were less likely to perceive challenges in teaching science to young children.

Teachers' understanding of science which were more aligned with the NGSS framework showed a weak, positive correlation with teachers' perceived comfortability teaching science ($r_s = .39$, $p = .016$) and their perceived benefit to children ($r_s = .33$, $p = .044$). Teachers' understanding of science which were more aligned with the NGSS also showed a weak, negative correlation with teachers' perceived challenges ($r_s = -.37$, $p = .024$). However, this understanding was not related to teachers' science self-efficacy (r_s= .12, p = .349). This shows that teachers with responses which were more aligned with the NGSS framework were more likely to have positive perceived comfortability teaching science, a greater understanding of the benefits of science for young children and were less likely to perceive challenges in teaching science to young children.

In addition to coding teachers' responses for alignment to science standards, I wanted to see how other funds of knowledge teachers had related to science were related to their other characteristics related to science. Therefore, I created groups of teachers from interesting themes that emerged as part of the thematic analysis I conducted in RQ1 that were not already accounted for in the HS or NGSS scores but reflected developmentally appropriate approaches to early education or science. Groups identified were teachers who discussed: science being child-led with teacher support (developmentally appropriate), using science to generate/expand knowledge, science related to other domains, nature as part of science, and materials to support science. Spearman rho correlations for these groups and teacher characteristic variables are displayed in Table 4. Science self-efficacy, comfort, child benefit, and challenges was not related to any of the groups created. Teachers' responses that aligned more with HS standards was weakly, positively correlated with responses that discussed other domains (r_s= .27, p = .023), and moderately, positively correlated with responses that discussed materials for science (r_s= .34, p = .003). Teacher responses that discussed the NGSS framework was weakly, positively, correlated with teachers who discussed nature (r_s= .28, p = .015), materials (r_s= .29, p = .011), and those who discussed generating/expanding knowledge (r_s= .27, p = .020). Finally, responses that discussed science being child-led had a weak, positive correlation with responses that discussed materials (r_s= .25, p = .031) and generating knowledge (r_s= .30, p = .011). This shows that teachers bring unique funds of knowledge to their understanding of science for young children, which might not be captured by the standards.

Teachers' Attributes About Science and Their Relation to Classroom Practices

To answer my final research question, I used regression analysis to determine to what extent teachers' ideas about science were related to their classroom science teaching practices. Three-step hierarchical regressions were run for each classroom science practice. Step one contained teachers' science self-efficacy to control for teachers' beliefs in their ability to teach science to young children. Teachers' understanding aligned with HS standards was entered in step two, while teachers' understanding aligned with the NGSS framework was entered in step three to determine if teachers' understanding of science above and beyond their current guiding science standards predicted their implementation of high-quality science practices. Due to the high amount of missing data for the comfort, child benefit, and challenges variables, these variables were not included in the regression analysis. Descriptive statistics for outcome variables are presented in Table 4. Scatterplots for the classroom practice variables (non-transformed) are in the Figure 1. Findings are presented by classroom science practice (i.e., amount of materials in the classroom, quality of science lesson, science practices within science lesson, and frequency of science taught).

Science Materials

Due to the non-normality of the science materials variable (Kolmogorov-Smirnov: D(73) = .20, $p < .001$), data was $\log_{10}$ transformed and used in subsequent analysis. Results using the originally scaled variable or a square root transformation yielded similar findings. The hierarchical multiple regression revealed no relationship between teacher characteristics and the amount of science materials in the classroom, (Step 1: F (1, 63) = .497, p = .483; adjusted R-square = -.008; Step 2: F (2, 62) = .295, p = .745.; adjusted R-square = -.023; Step 3: F (3, 61) = .223, p = .880; adjusted R-square = -.038).

Analysis was also conducted using a logistic regression framework, following the same hierarchical steps, with science materials dichotomously coded (above/below median). Results remained consistent with linear regression findings.

Quality of Science Lesson

Initial analysis revealed there was no significant difference in CLASS-IS scores by science activity, F (2, 49) = 1.131, p = .331. Similar to the science materials variable, CLASS-IS for a science lesson also was not normally distributed (Kolmogorov-Smirnov: D(64) = .348, p < .001). Data was $\log_{10}$ transformed and results are presented here. Results were also conducted using the originally scaled variable and a square root transformation, both yielding similar findings to the log transformation. The hierarchical multiple regression revealed no relationship between teacher characteristics and the quality of science lessons, (Step 1: F (1, 61) = .524, p = .472; adjusted R-square = -.008; Step 2: F (2, 60) = 1.084, p = .345.; adjusted R-square = .003; Step 3: F (3, 59) = .834, p = .480; adjusted R-square = -.038).

Analysis was also conducted using a logistic regression framework, following the same hierarchical steps, with CLASS-IS scores dichotomously coded (low quality and medium/high quality). Results remained consistent with linear regression findings.

Observed Use of Science Practices

Teachers' modeling and facilitation of science practices was normally distributed (Kolmogorov-Smirnov: D(66) = .056, p = .200) and used as the dependent variable in the hierarchical regression analysis. The hierarchical multiple regression revealed no relationship between teacher characteristics and the modeling and facilitation of science practices, (Step 1: F

(1, 63) = .145, *p* = .705; adjusted R-square = -.014; Step 2: *F* (2, 62) = .083, *p* = .921.; adjusted R-square = -.030; Step 3: *F* (3, 61) = .109, *p* = .955; adjusted R-square = -.044).

Engagement in Science

Frequency of engagement in science was not normally distributed (Kolmogorov-Smirnov: D(73) = .248, *p* < .001). Distribution for this variable was $\log_{10}$ transformed and results are presented here. Results were also conducted using the originally scaled variable and a square root transformation, both yielding similar findings to the $\log_{10}$ transformation. The hierarchical multiple regression revealed that the model at step 1 was significant, *F* (1, 63) = 8.928, *p* = .004, explaining 11% of the variance. Science self-efficacy significantly predicted the frequency in teachers reported engaging in science (β = -.352, *t* = -2.988, *p* = .004; Note: lower scores on engagement represent teachers engaging with science more often. Introducing HS alignment did not explain any additional variance (R-squared change = .014; *F-change* (1, 62) = 1.004, *p* = .320) nor did adding NGSS alignment explain any additional variance (adjusted R-squared = .112; *F* (1, 61) = 1.153, *p* = .287).

Combined Classroom Practices

To explore the relationship between teachers' ideas about science and their classroom science practices further, I ran a principal components analysis to summarize the science practices variables (i.e., science materials, quality of science lesson, use of science practices, and engagement in science) into one component. A principal components analysis was chosen because it transforms the variables into a smaller set of linear combinations for analysis but utilizes all the variance in the observed variables, as opposed to analyzing only the shared variance which happens with factor analysis (Tabachnick & Fidell, 2013). Component scores were saved for each participant and used as the dependent variable in a hierarchical regression.

As with the previous regression analysis, step one contained teachers' science self-efficacy, step two contained teachers' understanding aligned with HS standards and step three contained teachers' understanding aligned with the NGSS. The hierarchical multiple regression revealed no relationship between teacher attributes and the principal component for science practices, (Step 1: F (1, 61) = 2.771, p = .101; adjusted R-square = .028; Step 2: F (2, 60) = 1.915, p = .156.; adjusted R-square = .029; Step 3: F (3, 59) = 1.371, p = .260; adjusted R-square = .018).

Chapter 5: Discussion

The current study examined Head Start teachers' ideas about science for young children by using both qualitative and quantitative data to explore how these ideas relate to classroom science practices. This study contributes to the literature in four significant ways. First, it furthers our understanding of the funds of knowledge early childhood teachers possess related to science and highlights aspects more formal measures of teachers' ideas about science may be missing. Second, this study shows a disconnect between early childhood teachers' ideas about science and their classroom science practices. Third, this study emphasizes a need for continued theoretical and measurement work to understand this relationship better. Finally, this work contributes to the development and implementation of professional learning for early childhood teachers on science topics and pedagogy.

Teacher Ideas' About Science

A qualitative approach was taken in order to capture a wider understanding of the ideas about science early childhood teachers bring into their classrooms. This study thematically analyzed teachers' responses to open-ended questions about what science was for young children and how to teach science to young children. Contrary to previous findings, the current study found early childhood teachers had more positive ideas about science than previous research suggested (Greenfield et al., 2009; Tu, 2006). All teachers in the current study described science as appropriate for young children and that it should be incorporated as part of the preschool curriculum.

However, other ideas varied based on the teacher. While themes did emerge in teachers' responses, it was clear there wasn't a shared language between teachers on how to describe early childhood science. Some teachers gave detailed responses describing the process of how children learned science, what topics should be taught, and how teachers could support children's sensemaking around science. Other teachers listed general ideas, such as exploring and experimenting, but did not go into detail on how to support these science experiences, even when explicitly asked. While research supports children to be actively engaged in all elements of exploration on the topic, such as asking questions, collecting data, and presenting and reporting findings, a skilled teacher (or adult) needs to be present to help guide the experience (Torres-Crespo et al., 2014). Teachers seemed to know broad ideas related to early science learning (e.g., hands-on), but not specific strategies to further describe these experiences or how to scaffold children's learning throughout them. This is an important finding that can influence professional learning about science opportunities for teachers in the future. Professional learning should begin by acknowledging and unpacking teachers' existing ideas about science, then focus on deepening these ideas and ways to scaffold children's science learning.

When teachers did describe science for young children, their views were aligned with developmentally appropriate practices and curriculum (Copple & Bredekamp, 2008). For example, some teachers mentioned science should be hands-on, based on children's interest, and integrated into other learning areas. However, many teachers provided the same, or very similar, responses to both questions asked (i.e., *What is science for young children?* and *How do you teach science to young children?*). This aligns with other findings in which early childhood teachers know *what* they should teach regarding science, but not *how* to teach it, emphasizing a need for more research and targeted professional learning opportunities around early childhood teachers pedagogical content knowledge for science (Andersson & Gullberg, 2014; Nilsson & Elm, 2017).

Early childhood teachers' responses tended to align with both HS standards and NGSS. This is unsurprising as current standards have been shown to impact what teachers focus on in their classrooms (Smith & Kovacs, 2011). While teachers shared ideas that aligned with both standards, it was rare for a response to capture all the components of either set of standards. For example, in the current study only two teachers' responses aligned with all three dimensions of the NGSS framework and no teachers mentioned all six HS learning goals. Similar work looking at later elementary grades found teachers had a hard time articulating elements of the NGSS framework, specifically the science and engineering practices (Smith & Nadelson, 2017). This may be because both sets of standards are relatively new, with Head Start beginning in 2015 and NGSS beginning in 2013, and it takes time for reform-based instruction to make its way from standards to training/curricular supports, and finally to being implemented within the classroom (Barak & Shakhman, 2008). However, learning and aligning to new standards can be mediated through professional learning opportunities (Barenthein et al., 2019; Barenthien et al., 2020; Gropen et al., 2017; Maeng et al., 2020).

For preschool aged children, it has yet to be determined if teachers, and therefore professional learning, should focus on all three dimensions of the NGSS or if certain dimensions are more advantageous than others for young children. Currently, most early childhood standards focus on science practices or content (e.g., HS Early Learning Framework, U.S. Department of Health and Human Services, 2015; High/Scope Child Observation Record, Schweinhart et al., 1993), but future work should examine the role crosscutting concepts play in young children's science development. Research by Fick and colleagues (2018; 2022) has begun to examine teachers' use of crosscutting concepts to support children's science learning in later elementary classrooms. This work highlights the need for professional learning experiences, so teachers are able to scaffold crosscutting concepts within their classroom (Fick et al., 2022). Future work should also explore the ways crosscutting concepts are used to support scientific sensemaking within early childhood classrooms.

Beyond the Standards

Teachers' open-ended responses also included ideas not explicitly covered by standards. Analyzing these responses with a thematic approach allowed me to extract the full range of ideas teachers possessed related to science, as opposed to using researchers-generated questionnaires or coding the data with an *a priori* approach which can limit the scope of interpretation of teachers' ideas. Some of the ideas teachers shared were aligned with a recent framework for promoting scientific inquiry in preschool (Ramanathan et al., 2022). Specifically, some teachers in the current study discussed the importance of following children's interest in science. The framework for scientific inquiry in preschool emphasizes the importance of science learning opportunities being based on children's interests but stresses the importance of integrating all of the components of the framework to support inquiry learning in preschool (Ramanathan et al., 2022). This shows that Head Start teachers' ideas about science align with inquiry-based models.

Another idea teachers in the current study discussed were materials to support science. Some teachers mentioned specific materials that should be present in the classroom, such as science tools, but most said open-ended materials or materials children could manipulate. A recent literature review found the discussion on the importance of open-ended materials for children to manipulate to be a recurring theme in early childhood science studies (Ramanathan et al., 2022). However, just providing materials is not enough for children to engage with them in a scientific way, teachers need to introduce the materials and demonstrate ways to use them (Nayfeld et al., 2011). In addition, it has been found that while teachers often discuss the importance of materials for science, they often overestimate the amount of science materials available in their classrooms (Karademir et al., 2020).

Another idea discussed by teachers that was not explicitly part of the standards was using nature experiences to support science learning. Teachers mentioned going on nature walks with their class or using the natural environment to teach science. The emphasis on nature compared to other science subjects may be because most preschool teachers equate science with biology/nature studies, as opposed to other science areas (Thulin & Redford, 2017). This was true in kindergarten classrooms as well, with teachers reporting to teach life science concepts more frequently than physical science or earth and space science (Sackes, 2014). In addition, preschool teachers have shown comfortability in using the outdoor environment to informally teach science (Gomes & Fleer, 2020). Nature-based early childhood programs are growing exponentially in the United States (NAAEE, 2020), but little is known about how these programs use nature to support children's science understanding. This could be an ideal environment to incorporate within future professional learning by building on teachers' positive ideas about nature supporting science for young children, while also developing and fostering science pedagogy that includes learning opportunities in nature (Kloos et al., 2018).

Relationship to Other Teacher Science Measures

Teachers' ideas about science were related to other characteristics teachers possessed related to science. Early childhood teachers who were more aligned with existing standards had more positive beliefs about their ability to teach science, their perceived comfortability teaching science, and were less likely to be worried about challenges in teaching science to young children. In addition, the other ideas beyond the standards teachers possessed (e.g., discussion of materials, nature, and connection to other domains) were found to be related to teachers' alignment to existing standards, however these additional ideas were not found to be related to existing measures of teachers' beliefs about science. One possible reason for this could be conflicting beliefs teachers possess about science teaching. A case study examining an elementary teacher's beliefs about science found the teacher to hold dualistic beliefs, one founded in previously didactic science learning experiences and the other founded on a more hands-on and developmentally appropriate approach to learning science (Bryan, 2003). This may reflect limitations teachers face when using evidence-based pedagogy to implement science. When teachers do not fully understand a phenomenon, it is difficult to identify how to teach it in a way young children can understand and instead teachers may resort to didactic teaching strategies. While teachers in the current study were shown to have ideas that reflected developmentally appropriate practices, when the science content is outside of the ideas they feel confident explaining they may find it challenging to support children's sensemaking through inquiry and play-based pedagogy. This discrepancy between beliefs may need to be more intentionally targeted in teacher training programs, especially as science learning moves away from didactic science lessons and towards students "figuring out" about a phenomenon (NRC, 2011).

This study found that the way teachers' attributes related to science are currently being measured missed nuances in capturing the funds of knowledge preschool teachers have about early childhood science. Previous work on teachers' ideas about science have used researcher generated categories with Likert scale options (e.g., Greenfield et al., 2009; Pendergast et al., 2017), which I hypothesized limited the ability to capture the range of ideas teachers possessed related to science. The use of quantitative questionnaires for assessing teachers' beliefs has been criticized more broadly, with researchers calling for qualitative or mixed methods approaches to produce more insightful findings of the belief's teachers possess (Day et al., 2008; Olafson et al., 2014; Wyatt, 2012). This is the first study, to my knowledge, to apply these recommendations to the preschool teacher population. Initial work on this topic using a quantitative approach has shown early childhood teachers to have negative ideas about implementing science (Greenfield et al., 2009; Tu, 2006) however, by taking a strengths-based approach and placing value on the array of ideas early childhood teachers possess about science for young children this study yielded a more complete understanding of teachers' ideas related to science. More research is needed to determine the most appropriate way to capture the full range of ideas early childhood teachers are bringing into their classroom environment, specifically for science but future work should take a mixed methods approach when measuring early childhood teachers' ideas about science.

Connection Between Ideas and Practices

While teachers' ideas about science were more positive than previous studies found, the current study showed most of these ideas did not predict classroom science practices. As identified in previous work, teachers' science self-efficacy predicted the frequency in which they reported doing science within their classrooms (Gerde et al., 2018). Building off this finding, the current study explored the relations between teachers' science self-efficacy and other ideas about science (i.e., ideas aligned with HS standards and NGSS) and ran linear regressions to determine how teachers' understanding of science was related to their classroom science practices (i.e., frequency of science occurring, quality of science lessons, engagement with science practices, and amount of science materials). Although for other areas of curriculum self-efficacy and ideas have been shown to have an impact on teacher practice (Bingham et al., 2022; Bingham & Hall-Kenyon, 2013), teachers' understanding of science did not significantly predict classroom science practices. There are a few possible reasons for the lack of connection found between teachers' ideas about science and their classroom science practices.

Need to Reexamine How Teachers' Ideas and Practices About Science Relate to Each Other

There is a lack of consensus on the role teachers' ideas play in classroom practices (Lee, 2009; Liu, 2011; Wilkins, 2008). It's possible that for early childhood science, teachers' beliefs do not influence their practices. Work examining beliefs and practices more generally have found teachers' beliefs to be misaligned or inconsistent with their classroom practices (Jorgensen et al., 2010; Lim & Chai, 2008; Liu, 2011). While teachers in the current study shared mostly positive views on science for young children, their enactment of science practices was low. It is possible that educators may not know what meaningful engagement in science looks like for young children or how to implement it (NASEM, 2022). Science is rarely covered in preservice teacher training programs and professional learning opportunities (Piasta et al., 2014; Schacter, 2015). Without these training opportunities, teachers rely on their own previous science learning experiences (particularly in elementary school, high school, and college) when supporting science learning (Thomas & Pedersen, 2010), which are often didactic and not developmentally appropriate for young children.

It's also possible that teachers' beliefs about science are shaped by the practices they engage in (Lumpe et al., 2012). For example, a study by Lumpe and colleagues (2012) found how often teachers spent teaching science predicted their science self-efficacy. This relation is often mediated by professional learning opportunities, with some scholars arguing that beliefs only change after teachers have the tools to be successful in the classroom (Guskey, 2002; Guskey & Yoon, 2009). For example, when elementary teachers felt supported by a coach as part of a science professional development program, they felt more successful about the teaching experience and their self-efficacy increased (Lumpe et al., 2012).

However, it is more likely that the relation between teachers' beliefs and practices is reciprocal, with beliefs and practices influencing one another (Mansour, 2009) and the strength of this relationship being influenced by other factors and vary across individuals and contexts (Buehl & Beck, 2015). One factor possibly influencing the relationship between ideas and practices is teachers' knowledge of science content and pedagogical content knowledge of how to implement the instructional practices that align with their beliefs (Kang, 2008). In preschool, teachers need to be able to recognize science learning opportunities in everyday situations (Dunekacke et al., 2015; Oppermann et al., 2016) and know how to support children's learning in these situations (Fleer, 2009; Samuelsson & Carlsson, 2008). Science content knowledge provides teachers with the knowledge of science phenomena, the ability to describe scientific processes, and the ability to explain scientific issues to children (Barenthien et al., 2018). Pedagogical content knowledge related to science allows teachers to find multiple ways to represent information, adapt material to children's developmental levels, prior knowledge, and misconceptions, and it allows teachers to tailor learning activities to children's curiosity and interests (Shulman, 1986). Therefore, teachers' science content knowledge and pedagogical content knowledge are *both* necessary to support young children who primarily engage in science experiences through play (Dunekacke et al., 2015; Oppermann et al., 2016). Future studies should consider the role content knowledge and pedagogical content knowledge play in early childhood science experiences.

External factors, such as classroom, school, or state and national policy, can also impact the relationship between teachers' beliefs and practices (Buehl & Beck, 2015). Classroom management issues determine the extent to which teachers are able to act on their beliefs (Savasci & Berlin, 2012; Teague et al., 2012). Depending on the level of support within the classroom and disposition of the children, early childhood teachers may avoid hands-on science experiences due to a perceived level of “chaos” associated with these activities. In addition, many early childhood teachers report having few, or no, science curricular supports (Sawchuck, 2019) or materials to facilitate science experiences (Gerde et al., 2018; Nayfeld et al., 2014; Tu, 2006). When teachers lack the resources they need to feel successful, their practices do not accurately reflect their beliefs (Bullock, 2010).

Finally, state or national level policies can cause a divide between beliefs and practices. With the recent introduction of more integrated standards for science, it can be challenging, and take time for teachers to align with these new science standards (Banilower, et al., 2013; Davis, et al., 2006; Tekkumru & Stein, 2015). When teachers’ beliefs are in flux or changing to address new information on evidence-based practices, they may not necessarily align with their observed practices (Ogan-Bekiroglu & Akkoc, 2009). In addition, the NGSS was officially created for K-12 classrooms. While there have been calls to include preschool in this framework (NASEM, 2022), these standards have yet to be incorporated nation-wide in preschool classrooms. Challenges exist when standards for preschool and kindergarten aren’t aligned as evidenced through early literacy (Tortorelli et al., 2022) and math (Clements et al., 2003; Duncan et al. 2015) standards. Recently a call has been made for a consistent vision for early childhood science (NASEM, 2022). A unifying set of standards that reflect evidence-based practices in cognitive development and science learning from birth through grade 12 would support teachers, particularly early childhood educators, to align practices with these standards.

Despite these differences in how beliefs and practices are related, scholars argue this is not a reason to ignore the role teachers' beliefs and ideas have, but rather to work to continue to understand the relations between ideas and practices and other factors that may influence this connection (Buehl & Beck, 2015). Teachers in this study were shown to have positive, but emerging, ideas about science. As they develop these ideas further, the relations to their practices may be more strongly related. For other areas of curriculum, teacher beliefs have been shown to influence practices (Bingham & Hall-Kenyon, 2013; McMullen, 1990), but more work needs to be done examining the relations between ideas and practices as it applies to early childhood science, as this is an area that has been understudied. Specifically, research should examine factors that may hinder teachers from implementing practices aligned with their beliefs (Buehl & Beck, 2015), such as content knowledge, pedagogical content knowledge, administration support or pressures, available resources and curriculum materials, and student factors (e.g., behavioral needs, executive function skills, etc.).

Measurement of Science Practices

In addition to further understanding the relations between ideas and practices, more work needs to be done on how early childhood science practices are measured. Compared to other studies (Oppermann et al., 2019), this dissertation examined multiple indicators of classroom science practices including the reported frequency of science occurring, quality of a science lesson, engagement with science practices, and the amount of science materials, however, to date the field has not reached a consensus on how best to assess the quality of classroom science practices. There is currently no “gold standard” regarding how to measure high-quality science practices in early childhood, nor is there a shared understanding of what constitutes high-quality science practices for young children.

One of the most commonly used measures of early childhood science practices are teacher reports of the frequency of science events within the classroom. Previous work connecting teachers' characteristics to practices has been limited in how they measure practices by only asking one question on the frequency in which science occurs (Oppermann et al., 2019). While the current study used frequency as one measure of science practices, it may not be ideal for measuring the construct as a whole. As a self-report measure, it asks teachers to identify how often they engage in science activities. However, since preschool teachers vary widely in their content knowledge, which is used to identify science occurrences in everyday situations or throughout children's play, they might not identify science opportunities outside of formal lessons within their classroom (Hopf, 2012). Also, while it is hypothesized that the more often teachers implement science, the higher quality it will be, frequency is not a direct measure of quality. It's possible that teachers who report teaching science often within their classroom are not using evidence-based practices. In a pilot study conducted with preservice teachers, over half of the teachers implemented what they believed to be a science lesson, when in actuality it was a math or aesthetics lesson (Pikus et al., *in prep)*, showing teachers may need support on identifying high-quality science experiences within their classrooms.

Another commonly used measure of science quality is the presence of science materials within the classroom. This study found that while classrooms contained more science materials than identified in previous studies (Tu, 2006), many materials and tools were only present in a few classrooms (Gerde et al., 2018). In addition, science materials are typically in low supply in under-resourced schools (NASEM, 2022), such as the ones participating in this study. The availability of science materials and tools is essential for engaging in science. However, the mere presence of materials and tools is not enough to gauge the quality of science experiences.

Materials provided in the classroom can enhance teacher-student interactions when introduced intentionally (Fleer et al., 2014; Nayfeld et al., 2011), but are largely ignored, or used for non-science purposes, if they aren't introduced and demonstrated for children (Nayfeld et al., 2011).

In addition to measuring the frequency of science interactions and science materials present, the current study used CLASS-IS (Pianta et al., 2008) to measure the quality of a science activity. While typically used for examining the quality of general teacher-child interactions (e.g., how teachers support and extend children's thinking or how they provide vocabulary support), the IS subscale pays particular attention to teacher and student interactions that support cognitive and language development (Hamre et al., 2013) and has been used previously to identify the quality of teacher-child interactions across varying learning contexts and contents, including science (e.g., Cabell et al., 2013). In this sample, we found teachers offered low to medium quality of instructional support when implementing science lessons. This is similar to other studies which have used CLASS-IS to examine instructional interactions during science activities within preschool classrooms. For example, the current study reported mean CLASS-IS scores of 2.82, whereas Cabell and colleagues (2013) reported mean CLASS-IS science scores of 2.94 and Fuccillo (2011) reported scores of 2.56. Despite these scores being classified as low (Pianta et al., 2008), prior work has found the scores for instructional quality during science in preschool classrooms to be greater than those for literacy, reading, or math activities (Cabell et al., 2013; Fuccillo, 2011).

While quality scores in the current study were similar to previous findings, they were not related to teachers' ideas about science. This may be due to the science topics teachers were randomly assigned to implement. Teachers in this study implement science lesson on either force/motion, sink/float, or waves. Early childhood teachers have been shown to be more comfortable with life science concepts compared to physical or Earth science (Sackes, 2014; Thulin & Redford, 2017). It is possible teachers would have demonstrated higher quality supports when teaching a science lesson on a topic they were more comfortable with and that they had planned themselves. The lack of variability within the quality of science across teachers in the current study may be why it's not related to teachers' ideas about science. However, it is important to consider what teachers do need to implement high-quality science, regardless of science content area, within preschool classrooms. It may be that teachers with more background knowledge or training on intentional instructional strategies related to science would implement higher-quality science experiences than those observed in this study.

Recognizing the current limitations in the field on how to measure early childhood science, this study tried to mediate this by using multiple measures hypothesized to be related to quality science practices. Other studies have used self-created measures (Gropen et al., 2017), however these are typically created around a specific curriculum and do not translate to other topics, nor are they generalizable to the field as a whole (and thus, were not appropriate for this study). Since the collection of data for this study, more classroom observation science measures have been developed that show some promise, however findings are mixed. For example, the Preschool Science Observation Measure (PSOM, Vitiello et al., 2018) was developed to assess the quality of instruction and content in structured science lessons. While reliability and validity evidence for this measure were not as strong as expected, the team reports to be working on refining the measure (Vitiello et al., 2018). Another is the Systematic Characterization of Inquiry Instruction in Early LearNing Classroom Environments (SCIIENCE, Kaderavek et al., 2015), which was developed to align with the NGSS framework in preK-3rd grade classrooms. While this measure shows promise, it was only validated in eight classrooms (Kaderavek et al., 2015) and has not been adopted widely in studies focusing on early childhood science practices. The lack of quality assessments with strong psychometric properties makes it challenging to compare findings across studies. More work must be done to identify the best way to assess the quality of science practices and how these practices relate to child outcomes.

Implications for Professional Learning

The findings from this study also have a broader impact on the ways in which we educate preservice teachers and in-service teachers. Despite having positive, child-centered views on science for young children, this study found classroom science practices to occur infrequently and reflect relatively low quality. This could be because of the education and experiences preservice preschool teachers have prior to formally entering the classroom. Most preschool teachers receive little exposure to high-quality, reform-based science as part of their teaching methods coursework (Brenneman et al., 2009), nor do they have many, if any, opportunities to practice implementing science as part of their practicum (Lobman et al., 2005). Not only should science teaching methods be given more attention in early childhood training programs, but preservice teachers should be encouraged to pursue general science courses as well to enhance their content knowledge. Research has shown that the number of science courses taken during a preschool teacher's education predicts the frequency in which they engage in science activities within their classroom (Sackes, 2014), though these courses are rarely a requirement of degree programs. This follows recent recommendations that preservice early childhood teachers need experiences not only with science and engineering practices, but also with experiences supporting children engaging in science and engineering practices (NASEM, 2022).

Not only should teachers have more experience with high-quality science prior to entering the classroom, but they need to be supported throughout their careers. Recent recommendations show teachers need to be supported in created learning environments conducive to engaging in science practices and pedagogies that support all learners within their classrooms (NASEM, 2020). When early childhood teachers receive professional learning interventions focused on science instruction, they provide higher quality science learning opportunities within their classrooms (Gropen et al. 2017; Piasta et al., 2015; Vick et al., 2016). However, professional learning focused on science is rarely offered in preschool programs (Schacter 2015).

As programs look to incorporate high-quality science experiences within their early childhood classrooms, emphasis should be placed on meeting teachers where they are and leveraging the resources about science and teaching science that they have. Previous studies have taken a deficit perspective regarding early childhood teachers' ideas about science for young children (e.g., Gropen et al., 2017), however the current study shows teachers have a range of ideas about what science is for young children and how to teach it. Instead of taking a deficit perspective, professional learning should focus on building on the beliefs and skills teachers already possess. As the vision of science for young children changes, teachers need support in understanding new frameworks and standards (i.e., NGSS) and understanding ways of supporting student sensemaking (Reiser et al., 2017; Wilson, 2013). Using teachers existing skills, while also positioning them as learners of these new ways of teaching (e.g., Berland et al., 2020) can allow educators to draw on the funds of knowledge teachers bring while learning and practicing new strategies (NASEM, 2021; Zembal-Saul, et al., 2020).

In addition to professional learning opportunities, there is a need for high-quality science curriculum to support teachers in implementing science. One challenge to increasing opportunities for science instruction in early childhood is a lack of curriculum materials for science aligned with the new vision of science (Sawchuck, 2019). Early childhood teachers benefit from high-quality, educative curriculum materials (NASEM, 2022), however these materials need to be able to be adapted, and teachers need to be comfortable adapting them, in order to respond to children's thinking and ideas (NASEM, 2022). In addition, teachers should be able to adapt these materials based on children's skills and interests to reflect children's explorations of science phenomena around them. Teachers' ideas about science, as well as the features of the curriculum materials and teaching context influences how they use and adapt the curriculum (NASEM, 2022). Moving forward, professional learning should be combined with curriculum materials to support teachers in implementing and adapting their science instruction (Hill et al., 2020; Wright et al., in prep).

Limitations

This study makes several important contributions to the field; however, it is not without its limitations. First, due to missing data this study was not able to analyze teachers' attitudes and beliefs as previously proposed. While this study aimed to capture a broader range of teachers' funds of knowledge than had been analyzed in previous studies, it's possible that this teacher attribute could have impacted classroom science practices. Further, we know teachers' decision making is informed by multiple factors (Schachter et al., 2016). While I investigated multiple viable attributes, future work should include other factors in relation to classroom science practices, such content knowledge and pedagogical content knowledge. Another limitation to this study was the sample size. While 73 participants are considered robust for qualitative analysis, this number of participants limited the complexity of the quantitative models possible for examination. Future work with larger sample sizes could increase the power in the analysis and increase the likelihood small effects, if present, would be detected. Finally, this study utilized data from one time point. However, work should be done to determine how teachers' ideas and practices change individually over time, as well as explore how the relationship between them changes over time.

Conclusions

This study is one of the first to take an asset-based approach to better understand the funds of knowledge early childhood teachers possess related to science. This approach showed teachers varied greatly in their ideas about science, however these ideas were more positive than previous studies suggested. Teachers' ideas are an important attribute for continued study as they were shown to be related to other characteristics teachers have related to science and can be built on through teacher learning.

REFERENCES

Ajzen, I., & Fishbein, M. (1975). A Bayesian analysis of attribution processes. *Psychological bulletin*, *82*(2), 261.

Alexander, J. M., Johnson, K. E., & Kelley, K. (2012). Longitudinal analysis of the relations between opportunities to learn about science and the development of interests related to science. *Science Education*, *96*(5), 763-786.

Alfieri, L., Brooks, P. J., Aldrich, N. J., & Tenenbaum, H. R. (2011). Does discovery-based instruction enhance learning?. *Journal of educational psychology*, *103*(1), 1.

Andersson, K., & Gullberg, A. (2014). What is science in preschool and what do teachers have to know to empower children?. *Cultural studies of science education*, *9*, 275-296.

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological review*, *84*(2), 191.

Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Campbell, K. M., & Weis, A. M. (2013). Report of the 2012 national survey of science and mathematics education. *Horizon Research, Inc.(NJ1)*.

Barak, M., & Shakhman, L. (2008). Reform-based science teaching: Teachers' instructional practices and conceptions. *Eurasia Journal of Mathematics, Science and Technology Education*, *4*(1), 11-20.

Barenthien, J., Oppermann, E., Anders, Y., & Steffensky, M. (2018). Preschool teachers' learning opportunities in their initial teacher education and in-service professional development–do they have an influence on preschool teachers' science-specific professional knowledge and motivation?. *International Journal of Science Education*, *42*(5), 744-763.

Barenthien, J., Oppermann, E., Anders, Y., & Steffensky, M. (2020). Preschool teachers' learning opportunities in their initial teacher education and in-service professional development–do they have an influence on preschool teachers' science-specific professional knowledge and motivation?. *International Journal of Science Education*, *42*(5), 744-763.

Bergen, D. (2009). Play as the Learning Medium for Future Scientists, Mathematicians, and Engineers. *American Journal of play*, *1*(4), 413-428.

Berland, L. K., Russ, R. S., & West, C. P. (2020). Supporting the scientific practices through epistemologically responsive science teaching. *Journal of Science Teacher Education*, *31*(3), 264-290.

Bingham, G. E., Gerde, H. K., Pikus, A. E., Rohloff, R., Quinn, M. F., Bowles, R. P., & Zhang, X. Y. (2022). Examining teachers' early writing knowledge and practices. *Reading and Writing*, *35*(9), 2201-2227.

Bingham, G. E., & Hall-Kenyon, K. M. (2013). Examining teachers' beliefs about and implementation of a balanced literacy framework. *Journal of Research in Reading*, *36*(1), 14-28.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101.

Braun, V., & Clarke, V. (2013). *Successful qualitative research: A practical guide for beginners*. sage.

Brenneman, K., Stevenson-Boyd, J., & Frede, E. C. (2009). Math and science in preschool: Policies and practice. *Preschool Policy Brief*, *19*, 1-12.

Brenneman, K. (2011). Assessment for Preschool Science Learning and Learning Environments. *Early Childhood Research & Practice*, *13*(1).

Brown, T. E. (2005). The influence of teachers' efficacy and beliefs regarding mathematics instruction in the early childhood classroom. *Journal of Early Childhood Teacher Education*, *26*(3), 239-257.

Bryan, L. A. (2003). Nestedness of beliefs: Examining a prospective elementary teacher's belief system about science teaching and learning. *Journal of research in science teaching*, *40*(9), 835-868.

Buehl, M. M., & Beck, J. S. (2015). The relationship between teachers' beliefs and teachers' practices. International handbook of research on teachers' beliefs, 1, 66-82.

Bulunuz, M. (2013). Teaching science through play in kindergarten: Does integrated play and science instruction build understanding?. European Early Childhood Education Research Journal, 21(2), 226-249.

Bureau of Labor Statistics (2021). Department of Labor. *Occupational Outlook Handbook*. Employment in STEM occupations. https://www.bls.gov/emp/tables/stem-employment.htm

Cabell, S. Q., DeCoster, J., LoCasale-Crouch, J., Hamre, B. K., & Pianta, R. C. (2013). Variation in the effectiveness of instructional interactions across preschool classroom settings and learning activities. *Early Childhood Research Quarterly*, *28*(4), 820-830.

Charmaz, K. (2014). *Constructing grounded theory*. sage.

Clements, D. H., Sarama, J., & DiBiase, A. M. (2003). *Engaging young children in mathematics: Standards for early childhood mathematics education*. Routledge.

Copple, C., & Bredekamp, S. (2008). Getting clear about developmentally appropriate practice. *YC Young Children*, *63*(1), 54.

Curtis, D., & Carter, M. (2014). *Designs for living and learning: Transforming early childhood environments*. Redleaf Press.

Davis, E. A., Petish, D., & Smithey, J. (2006). Challenges new science teachers face. *Review of educational research*, *76*(4), 607-651.

Day, C., Sammons, P., & Gu, Q. (2008). Combining qualitative and quantitative methodologies in research on teachers' lives, work, and effectiveness: From integration to synergy. Educational researcher, 37(6), 330-342.

Dewey, J. (1938). Experience and education. New York. Simon and Schuster.

Driver, R., & Erickson, G. (1983). Theories-in-action: Some theoretical and empirical issues in the study of students' conceptual frameworks in science.

Duncan, G. J., Jenkins, J. M., Watts, T. W., Magnuson, K., Clements, D., Sarama, J., ... & Spitler, M. E. (2015). Preventing Preschool Fadeout through Instructional Intervention in Kindergarten and First Grade. *Society for Research on Educational Effectiveness*.

Dunekacke, S., Jenßen, L., & Blömeke, S. (2015). Effects of mathematics content knowledge on pre-school teachers' performance: A video-based assessment of perception and planning abilities in informal learning situations. *International Journal of Science and Mathematics Education*, *13*(2), 267-286.

Erden, F. T., & Sönmez, S. (2011). Study of Turkish preschool teachers' attitudes toward science teaching. *International Journal of Science Education*, *33*(8), 1149-1168.

Fernandez, C. (2014). Knowledge base for teaching and pedagogical content knowledge (PCK): Some useful models and implications for teachers' training. *Problems of Education in the 21st Century*, *60*, 79.

Fleer, M. (2009). Understanding the dialectical relations between everyday concepts and scientific concepts within play-based programs. *Research in Science Education*, *39*, 281-306.

Fleer, M., Gomes, J., & March, S. (2014). Science learning affordances in preschool environments. *Australasian Journal of Early Childhood, 39*(1), 38-48. https://doi.org/10.1177/183693911403900106

French, L. (2004). Science as the center of a coherent, integrated early childhood curriculum. *Early Childhood Research Quarterly*, *19*(1), 138-149.

Fuller, T. (2013). Is scientific theory change similar to early cognitive development? Gopnik on science and childhood. *Philosophical Psychology*, *26*(1), 109-128.

Gauvain, M. (2001). *The social context of cognitive development*. Guilford Press.

Gelman, R., & Brenneman, K. (2004). Science learning pathways for young children. *Early Childhood Research Quarterly*, *19*(1), 150-158.

Gerde, H. K., Pierce, S. J., Lee, K., & Van Egeren, L. A. (2018). Early childhood educators' self-efficacy in science, math, and literacy instruction and science practice in the classroom. *Early Education and Development*, *29*(1), 70-90.

Gerde, H. K., & Wasik, B. A. (2021). Developing Language Through Science. *The Reading Teacher*.

Gomes, J., Fleer, M. Is Science Really Everywhere? Teachers' Perspectives on Science Learning Possibilities in the Preschool Environment. Res Sci Educ 50, 1961–1989 (2020). https://doi.org/10.1007/s11165-018-9760-5

Gopnik, A. (1996). The scientist as child. *Philosophy of science*, *63*(4), 485-514.

Gopnik, A. (2012). Scientific thinking in young children: Theoretical advances, empirical research, and policy implications. *Science*, *337*(6102), 1623-1627.

Gopnik, A., & Meltzoff, A. N. (1997). *Words, thoughts, and theories*. Mit Press.

Green, S. B., & Yang, Y. (2009). Reliability of summed item scores using structural equation modeling: An alternative to coefficient alpha. *Psychometrika*, *74*, 155-167.

Greenfield, D. B., Jirout, J., Dominguez, X., Greenberg, A., Maier, M., & Fuccillo, J. (2009). Science in the preschool classroom: A programmatic research agenda to improve science readiness. *Early Education and Development*, *20*(2), 238-264.

Gropen, J., Kook, J. F., Hoisington, C., & Clark-Chiarelli, N. (2017). Foundations of science literacy: Efficacy of a preschool professional development program in science on classroom instruction, teachers' pedagogical content knowledge, and children's observations and predictions. *Early Education and Development*, *28*(5), 607-631.

Guo, Y., Piasta, S. B., Justice, L. M., & Kaderavek, J. N. (2010). Relations among preschool teachers' self-efficacy, classroom quality, and children's language and literacy gains. *Teaching and Teacher education*, *26*(4), 1094-1103.

Guo, Y., Justice, L. M., Sawyer, B., & Tompkins, V. (2011). Exploring factors related to preschool teachers' self-efficacy. *Teaching and Teacher Education*, *27*(5), 961-968.

Guskey, T. R. (2002). Professional development and teacher change. *Teachers and teaching*, *8*(3), 381-391.

Guskey, T. R., & Yoon, K. S. (2009). What works in professional development?. *Phi delta kappan*, *90*(7), 495-500.

Hamre, B. K., Pianta, R. C., Downer, J. T., DeCoster, J., Mashburn, A. J., Jones, S. M., ... & Hamagami, A. (2013). Teaching through interactions: Testing a developmental framework of teacher effectiveness in over 4,000 classrooms. *The elementary school journal*, *113*(4), 461-487.

Heller, J. I., Daehler, K. R., Wong, N., Shinohara, M., & Miratrix, L. W. (2012). Differential effects of three professional development models on teacher knowledge and student achievement in elementary science. *Journal of Research in Science Teaching*, *49*(3), 333-362.

Heroman, C., Burts, D. C., Berke, K. L., & Bickart, T. S. (2010). Teaching Strategies GOLD® objectives for development and learning. *Washington, DC: Teaching Strategies*.

Hill, M. A., Overton, T. L., & Thompson, C. D. (2020). Evaluating the impact of reflecting on curriculum-embedded skill development: the experience of science undergraduates. *Higher Education Research & Development*, *39*(4), 672-688.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: a response to Kirschner, Sweller, and. Educational psychologist, 42(2), 99-107.

Hong, S. Y., Torquati, J., & Molfese, V. J. (2013). Theory guided professional development in early childhood science education. In *Learning Across the Early Childhood Curriculum*. Emerald Group Publishing Limited.

Howe, A. C. (1996). Development of science concepts within a Vygotskian framework. *Science Education*, *80*(1), 35-51.

Jones, M. G., & Carter, G. (2013). Science teacher attitudes and beliefs. In *Handbook of research on science education* (pp. 1067-1104). Routledge.

Jorgensen, R., Grootenboer, P., Niesche, R., & Lerman, S. (2010). Challenges for teacher education: The mismatch between beliefs and practice in remote Indigenous contexts. *Asia-Pacific Journal of Teacher Education*, *38*(2), 161-175.

Kaderavek, J. N., North, T., Rotshtein, R., Dao, H., Liber, N., Milewski, G., ... & Czerniak, C. M. (2015). SCIIENCE: The creation and pilot implementation of an NGSS-based instrument to evaluate early childhood science teaching. *Studies in Educational Evaluation*, *45*, 27-36.

Karademir, A., Kartal, A. & Türk, C. Science Education Activities in Turkey: A Qualitative Comparison Study in Preschool Classrooms. Early Childhood Educ J 48, 285–304 (2020). https://doi.org/10.1007/s10643-019-00981-1

Klahr, D., & Nigam, M. (2004). The equivalence of learning paths in early science instruction: Effects of direct instruction and discovery learning. Psychological science, 15(10), 661-667.

Kloos, H., Waltzer, T., Maltbie, C., Brown, R. D., & Carr, V. (2018). Inconsistencies in early science education: can nature help streamline state standards?. *Ecopsychology*, *10*(4), 243-258.

Koballa Jr, T. R. (1988). Attitude and Related Concepts in Science Education. *Science education*, *72*(2), 115-26.

Kolb, D. A. (1984). The process of experiential learning. Experiential leaning theory

Kontos, S., & Wilcox-Herzog, A. (1997). Influences on children's competence in early childhood classrooms. Early Childhood Research Quarterly, 12(3), 247-262.

Krippendorff, K. (2013). Commentary: A dissenting view on so-called paradoxes of reliability coefficients. *Annals of the International Communication Association*, *36*(1), 481-499.

Kuhn, D. (2011). What is scientifi c thinking and how does it develop? In U. Goswami (Ed.), Handbook of childhood cognitive development (2nd ed., pp. 497–523). Oxford: Wiley-Blackwell.

Larimore, R. A. (2020). Preschool science education: A vision for the future. *Early Childhood Education Journal*, 1-12.

Larimore, R. A., Schwarz, C. V., Van Egeren, L., & Lee, K. (2018). *Head start on science preschool teaching observation measure and findings*. Atlanta, GA: In National Association for Research of Science Teaching.

Larimore, R. A., Schwarz, C. V., Van Egeren, L., Lee, K., & Gerde, H. K. (*submitted). Preschool science teaching in Head Start classrooms.*

Lee, I. (2009). Ten mismatches between teachers' beliefs and written feedback practice. *ELT journal*, *63*(1), 13-22.

Lim, C. P., & Chai, C. S. (2008). Teachers' pedagogical beliefs and their planning and conduct of computer-mediated classroom lessons. *British journal of educational technology*, *39*(5), 807-828.

Linneberg, M. S., & Korsgaard, S. (2019). Coding qualitative data: A synthesis guiding the novice. *Qualitative research journal*, *19*(3), 259-270.

Liu, S. H. (2011). Factors related to pedagogical beliefs of teachers and technology integration. *Computers & Education*, *56*(4), 1012-1022.

Lobman, C. (2005). “Yes and”: The uses of improvisation for early childhood professional development. *Journal of Early Childhood Teacher Education*, *26*(3), 305-319.

Lumpe, A., Czerniak, C., Haney, J., & Beltyukova, S. (2012). Beliefs about teaching science: The relationship between elementary teachers’ participation in professional development and student achievement. *International journal of science education*, *34*(2), 153-166.

Maeng, J. L., Whitworth, B. A., Bell, R. L., & Sterling, D. R. (2020). The effect of professional development on elementary science teachers’ understanding, confidence, and classroom implementation of reform-based science instruction. *Science Education*, *104*(2), 326-353.

Maier, M. F., Greenfield, D. B., & Bulotsky-Shearer, R. J. (2013). Development and validation of a preschool teachers’ attitudes and beliefs toward science teaching questionnaire. *Early Childhood Research Quarterly*, *28*(2), 366-378.

Mansour, N. (2009). Science teachers' beliefs and practices: Issues, implications and research agenda. *International Journal of Environmental and Science Education*, *4*(1), 25-48.

Mantzicopoulos, P., Patrick, H., & Samarapungavan, A. (2013). Science literacy in school and home contexts: Kindergarteners’ science achievement and motivation. Cognition and instruction, 31(1), 62-119.

McCray, J. S., & Chen, J. Q. (2012). Pedagogical content knowledge for preschool mathematics: Construct validity of a new teacher interview. *Journal of Research in Childhood Education*, *26*(3), 291-307.

McCutchen, D., Abbott, R. D., Green, L. B., Beretvas, S. N., Cox, S., Potter, N. S., ... & Gray, A. L. (2002). Beginning literacy: Links among teacher knowledge, teacher practice, and student learning. *Journal of learning disabilities*, *35*(1), 69-86.

McDevitt, T. M., Gardner, A. L., Shaklee, J. M., Bertholf, M. M., & Troyer, R. (1999). Science and mathematics instruction of beginning elementary teachers. *Journal of Science Teacher Education*, *10*(3), 217-233.

McMullen, M. B. (1999). Characteristics of teachers who talk the DAP talk and walk the DAP walk. *Journal of Research in childhood Education*, *13*(2), 216-230.

Menon, D., & Sadler, T. D. (2016). Preservice elementary teachers’ science self-efficacy beliefs and science content knowledge. *Journal of Science Teacher Education*, *27*(6), 649-673.

Metz, K. E. (2004). Children's understanding of scientific inquiry: Their conceptualization of uncertainty in investigations of their own design. Cognition and instruction, 22(2), 219-290.

Moll, L. C. (2019). Elaborating funds of knowledge: Community-oriented practices in international contexts. *Literacy Research: Theory, Method, and Practice*, *68*(1), 130-138.

Montessori, M. (1917). *The advanced Montessori method* (Vol. 1). Frederick A. Stokes Company.

Morgan, P. L., Farkas, G., Hillemeier, M. M., & Maczuga, S. (2016). Science achievement gaps begin very early, persist, and are largely explained by modifiable factors. *Educational Researcher*, *45*(1), 18-35.

Morris, B. J., Croker, S., Masnick, A. M., & Zimmerman, C. (2012). The emergence of scientific reasoning. In *Current topics in children's learning and cognition*. IntechOpen.

National Academies of Sciences, Engineering, and Medicine. (2022). Science and Engineering in Preschool Through Elementary Grades: The Brilliance of Children and the Strengths of Educators. Washington, DC: The National Academies Press. https://doi.org/10.17226/26215.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

National Science Teachers Association (NSTA). (2014). *Statement of early childhood education.* Retrieved from http://www.nsta.org/about/positions/earlychildhood.aspx

Nayfeld, I., Brenneman, K., & Gelman, R. (2011). Science in the classroom: Finding a balance between autonomous exploration and teacher-led instruction in preschool settings. Early Education & Development, 22(6), 970–988. https ://doi.org/10.1080/10409 289.2010.50749 6.

NGSS Lead States. (2013). Next generation science standards: for states, by states. The National Academies Press.

Nilsson, P., & Elm, A. (2017). Capturing and developing early childhood teachers' science pedagogical content knowledge through CoRes. *Journal of Science Teacher Education*, *28*(5), 406-424.

North American Association for Environmental Education (NAAEE). (2020). *Nature-based preschools in the US: 2020 Snapshot.* Washington, DC: NAAEE.

Ogan-Bekiroglu, F., & Akkoç, H. (2009). Preservice Teachers' Instructional Beliefs and Examination of Consistency Between Beliefs and Practices. *International Journal of Science and Mathematics Education*, *7*, 1173-1199.

Olafson, L., Grandy, C.S., & Owens, M. C. (2014). Qualitative approaches to studying teachers' beliefs. In International handbook of research on teachers' beliefs (pp. 140-161). Routledge.

Osborne, M. D., & Brady, D. J. (2001). Constructing a space for developing a rich understanding of science through play. Journal of Curriculum Studies, 33(5), 511-524.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International journal of science education*, *25*(9), 1049-1079.

Oppermann, E., Anders, Y., & Hachfeld, A. (2016). The influence of preschool teachers' content knowledge and mathematical ability beliefs on their sensitivity to mathematics in children's play. *Teaching and Teacher Education*, *58*, 174-184.

Oppermann, E., Brunner, M., & Anders, Y. (2019). The interplay between preschool teachers' science self-efficacy beliefs, their teaching practices, and girls' and boys' early science motivation. *Learning and Individual Differences*, *70*, 86-99.

Palmer, D. (2004). Situational interest and the attitudes towards science of primary teacher education students. *International Journal of Science Education*, *26*(7), 895-908.

Park, M. H., Dimitrov, D. M., Patterson, L. G., & Park, D. Y. (2017). Early childhood teachers' beliefs about readiness for teaching science, technology, engineering, and mathematics. *Journal of Early Childhood Research*, *15*(3), 275-291.

Pendergast, E., Lieberman-Betz, R. G., & Vail, C. O. (2017). Attitudes and beliefs of prekindergarten teachers toward teaching science to young children. *Early Childhood Education Journal*, *45*(1), 43-52.

Pentimonti, J. M., Gerde, H. K., & Pikus, A. E. (2020). Finding Time for Science. *YC Young Children*, *75*(4), 14-22.

Piaget, J. (1973). *The child and reality: Problems of genetic psychology.(Trans. Arnold Rosin)*. Grossman.

Pianta, R. C., La Paro, K. M., & Hamre, B. K. (2008). *Classroom Assessment Scoring System™: Manual K-3*. Paul H Brookes Publishing.

Piasta, S. B., Logan, J. A., Pelatti, C. Y., Capps, J. L., & Petrill, S. A. (2015). Professional development for early childhood educators: Efforts to improve math and science learning opportunities in early childhood classrooms. *Journal of educational psychology*, *107*(2), 407.

Piasta, S. B., Pelatti, C. Y., & Miller, H. L. (2014). Mathematics and science learning opportunities in preschool classrooms. *Early education and development*, *25*(4), 445-468.

Pramling Samuelsson, I., & Johansson, E. (2006). Play and learning—inseparable dimensions in preschool practice. Early child development and care, 176(1), 47-65.

Ramanathan, G., Carter, D., & Wenner, J. (2022). A framework for scientific inquiry in preschool. *Early Childhood Education Journal*, *50*(7), 1263-1277.

Reiser, B. J., Michaels, S., Moon, J., Bell, T., Dyer, E., Edwards, K. D., ... & Park, A. (2017). Scaling up three-dimensional science learning through teacher-led study groups across a state. *Journal of Teacher Education*, *68*(3), 280-298.

Richardson, V. (2003). Constructivist pedagogy. *Teachers college record*, *105*(9), 1623-1640.Ritz, W. C. (2007). A head start on science: Encouraging a sense of wonder. NSTA Press.

Saçkes, M. (2014). How often do early childhood teachers teach science concepts? Determinants of the frequency of science teaching in kindergarten. European early childhood education research journal, 22(2), 169-184.

Saldaña, J. (2021). *The coding manual for qualitative researchers*. Sage.

Samuelsson, I. P., & Carlsson, M. A. (2008). The playing learning child: Towards a pedagogy of early childhood. *Scandinavian journal of educational research*, *52*(6), 623-641.

Savasci, F., & Berlin, D. F. (2012). Science teacher beliefs and classroom practice related to constructivism in different school settings. *Journal of Science Teacher Education*, *23*(1), 65-86.

Schachter, R. E. (2015). An analytic study of the professional development research in early childhood education. *Early education and development*, *26*(8), 1057-1085.

Schachter, R. E., Spear, C. F., Piasta, S. B., Justice, L. M., & Logan, J. A. (2016). Early childhood educators' knowledge, beliefs, education, experiences, and children's language- and literacy-learning opportunities: What is the connection?. *Early Childhood Research Quarterly*, *36*, 281-294.

Schauble, L., & Gleason, M. (2000). What do adults need to effectively assist children's learning. In Paper presented as part of a paper set, Museum Learning Collaborative: Studies of Learning from Museums, at the annual meeting of the American Educational Research Association, New Orleans.

Schulz, L. E., & Bonawitz, E. B. (2007). Serious fun: preschoolers engage in more exploratory play when evidence is confounded. Developmental psychology, 43(4), 1045.

Schwarz, C. V., Passmore, C., & Reiser, B. J. (2017). Moving beyond "knowing about" science to making sense of the world. Helping students make sense of the world using next generation science and engineering practices, 3-21.

Schweinhart, L. J., Mcnair, S., Barnes, H., & Larner, A. M. (1993). Observing young children in action to assess their development: The High/Scope Child Observation Record study. *Educational and Psychological Measurement*, *53*(2), 445-455.

Shonkoff, J. P., Phillips, D. A., & National Research Council. (2000). The developing brain. In *From neurons to neighborhoods: The science of early childhood development*. National Academies Press (US).

Shrigley, R. L., Koballa Jr, T. R., & Simpson, R. D. (1988). Defining attitude for science educators. *Journal of research in science teaching*, *25*(8), 659-678.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. Educational researcher, 15(2), 4-14.

Smith, J. M., & Kovacs, P. E. (2011). The impact of standards-based reform on teachers: the case of 'No Child Left Behind'. *Teachers and Teaching: theory and practice*, *17*(2), 201-225.

Smith, J., & Nadelson, L. (2017). Finding alignment: The perceptions and integration of the next generation science standards practices by elementary teachers. *School Science and Mathematics*, *117*(5), 194-203.

Spektor-Levy, O., Baruch, Y. K., & Mevarech, Z. (2013). Science and Scientific Curiosity in Pre-school—The teacher's point of view. *International Journal of Science Education*, *35*(13), 2226-2253.

Straits, W. (2018). *A head start on life science: Encouraging a sense of wonder.* NSTA Press.

Strand-Cary, M., & Klahr, D. (2008). Developing elementary science skills: Instructional effectiveness and path independence. Cognitive Development, 23(4), 488-511.

Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2013). *Using multivariate statistics* (Vol. 6, pp. 497-516). Boston, MA: pearson.

Tamir, P. (1991). Professional and personal knowledge of teachers and teacher educators. *Teaching and Teacher Education*, *7*(3), 263-268.

Tao, Y., Oliver, M., & Venville, G. (2012). Long-term outcomes of early childhood science education: Insights from a cross-national comparative case study on conceptual understanding of science. *International Journal of Science and Mathematics Education*, *10*(6), 1269-1302.

Teague, G. M., Anfara Jr, V. A., Wilson, N. L., Gaines, C. B., & Beavers, J. L. (2012). Instructional practices in the middle grades: A mixed methods case study. *Nassp Bulletin*, *96*(3), 203-227.

Tekkumru Kisa, M., & Stein, M. K. (2015). Learning to see teaching in new ways: A foundation for maintaining cognitive demand. *American Educational Research Journal*, *52*(1), 105-136.

Thulin, S., & Redford, A. (2017). Student Preschool Teachers' Experiences of Science and Its Role in Preschool. *Early Childhood Education Journal*; 45, 509–520 https://doi.org/10.1007/s10643-016-0783-0

TIMSS. (2019). *U.S. Highlights Web Report*. U.S. Department of Education. Institute of Education Sciences, National Center for Education Statistics. Available at https://nces.ed.gov/timss/results19/index.asp.

Torres-Crespo, Marisel N., Emily Kraatz, and Lindsey Pallansch. "From Fearing STEM to Playing with It: The Natural Integration of STEM into the Preschool Classroom." *SRATE Journal* 23, no. 2 (2014): 8-16.

Tortorelli, L. S., Gerde, H. K., Rohloff, R., & Bingham, G. E. (2022). Ready, set, write: Early learning standards for writing in the Common Core era. *Reading Research Quarterly*, *57*(2), 729-752.

Tosun, T. (2000). The beliefs of preservice elementary teachers toward science and science teaching. *School science and mathematics*, *100*(7), 374-379.

Tournaki, N., & Podell, D. M. (2005). The impact of student characteristics and teacher efficacy on teachers' predictions of student success. *Teaching and Teacher Education*, *21*(3), 299-314.

Tu, T. (2006). Preschool science environment: What is available in a preschool classroom?. *Early Childhood Education Journal*, *33*(4), 245-251.

Tu, T. H., & Hsiao, W. Y. (2008). Preschool teacher-child verbal interactions in science teaching. The Electronic Journal for Research in Science & Mathematics Education.

US Department of Health and Human Services. (2015). Head start early learning outcomes framework. *Washington, DC: Administration for Children and Families, Office of Head Start*.

van Aalderen-Smeets, S. I., & Walma van der Molen, J. H. (2015). Improving primary teachers' attitudes toward science by attitude-focused professional development. *Journal of research in science teaching*, *52*(5), 710-734.

Van Egeren, L. A., Watson, D., Morris, B., Farrand, M., & Lownds, N. (2007). *Creating school readiness through early childhood science education: Evaluation of Head Start on Science*. East Lansing: Michigan State University.

Vartuli, S. (2005). Beliefs: The heart of teaching. *YC Young Children*, *60*(5), 76.

Vick, M. E., & Garvey, M. P. (2016). Environmental Science and Engineering Merit Badges: An Exploratory Case Study of a Non-Formal Science Education Program and the US Scientific and Engineering Practices. *International Journal of Environmental and Science Education*, *11*(18), 11675-11698.

Vitiello, V. E., Whittaker, J. V., Mulcahy, C., Kinzie, M. B., & Helferstay, L. (2019). Reliability and validity of the preschool science observation measure. *Early Education and Development*, *30*(2), 196-215.

Von Blum, R. (1998). "A Head Start on Science" final evaluation. Long Beach: California State University, Long Beach.

Vosniadou, S., & Brewer, W. F. (1992). Mental models of the earth: A study of conceptual change in childhood. Cognitive psychology, 24(4), 535-585

Vygotsky, L. S. (1986). *Thought and language.* Cambridge, MA: MIT Press.

Wallace, J., & Loughran, J. (2012). Science teacher learning. *Second international handbook of science education*, 295-306.

Wilinski, B. (2017). When pre-K comes to school: Policy, partnerships, and the early childhood education workforce. Teachers College Press.

Wilkening, F., & Sodian, B. (2005). Scientific reasoning in young children: Introduction. *Swiss Journal of Psychology*, *64*(3), 137-139.

Wilkins, J. L. (2008). The relationship among elementary teachers' content knowledge, attitudes, beliefs, and practices. *Journal of Mathematics Teacher Education*, *11*, 139-164.

Wilson, S. M. (2013). Professional development for science teachers. *Science*, *340*(6130), 310-313.

Wyatt, M. (2014). Towards a re-conceptualization of teachers' self-efficacy beliefs: Tackling enduring problems with the quantitative research and moving on. International Journal of Research & Method in Education, 37(2), 166-189.

Zacharia, Z. C., Loizou, E., & Papaevripidou, M. (2012). Is physicality an important aspect of learning through science experimentation among kindergarten students?. *Early Childhood Research Quarterly*, *27*(3), 447-457.

Zembal-Saul, C., Carlone, H., & Brown, M. (2020). A possibility-centric vision of elementary teachers and ambitious science teaching. *Preparing science teachers through practice-based teacher education*, 117-132.

Zimmerman, C. (2007). The development of scientific thinking skills in elementary and middle school. *Developmental review*, *27*(2), 172-223.

APPENDIX A: TABLES

Table 1

Demographics of Participants in Study

Variable	n	%
Sex		
Female	72	98.6
Male	1	1.4
Race		
African American/Black	9	12.5
American Indian/Native American	1	1.4
White/Caucasian	60	83.3
Other	2	1.8
Educational attainment		
High school/GED	1	1.4
Associate's degree	16	22.2
Bachelor's degree	50	69.4
Master's degree	5	6.9

	Mean	*(SD)*	Range
Age (years)	41.19	9.37	25--60
Tenure in current position (years)	6	6.16	0--25
Teaching experience (years)	11	7.38	2--31

Note: One teacher did not report race or educational attainment.

Table 2

Initial Codes of Teacher Responses to "What is your definition of science for young children?"

- Science is everything around them
- Every realm of a child's learning
- Related to all areas of development
- All around us; all parts of our day/lives
- Learning about the world through exploration
- World around them
- Push to a higher level of understanding
- Integration across curriculum (or within 2+ areas)
- Knowledge, content knowledge
- Different fields of science
- Generating knowledge; knowledge obtained through everyday life
- Scaffolding
- Child led
- Child's interest
- At children's pace and skill level
- On their (*child*) own
- Take their *(child)* time; take time
- Child led/initiated and teacher supported
- Teacher work alongside the child/with the child
- Adult directed
- Teacher/adult guided
- Practices
- Great idea
- No reading
- Using 5 senses
- Hands on
- Field trips
- Active learning

Table 2 (cont'd)

- Interactive
- Listening to what they (*children)* say and learn
- No wrong ideas
- Spontaneity or unplanned
- Open-ended experiences
- Children can use their minds
- Through simple questions
- Informal
- Fun
- Play
- Should not have to "work at the science"
- Getting messy
- Curiosity (e.g., thirst for more, not afraid of unknown)
- Sense of wonder
- Ability to build wonder
- Analyze
- Categorize
- Cause and effect
- Classify
- Collaborate
- Collect data
- Communicate
- Counting
- Creative
- Demonstrating
- Describe
- Discover
- Discussing
- Document

Table 2 (cont'd)

- Draw conclusions
- Evaluate
- Experiment
- Explain
- Explanation of why things happen
- Explore
- Explore changes
- Finding out
- Guessing
- How things work, change, grow
- Hypotheses
- Identify
- Ins and outs of objects; properties of objects
- Investigate
- Learn definitions
- Measure
- Mechanics
- Mixing
- Observe
- Organize
- Outcomes
- Predict
- Problem-solving
- Questioning
- Reason
- Recording data
- Reference to known or unknown ideas
- Report findings
- Research

Table 2 (cont'd)

- Testing
- Trial and error
- Use procedures
- Materials and tools
- Sensory table
- Topics – General
- Topics – Miscellaneous list of topics covered or examples (e.g., weather, sky, mixing paint, magnets, etc.).
- Nature
- Living and non-living
- Language/vocabulary
- Physics, physics concepts
- Googled definition of science
- "I do not have a definition"

Table 3

Initial Codes of Teacher Responses to "How should science be taught to young children?"

- Every aspect of a child's day
- World around them
- Using the 5 senses. Using their senses, allowing them to touch/feel, provide visuals
- Active learning and interactive, engaged, interaction
- Appropriate for children
- Build on what children are learning
- Caring
- Science center
- Promoting children to talk about their ideas/experiences
- Meet children where they are; right at their level
- Enough time, own pace, not rushed
- Attention to child variation; learning styles, differences among skills; know differences in child learning
- Enjoy the learning with the children; find out with them; working with children/Enjoy the learning with the children; find out with them; working with children
- Stimulate/promote curiosity, sense of wonder
- Enthusiastically
- Involve everyone
- Learn through experiences. Everyday experiences
- Free play/free choice
- Fun
- Large group
- Small group
- Hands on. When teachers say 'hands on'
- Informal
- Integrated; across the curriculum; throughout the classroom
- Naturally
- Nature

Table 3 (cont'd)

- Nature walks
- Open-ended experiences
- Outside
- Play
- Safe environment (can take risk, can ask questions)
- Use self-talk or talking about what you (*teacher)* are doing or what you (*teacher)* see
- Simple thing
- Spiral (scientific spiral)
- Use teachable moments
- All day
- Daily
- Balance of open-ended and teacher directed
- Child led; teacher supported
- Progression from teacher led to child-led and teacher guide; little instruction and let them do it
- Teacher and child explore together
- Teacher introduced then child exploration
- Learn through own ideas; create own/new ideas
- Based on child's interest; when activities are based on what the child wants or asks
- Child initiated; when child is allowed to lead
- Guidance from peers
- Teacher/adult facilitating
- Teacher/adult guidance, assistance
- Teacher/adult guided; any kind of guidance, assistance, scaffolding, planning, or asking questions
- Teacher/adult introducing
- Encourage ideas and concepts; introduce new ideas and concepts
- Teacher led
- Teacher/adult listen to children

Table 3 (cont'd)

- Teacher/adult planning
- Teacher/adult scaffolding
- Analyze, evaluate, compare, contrast
- Cause and effect
- Collect data
- Create conclusions
- Vocabulary, using vocabulary, promoting vocabulary, science terms and integrating language, modeling, verbal self-expression vocabulary
- Discovery
- Discussion
- Share/disseminate information to others
- Experimenting
- Exploration; when teachers reported that they allow children to "explore"
- Finding out
- How things work
- Hypothesize
- Science is a method/process
- Observation
- Ongoing process
- Predictions
- Problem-solving
- Child asks questions; supporting the child to ask questions; time to ask questions
- Through questioning (when the teacher asks open-ended questions); asking questions; questioning; asking wonder questions
- Record data, information
- Summarize or report findings
- Research
- Scientific techniques
- Testing

Table 3 (cont'd)

- Trial and error
- Science tools
- Providing appropriate materials
- Through books; use of books
- Explain new tools/materials
- Man-made materials
- Natural materials
- Real materials
- Topic(s) taught
- "I don't know"

Table 4

Descriptive Statistics and Correlations Among Study Variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Teacher Attributes																
1. Ideas aligned with HS	-															
2. Ideas aligned with NGSS	.266*	-														
3. Science self-efficacy	.291*	.118	-													
4. P-TABS: Comfort	.431**	.388*	.599**	-												
5. P-TABS: Child Benefit	.272	.329*	.411*	.585**	-											
6. P-TABS Challenges	-.429**	-.365*	-.472**	-.559**	-.226	-										
7. Child-led/teacher supported	.156	.035	.018	.209	.157	-.105	-									
8. Generate/expand knowledge	.183	.273*	-.071	.240	.000	-.096	.296*	-								
9. Other domains	.266*	.027	.083	.067	.000	-.241	-.096	-.055	-							
10. Nature/natural environment	.079	.283*	.098	.045	-.094	-.111	-.035	-.062	.215	-						
11. Materials to support	.341**	.294*	-.175	-.057	-.043	.028	.253*	.216	.147	.048	-					
Classroom Science Practices																
12. PCSMEC	-.034	.005	.105	-.215	.094	.160	-.137	.014	.033	.043	.078	-				
13. CLASS-IS	.169	-.030	-.067	-.089	-.058	.089	.110	.100	-.049	-.286*	-.037	.079	-			
14. SciTOP-P	-.020	.074	-.036	-.111	-.143	.141	-.045	-.021	.092	-.064	.150	-.040	.152	-		
15. Science Engagement	-.207	-.159	-.354**	-.442**	-.238	.200	-.050	-.093	-.147	-.211	.006	-.251*	-.007	.189	-	
16. PC of Science Practices	.190	.112	.178	.098	.001	-.016	.026	.085	.087	.181	-.027	.721**	.342**	-.261*	-.741**	-
M	1.59	1.42	18.71	58.61	45.97	17.95	0.315	0.247	0.082	0.329	0.425	22.16	2.878	7.372	1.96	.000
SD	1.245	0.686	3.617	7.217	3.949	5.077	0.467	0.434	0.277	0.473	0.498	11.294	0.731	3.08	0.978	1.000
Range	0 - 5	0 - 3	12 - 25	41 - 70	37 - 50	7 - 30	0 - 1	0 - 1	0 - 1	0 - 1	0 - 1	8 - 49	1.33 - 5	0 - 14.15	1 - 5	-0.219 - 2.423
n	73	73	65	38	38	38	73	73	73	73	73	73	71	66	73	64

Note: Correlations reported were conducted using Spearman rho.

HS = Head Start; NGSS = Next Generation Science Standards; P-TABS = Preschool Teachers Attitudes and Beliefs Toward Science; PCSMEC = Preschool Classroom Science Materials and Equipment Checklist;

CLASS-IS = Classroom Assessment Scoring System: Instructional Support domain; SciTOP-P = Science Teacher Observation Protocol for Preschool; PC = Principal Component.

*$p < .05$. **$p < .001$.

APPENDIX B: FIGURES

Figure 1

Scatterplots for classroom practice variables