Science learning opportunities and the Project Approach in preschool classrooms

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Science learning opportunities and the Project Approach in preschool classrooms

by

Melissa E. Clucas

A dissertation submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

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Program of Study Committee:
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The student author, whose presentation of the scholarship herein was approved by the program of study committee, is solely responsible for the content of this dissertation. The Graduate College will ensure this dissertation is globally accessible and will not permit alterations after a degree is conferred.

Iowa State University

Ames, IA

2018

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lose your amazing sense of curiosity and that you always strive to continue learning. This dissertation is dedicated to you.
ABSTRACT

Effective early science learning opportunities are critical for young children to build a solid foundation for subsequent development of concepts, as well as positive attitudes towards science (Eshach & Fried, 2005). However, these opportunities are often lacking in typical preschool classrooms (Connor, Morrison, & Slominski, 2006; Early et al., 2010). A multiple case study design was used to examine science learning opportunities in preschool classrooms using the Project Approach (PA; Helm & Katz, 2011). Guided by theoretical tenets from Dewey, Piaget, and Vygotsky, this study sought to explore the feasibility and efficacy of using the PA to promote high-quality science learning opportunities by examining the specific strategies teachers used to plan for authentic and meaningful experiences, structure the environment, and interact with children during project investigations. Within case and cross case analyses of six classrooms revealed nine overall themes of strategies teachers used to promote high-quality science learning opportunities. Findings from this study are discussed in terms of four recommendations for practice and implications for future research regarding the relationship between the Project Approach and early science education.
CHAPTER 1. INTRODUCTION

With an increasing emphasis on both early learning and the importance of science, technology, engineering, and mathematics (STEM) education, researchers and policy makers are advocating for the integration of STEM education into early childhood settings (Early Childhood STEM Working Group, 2017; McClure et al., 2017). While research and policy recommendations support the need for high-quality STEM in early childhood classrooms, there remains a disconnect between research and practice with limited high-quality practical guidance for early childhood educators. Recent research has led to understanding early mathematics learning trajectories (Clements, Sarama, Spitler, Lange, & Wolfe, 2011) and developing effective early childhood mathematics instruction (Clements & Sarama, 2014), however, less research has focused on studying effective early childhood science teaching practices. The aim of this collective case study was to explore how preschool teachers implementing the Project Approach (PA) in their classrooms promote high-quality science learning opportunities. It was anticipated that this inquiry would elicit specific strategies for promoting these early science skills and inform preschool science pedagogy.

Background

In 2015, President Obama announced over $240 million in new STEM commitments (The White House, Office of the Press Secretary). This announcement was the latest advancement of the Educate to Innovate initiative, which was launched in 2009 to focus efforts on providing high quality education in STEM to increase the number and quality of students in these fields. While this mandate included improving preschool through twelfth grade STEM instruction, much of the initial focus was on STEM education at the elementary, secondary, and postsecondary levels, including the development of the Next Generation Science Standards.
(NGSS Lead States, 2013), which are science standards for K-12 education that have been adopted by 19 states and the District of Columbia (National Science Teachers Association [NSTA], 2014).

The lack of focus on early childhood STEM education is problematic because research supports that quality STEM experiences during the early childhood years provide children with a solid foundation for subsequent development of concepts, as well as positive attitudes towards STEM (Eshach & Fried, 2005). In the executive summary of their report *STEM Starts Early*, McClure and colleagues (2017) assert, “Just as the industrial revolution made it necessary for all children to learn to read, the technology revolution has made it critical for all children to understand STEM. To support the future of our nation, the seeds of STEM must be planted early, along with and in support of the seeds of literacy.” In response to the growing area of research in early STEM, the White House hosted a symposium for researchers, policymakers, funders, and practitioners to discuss the importance of integrating STEM into early childhood settings (White House Symposium on Early STEM, 2016).

Much of the research conducted in early STEM has been in the area of early mathematics due to findings that indicate early math skills are one of the best predictors of later school achievement (Duncan et al., 2007). Yet, according to results from the 2011 National Assessment of Education Progress (NAEP), just over one-third of U.S. eighth graders are proficient in science, with more than one-third performing at a below basic level (National Center for Education Statistics [NCES], 2012). Recent findings from the 1998-1999 Early Childhood Longitudinal Study (ECLS-K) indicate the strongest overall contributor to science achievement gaps in U.S. eighth graders is general knowledge (i.e., earth, physical, and life sciences and social studies) gaps already present at kindergarten entry (Morgan, Farkas, Hillemeier, &
Maczuga, 2016). These findings illustrate the need for high quality early learning experiences that promote the development of thinking skills and positive attitudes for learning prior to the beginning of kindergarten.

Science is particularly important in early childhood because scientific thinking skills, such as questioning, transfer to and support development in other academic domains (Kuhn & Pearsall, 2000). When children are engaged in collaborative science experiences with other children they are working on their social-emotional skills, as well as language and literacy development (Early Childhood STEM Working Group, 2017). Moreover, researchers have found strong associations between early childhood science and approaches to learning (Bustamante, White, & Greenfield, 2016) and executive functioning (Nayfeld, Fuccillo, & Greenfield, 2013). In the book Eager to Learn: Educating our Preschoolers, editors Burns, Donovan, and Bowman (2000) call science a “privileged domain”, in which children have a natural proclivity to learn. Children are intrinsically motivated to explore scientific concepts and practice scientific skills as they ask questions of their everyday interactions with the world, such as “Why does it get dark at night?” or “How do spiders spin their webs?”

In their position statement on early childhood science education, The National Science Teachers Association (2014) affirms the importance of early science for fostering children’s natural curiosity and advocates for providing experiences in the early years that connect to the Next Generation Science Standards (NGSS Lead States, 2013) and lay the foundation for future science learning. The importance of early science for child development is also recognized within the Cognition domain of the Head Start Early Learning Outcomes Framework (Head Start ELOF; Administration for Children and Families [ACF], 2015). The central domain of Cognition for preschool children is split into the two domains of Mathematics Development and Scientific
Reasoning. The domain of Scientific Reasoning has two further sub-domains consisting of Scientific Inquiry and Problem Solving. Each of these sub domains includes three goals for children. Under the sub-domain of Scientific Inquiry children are expected to observe and describe observable phenomena, engage in scientific talk, and compare and categorize observable phenomena. Under the sub-domain of Reasoning and Problem-Solving children are expected to ask a question, gather information and make predictions; plan and conduct investigations and experiments; and analyze results, draw conclusions, and communicate results (Figure 1). These goals are not only essential for providing a solid foundation for the subsequent development of scientific concepts, but they are also important for developing higher order thinking skills that will be necessary in every academic domain. Rather than continuing to layer additional content domains and curricula into the preschool day, the focus should be on implementing integrated approaches for teaching (Brenneman, Stevenson-Boyd, & Frede, 2009). The combination of children’s natural curiosity about the world and the transferability of skills make science an ideal domain on which to center integration efforts.

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<td>P-SCI 6. Child analyzes results, draws conclusions, and communicates results.</td>
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*Figure 1. Head Start Early Learning Outcomes Framework preschool science goals (ACF, 2015)*
Problem Statement

Despite the wealth of research and policy recommendations in support of early science, teachers are spending less time on science than other academic content areas (Connor, Morrison, & Slominski, 2006; Early et al., 2010), and children are exhibiting less growth throughout the preschool years when compared to other academic domains (Greenfield et al., 2009). In a study conducted by Greenfield and colleagues (2009), Head Start teachers participating in focus group sessions discussed barriers they faced in teaching science in their classrooms. Two main themes emerged from these discussions. Firstly, many teachers described feeling pressure to focus on language and literacy skills and having difficulty in finding time to provide children with learning experiences in other readiness domains, including science. This finding illustrates the need for a pedagogical approach that integrates all readiness domains with science to ensure that preschoolers are getting the science-learning opportunities they need. The second theme that emerged is that many teachers felt less prepared and competent to teach science due to lack of training and practical guidance for teaching science in early childhood classrooms. Indeed, one of the major recommendations in the Early STEM Matters policy report is to “develop and support a research agenda that informs…best practices in early childhood STEM education” (Early Childhood STEM Working Group, 2017, p.4). Additionally, the group calls for more applied early STEM research conducted in authentic early childhood settings to decrease the gap between research and practice and influence early STEM teaching and learning practices.

Purpose Statement

The purpose of this collective case study was to explore how six preschool teachers promote high-quality science learning opportunities within the context of an emergent curriculum. This study is based on a social constructivist orientation centered on theoretical
tenets of Piaget, Vygotsky, and Dewey about best practices in preschool science education. Taken together, these three theorists posit that children need a stimulating environment for authentic and meaningful exploration, with teachers who serve as partners in learning by guiding their explorations. These practices are embedded in emergent curriculum, such as the PA (Helm & Katz, 2011), making it an integrated pedagogical approach for teaching science using best practices derived from a theoretical framework. In response to the Early Childhood STEM Working Group’s (2017) call for more applied research, the central goal of this study was to discover specific strategies that preschool teachers use during projects to promote children’s scientific inquiry and problem-solving skills as defined by the Head Start ELOF (ACF, 2015). In alignment with the theoretical underpinnings of social constructivism, data were analyzed to address three research questions:

1. How do teachers plan for authentic and meaningful experiences?
2. How do teachers structure the environment for science learning?
3. How do teachers interact with children when guiding explorations?

**Significance**

The primary significance of this study lies in the potential to inform professional development in preschool science pedagogy through a theoretically based, developmentally appropriate, and integrated approach. This is important because an integrated pedagogical approach could potentially reduce strain on teachers for finding time to teach literacy and other academic subject areas. More importantly, an integrated approach allows children to connect their learning and experiences across curricular areas, which promotes deeper understanding of concepts over time (National Research Council [NRC], 2000).
This study adds to the growing literature base on early STEM education. While there is a heavy emphasis on child-focused (e.g., assessment of the academic outcomes) studies in pre-K, fewer studies have focused on teacher experiences and teaching strategies (McClure, 2017). The design of this study was significant because a collective case study provided an in-depth look into the strategies preschool teachers use to promote high-quality science learning opportunities. The collective case study design provided opportunity to explore teaching strategies within each classroom, as well as across several different classrooms, to increase transferability of the findings and determine which strategies can be applied in similar contexts and settings (Bloomberg & Volpe, 2016). Finally, while the purpose of this study was to elicit specific teaching strategies that promote children’s science learning opportunities, this study also adds to the empirical literature base for emergent curriculum and the PA through an examination of implementation of the PA in relation to overall classroom quality and science experiences.
CHAPTER 2. LITERATURE REVIEW

Research on science in early childhood settings is in its infancy when compared to research on other academic domains, such as literacy and mathematics. Less is known about early science due to misconceptions about young children’s cognitive capacity that led to the long-held beliefs that science is for adults and that children lack the mental structures needed to think scientifically (Kermani & Aldemir, 2015). On the contrary, young children have foundational competence in science concepts related to physics, biology, psychology, and chemistry (Duschl, Schweingruber, & Shouse, 2007), and they possess dispositions and skills that support later, more sophisticated abstract thought and reasoning (Brenneman, Stevenson-Boyd, & Frede, 2009). The literature presented in this chapter first provides an overview of science knowledge acquisition in early childhood and an examination of the quantity and quality of science learning opportunities currently offered in preschool classrooms. Next, identified barriers to teaching science in early childhood are considered, as well as curricular efforts to improve early science education. Finally, a theoretical framework linking best practices in science education to emergent curriculum and the PA is presented.

Science Knowledge Acquisition in Early Childhood

Traditional stage theorists of cognitive development (e.g., Piaget) propose that young children’s cognition is dependent upon their sensory perceptions and that they are incapable of abstract thought. Misapplication of theoretical propositions have contributed to the belief that young children are incapable of scientific thinking, and therefore science is not developmentally appropriate for preschoolers (Metz, 1995). For example, according to Piaget’s theory, thinking at the formal operations level is “hypothetical-deductive in the sense that it permits one to draw conclusions from pure hypothesis and not merely from actual observations” (Piaget, 1968, p.63).
Because Piaget’s stage views of development suggested that children do not reach this “hypothetical-deductive” stage of thinking until adolescence, many experts believed scientific inquiry was developmentally inappropriate for young children. Metz (1995) argues that close examination of Piaget’s writings fails to support this belief and that both Piagetian and non-Piagetian literature supports young children’s ability to explore cause and effect, manipulate variables, and explain physical phenomena.

Indeed, a closer examination of Piaget’s theory, as well as modern developmental research, indicates that young children are capable of basic science skills beginning at birth and are well prepared for science learning. According to Piaget, infants in the stage of “secondary circular reactions” are intent on repeating interesting events, such as repeatedly dropping a toy from a high chair so that a caregiver will retrieve it (Piaget, 1968). This demonstrates an infant’s ability to explore cause and effect relationships, as well as supports the infant’s emerging understanding of physics. Modern cognitive development research adds that infants are also able to observe and categorize information (Wu, Gopnik, Richardson, & Kirkham, 2011) and begin to understand causal inference (Sobel & Kirkham, 2006).

While experts now agree that young children are capable of scientific thinking and emphasize the importance of science in early childhood (Duschl, Schweingruber & Shouse, 2007; Gopnik, 2012; NSTA, 2014), debates exist around how children acquire science knowledge (NRC, 2005a). Traditional developmental theories suggest that knowledge acquisition is a global process that is domain-general. In other words, children learn using brain mechanisms, such as assimilation and accommodation (Piaget, 2013), that support and guide learning across all developmental and academic domains, regardless of the type of information being learned. In contrast, post-Piagetian studies of cognitive development suggest that
knowledge acquisition is domain-specific, with specialized learning mechanisms relevant to particular cognitive domains (Gelman, 1990; Keil, 1981).

These debates over how children acquire science knowledge have important implications for early childhood science education. Eshach and Fried (2005) propose that science concerns both domain-general (process/procedural) and domain-specific (content) knowledge. Chaillé and Britain (2002) discussed the differentiation of process from content within the context of science education. Process involves skills for “doing science” such as inquiry and experimentation, while content refers to specific information in a given scientific domain. A review of early childhood science standards (Greenfield et al., 2009) resulted in eight process skills (observing, describing, comparing, questioning, experimenting, reflecting, and cooperating) and three broad content areas (life science, Earth/space sciences, and physical/energy science). According to Chaillé and Britain (2002), the distinction between process and content is artificial because children’s construction of knowledge involves both. The processes of scientific inquiry naturally leads to learning content. While Dewey (1974) concurred that both process and content skills are important, he advocated that science as process should precede science as content. The Head Start ELOF (ACF, 2015) follows this line of thinking as the two sub-domains of science include Scientific Inquiry, and Reasoning and Problem-Solving, which are both process skills.

In a recent examination of 194 preschool children’s science content knowledge (Guo, Piasta, & Bowles, 2015), a single factor model of children’s science knowledge was supported over other multifactor models. This finding suggests that preschool science content knowledge might not be differentiated into specific content areas. Regardless of the one factor model of children’s science knowledge, the researchers found that children demonstrated broad science content knowledge at the beginning of the preschool year, which supports the aforementioned theories
and research suggesting children can and do develop basic science knowledge during early childhood. Although the children in this study demonstrated gains in science knowledge over the year, the effect size for these gains was smaller than those for other academic domains. This finding is congruent with a previous study that found readiness scores in science are low at the beginning of prekindergarten, and growth throughout the prekindergarten year is below that of other domain areas including approaches to learning, creative arts, early math, language & literacy, motor development, physical health, and social and emotional skills (Greenfield et al., 2009). These findings are not surprising given the national focus over the past decade on early language and emergent literacy through the No Child Left Behind Act (2002). In addition, the Good Start, Grow Smart (The White House, 2002) early childhood initiative placed a primary focus on language and literacy skills for school readiness, which succeeded in significantly increasing the frequency of literacy activity in classrooms from 2000 to 2009 (Walter & Lippard, 2017). With a growing emphasis on STEM education, it is essential that we also consider how science learning opportunities can be integrated into early childhood classrooms.

Science Learning Opportunities in Preschool Classrooms

Learning opportunities can be defined as “interactions between adults and children with empirically supported links to children’s social, emotional, and academic development” (Hamre & Pianta, 2007, p.4). These include both the “amount of exposure children have to particular types of instructional interactions…as well as the quality of those interactions” (La Paro et al., 2009, p. 658). Low science readiness scores and national mandates to focus on early science education call for an examination of both the quantity and quality of science learning opportunities afforded to children in preschool classrooms.
**Quantity of Science Learning Opportunities**

In 2004, *Early Childhood Research Quarterly* released a special issue titled “Early Learning in Math and Science” (Ginsburg & Golbeck, 2004). While this special issue contained thirteen peer-reviewed articles, only three of these articles were about early science (French, 2004; Gelman & Brenneman, 2004; Tenenbaum, Rappolt-Schlichtmann & Zanger, 2004). Of these three articles, none included empirical data regarding science practices in preschool classrooms and outcomes. Since the release of that special issue, a few studies have been published that include information about the amount of exposure preschool children have to science learning opportunities. These studies provide a picture of the current state of the quantity of science education in preschool classrooms.

Although not the specific research focus, several articles provided information about how much time was spent on science experiences in preschool classrooms. For example, Connor, Morrison, and Slominski (2006) explored classroom language and literacy activities with 156 children across 34 different classrooms. One of the measures in this study included observational coding of the amount of time that teachers and participating students spent in both academic and non-academic activities. Results from this study indicated that in a 90-minute observation, on average 3 minutes of this time were spent on science, 4 minutes on math, and 15 minutes on language and literacy. Similarly, in a study of quality of children’s learning opportunities, La Paro and colleagues (2009) used time sampling observational data from the National Center for Early Development and Learning’s (NCEDL) Multi-State Study of Pre-Kindergarten to describe children’s moment-by-moment classroom experiences in 240 pre-kindergarten and 730 kindergarten classrooms in six states. The observational data was collected using the Emerging Academics Snapshot (Ritchie, Weiser, Kraft-Sayer, Howes, & Weiser, 2001), which consists of
coding child activity every 20 seconds, and the child can be engaged in one activity, multiple activities, or no activities. Activities were coded using 11 activity codes including: read to, pre-read/reading, letter/sound, oral language development, writing, math, science, social studies, art, gross motor, and fine motor. The Snapshot observation lasted for an entire day in part-day programs and until naptime in full-day programs. Results revealed that prekindergarten children spent about 7% of their time in science activities, 6% in math, and 14% in literacy. Using the same dataset (NCEDL) in combination with data from the Study of State-Wide Early Education Programs (SWEEP), Early and colleagues (2010) described how 2,061 children in 642 classrooms across 11 states spend their time in state-funded pre-kindergarten programs. They found that on average children spent 11% of their time in science activities, 8% on math, and 17% on language and literacy. One common finding across these three studies is the significant amount of time that is spent in the “no coded learning activity” category, indicating that a child did not do any of the 11 activities at any time during a 20-second observation interval. The percentage of “no coded learning activity” was 42%, 44%, and 44% in the three studies respectively. These large percentages of time spent in “no coded learning activity” illustrate the need for an integrated pedagogical approach, which could significantly decrease the amount of time children spend in transition or waiting for the next activity.

An extensive review of the literature resulted in just two studies that focused exclusively on children’s opportunities to experience science in preschool classrooms. In the first study, the preschool science environment was explored in 20 preschool classrooms (Tu, 2006). Each classroom was videotaped during morning free-play time for 60 minutes each on two consecutive days for a total of 120 minutes. The videos were then coded to determine the amount of time that was spent in science-related activities. Three categories of science-related activities
were coded by operationalizing Neuman’s (1972) concept of *sciencing*. These categories included: formal sciencing where the teacher plans lessons, prepares materials, and presents activities to children; informal sciencing where the teacher sets up a section of the room and makes materials available but children freely choose when and how to explore the materials; and incidental sciencing, where the teacher elaborates or expands on an incident of interest to one or more children. In Tu’s study, only 4.5% of the activities were dedicated to formal science, 8.8% to informal science, and none involved incidental sciencing. This means that, on average, in a 120-minute observation, 86.8% of the activities did not involve any science learning opportunities.

In the most recent study of science opportunities in preschool classrooms, Piasta, Pelatti, & Miller (2014) observed and coded instruction in 65 preschool classrooms, including 13 Head Start classrooms, to examine the extent of math and science learning opportunities during a typical day. Videotaped observations of each classroom ranged from 45-203 minutes (*M* = 101, *SD* = 37.5) and included whole group, small group, free choice, center time, and circle time. These videos were coded using the Early Learning Math and Science (ELMS) coding scheme, which was developed specifically for this study. The ELMS was developed from a synthesis of early learning content standards, guiding documents about developmentally appropriate practice (Copple & Bredekamp, 2009), early childhood mathematics and national science standards (Clements, Copple, & Hyson, 2002). The coding scheme includes seven categories to capture children’s involvement in math opportunities and eleven categories to capture children’s involvement in science opportunities. The eleven science categories are organized into three major topic areas of science including: investigation and observation, the living world, and the physical world. Any formal or informal learning opportunity in which at least one child was
involved in one of these categories for at least ten seconds was coded. Results revealed that 96% of classrooms afforded at least some time to learn science, meaning two classrooms did not offer any science-learning opportunities. Overall, an average of 26% of time ($M = 26.3$ minutes, $SD = 25.1$ minutes) was spent on science learning opportunities. While this percentage is strikingly different from other studies about time use in classrooms, the authors caution that the operational definitions of instructional time varied among studies. Additionally, the amount of time spent on science learning opportunities was skewed from 0-120 minutes. One concerning finding in this study is that only 63% of classrooms afforded children with critical thinking experiences, such as opportunities to predict, observe, or ask questions, and an average of just 3.35 minutes was spent on these experiences. This means that 1/3 of the classrooms afforded no opportunities for higher order thinking and scientific process skills, and those that did spent less than 5% of the day doing so.

**Quality of Science Learning Opportunities**

Considering the relative recency of research in early childhood science education and the lack of science learning opportunities afforded to children, it is not surprising that there is limited research examining the quality of science learning opportunities. Compounding this issue is a dearth of instrumentation to specifically measure classroom science quality (Brenneman, 2011; NRC, 2008). Currently, the Early Childhood Environment Rating Scale-Extension (ECERS-E; Sylva, Siraj-Blatchford, & Taggart, 2003) is the only widely available observational measure of classroom science supports (Brenneman, 2011). This measure includes items to evaluate the presence of classroom science areas and science resources, including the presence of natural materials. While the ECERS-E assesses the quality of the science learning environment, it does not include other important aspects of science learning, such as effectiveness of instructional
interactions. The National Institute for Early Education Research (NIEER) developed the Preschool Rating Instrument for Science and Mathematics (PRISM) (Stevenson-Garcia, Brenneman, Fred, & Weber, 2010) to assess both the presence of materials and teaching interactions. Although the instrument measures the quality of support for mathematics and science learning, only five of the sixteen items relate to supports for early science. The Science Teaching and Environment Rating Scale (STERS; Chalufour, Worth, & Clark-Chiarelli, 2009) is the only known measure that focuses on the quality of both the science environment and classroom science instruction. Although the authors report high internal consistency (Cronbach’s alpha = .96), the measure is currently unpublished and therefore not available for widespread use.

Given the lack of specific instrumentation for assessing the quality of early science learning opportunities, it is important to review the research-base and measures related to the overall quality of instructional environments and interactions in preschool classrooms. The Classroom Assessment Scoring System (CLASS; Pianta, La Paro, & Hamre, 2008) is a reliable and valid observational rating scale of teacher-child interactions throughout the day, which have been associated with positive child outcomes (Burchinal et al., 2008; Curby, Rimm-Kaufman, & Ponitz, 2009). The Instructional Support domain assesses the quality of teacher-child interactions related to instruction, such as a teacher’s ability to promote higher-order thinking skills, provide feedback, and model language. This domain is particularly relevant to quality of science learning opportunities because many science process skills require higher-order thinking and the ability to speak the “language” of science. In fact, results from one study of instructional interactions across different types of teacher-directed activities (i.e. circle time, math time, science activities, and storybook reading) indicate that the quality of instructional interactions was higher during
science activities, likely due to an emphasis on higher-order thinking skills and reasoning (Fuccillo, 2012). Unfortunately, the overall quality of instructional interaction tends to be low in preschool classrooms (Burchinal et al., 2008; Hamre & Pianta, 2007). An example of these low scores is evidenced in a cluster analysis of 692 preschool classrooms resulted in five profiles of varying levels of quality (LoCasale-Crouch et al., 2007). The profile with the highest level of instructional support had an average score of 3.29 on a scale from 1 to 7. Bearing in mind that the overall quality of instructional support in these classrooms is low, it is likely that the quality of science learning opportunities is also low. It is evident from these studies that science-learning opportunities are severely lacking in preschool classrooms, and when they are offered, they are likely to be low quality. This necessitates an examination of the potential barriers early childhood educators face in providing quality science learning opportunities in their classrooms.

**Barriers to Preschool Science Education**

In a study conducted by Greenfield and colleagues (2009), Head Start teachers participating in focus group sessions discussed barriers they faced in teaching science. Two main themes emerged from these discussions. First, many teachers described feeling pressure to focus on language and literacy skills and having difficulty in finding time to provide children with learning experiences in other readiness domains, including science. This finding illustrates the need for integrated learning experiences that promote learning across multiple readiness domains. The second theme that emerged is that many teachers felt less prepared and competent to teach science. This finding is congruent with other studies that reported teachers felt they had inadequate science knowledge and difficulty in answering children’s science-related questions (Kallery, 2004; Watters, Diezmann, Grieshaber, & Davis, 2000). Fleer (2009) argues there are systemic reasons for these feelings of inadequacy that are not related to a lack of science
knowledge, such as difficulty modifying and applying science teaching models intended for older children, not recognizing science knowledge gained through informal experiences, and not being supported in professional development. Most pre and in-service education programs, as well as accreditation procedures, do not prioritize preparing educators to provide high-quality instruction in STEM (Early Childhood STEM Working Group, 2017). This is a compounding problem for pre-service teachers as they train under in-service teachers who either doubt the appropriateness of science learning for young children (Fleer, 2006), or who are inexperienced in teaching science in their classrooms.

A complementary barrier to preschool teachers feeling less prepared and competent to teach science may be their pre-existing attitudes and beliefs about science teaching, which have been positively associated with observed classroom practices (Maier, Greenfield, & Bulotsky-Shearer, 2013). Indeed, teachers who report more positive attitudes and beliefs regarding the benefit of science for young children are more likely to use and promote science process skills in the classroom. Fleer (2009) even suggests that teacher knowledge and beliefs about how children learn science may be even more important to consider than a teacher’s science content knowledge. As noted by Kermani and Aldemir (2015), teachers need to critique their attitudes and beliefs about preschool science in order to overcome the notion that science is for adults wearing white lab coats and that children lack the mental structures needed to think scientifically.

**Preschool Science Curricula**

In an effort to support teachers in their lack of confidence and to provide more science learning opportunities, different science curricula have been developed for preschool classrooms. Before providing an overview, it is important to define the term “curriculum”. As discussed by
participants at a national workshop for mathematical and scientific development in early childhood (NRC, 2005b), curricula can include notions of what content is presented, as well as how content is presented. They caution that what many people refer to as curriculum is actually a pedagogical style (e.g. Montessori), which is more about the way children are taught. For the purposes of this discussion, curriculum is defined as the what, or the content that is presented.

With the increasing emphasis on science and the lack of science learning opportunities, many traditional early childhood curricula are being infused with science experiences (e.g. Epstein, 2010; Heroman, Trister Dodge, Kai-lee Berke, & Bickart, 2010). Moreover, several curricula have been developed with science as the foundation (e.g. Brown & Greenfield, 2006; DeVries & Sales, 2011; French, 2004; Gelman & Brenneman, 2004). For example, the ScienceStart! (French, 2004) curriculum consists of four modules (measurement and mapping, color and light, properties of matter, and neighborhood habitats), each of which contains several units. Activities in each unit progress through a daily four-part structure including: reflect and ask, plan and predict, act and observe, and report and reflect. Multiple school readiness domains are also integrated into each unit. Data collected on cross-sectional cohorts between 1995 and 2001 revealed children who attended a classroom with ScienceStart! had greater gains on general receptive vocabulary skills compared to children in control classrooms (French, 2004), however no data were collected on science skills. MyTeachingPartner-Math/Science (MTP-MS) is a more recent curriculum designed to improve the quality of instructional interactions related to mathematics and science (Kinzie et al., 2014). The MTP-MS is unique in that it includes a teacher support system in the form of web-based supports and in-person workshops. The math and science curricula each include two 15-20-minute activities per week throughout the school year. Despite the specialized curricula and teacher supports, a randomized control trial revealed
no significant differences in children’s science skills. The authors note that one important limitation of the MTP-MS is the fact that teachers had to learn new curricula in two subject areas, which had implications for both the teachers’ capacity to learn as well as the amount of learning opportunities children were afforded in each domain. This again emphasizes the need for an integrated curricular approach.

After learning that many preschool teachers feel they lack the confidence and time to teach science in preschool, Greenfield and his colleagues (2009) set out to integrate other readiness domains around science activities. Noting that substituting a brand-new curriculum for the curriculum currently in use would be time-intensive, Greenfield instead collaborated with a local science museum to incorporate science into the current program. This collaboration resulted in the Early Childhood Hands-On Science (ECHOS) program (Brown & Greenfield, 2006). Through this program, teachers volunteered to meet for a 2-day training period where they were introduced to the seven science units in a hands-on manner. Teachers then conducted trial lessons for one of the seven units and reported back on successes and problems. Teachers continued to meet once per month through a spring term. Multivariate analyses of children in ECHOS classrooms and control classrooms revealed significant differences in eight school readiness gains (Greenfield et al., 2009), however the science and social-emotional gains were only marginally significant. While this approach worked for the ECHOS program, it is not feasible for all early childhood science classrooms to collaborate with a local museum, especially for classrooms in rural areas.

One approach, suggested by a participant at the Mathematical and Scientific Development in Early Childhood Workshop, is to use the objectives already established for elementary mathematics and science to guide the development of preschool curriculum (NRC,
2005b). This would provide continuity between preschool curricula and long-term goals for development in mathematics and science. Along this line of thought, Greenfield and colleagues (2017) have adapted the K-12 Framework for Science Education (NRC, 2012) into the Early Science Framework. The K-12 Framework for Science Education consists of practices (i.e., asking questions; developing and using models; planning and carrying out investigation; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations; engaging in argument from evidence; and obtaining, evaluating, and communicating information) and crosscutting concepts (i.e., patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and stability and change) that contribute to learning in four core domains of science (Physical Science, Life Science, Earth and Space Science, and Engineering Design). These ideas are adapted for young children in a developmentally appropriate manner in the Early Science Framework. Greenfield and colleagues (2017) visualize the framework as a set of gears, with each component driving the next. The first gear represents the disciplinary core ideas, which is the inherently interesting science content. Children’s interests then drive them to use scientific practices to explore and answer their questions about content. As children gain answers to their questions, crosscutting concepts emerge as big ideas that help them create a coherent worldview.

This Early Science Framework (Greenfield et al., 2017) can be implemented in early childhood classrooms to help children develop science skills, build foundational knowledge in the four science disciplines, and acquire a beginning understanding of crosscutting concepts. While this framework serves as useful curriculum guide as to what should be taught in early childhood science, the framework does not provide specific strategies for how to teach the content. A pedagogical approach that is theoretically based, integrates readiness domains, and is
capable of integrating the Early Science Framework is necessary to ensure that preschoolers are getting the science-learning opportunities they need.

**Theoretical Framework**

Consideration of literature on how children learn can provide insight into important components of an integrated approach to science education. Two theories of cognitive development have dominated the field of early childhood and led to many pedagogical implications. Perhaps the most well-known is Piaget’s (1971) cognitive-developmental theory, which postulates that children actively construct their own knowledge as they explore their world and that an adult’s role is to provide the child with a stimulating environment. Piaget described children in terms of what they cannot do or understand. Indeed, his tenet of stages of cognitive development, including the limitations of children in the preoperational stage, are one of the primary reasons experts believed young children are incapable of scientific thinking. Recall that Metz (1995) argued that this line of thought is actually a misapplication of the writings of Piaget and that both Piagetian and non-Piagetian literature support the feasibility of science curricula for young children.

Regardless of his thoughts on the limitations of young children’s cognitive abilities, Piaget’s ideas about cognitive change and construction of knowledge continue to influence classroom practices. Piaget theorized that we make sense of experiences through the development of schemes, which are used to interpret the world through the process of assimilation. Schemes are also adapted through direct interaction with the environment through the process of accommodation. During accommodation, we create new schemes or adjust old ones to make sense of our experiences. The fact that schemes are built and adapted through direct experience leads to the implication that children actively create, test, and refine their own
ideas and that knowledge cannot simply be imparted (Piaget, 2013). Advances in neuroscience confirm the importance of experiences on the development of the brain (NRC, 2000). Neurons are nerve cells in the brain that store and transmit information. Neurons form connections with other neurons called synapses, where fibers come close together but do not touch. At birth, the human brain has only a small proportion of synapses, as the rest are formed after birth and depend on experience. Throughout life, neurons modify and add synapses through learning experiences, similar to the way Piaget theorized we adjust schemes or add new ones to make sense of experiences. These findings appear to directly support the notion that children need a stimulating environment with opportunities for active exploration (Phillips & Shonkoff, 2000).

It is important to note, however, that experiences do not just include the physical environment. Vygotsky’s (1978) sociocultural theory stresses the importance of the social context of cognitive development. Vygotsky proposed that cognitive development is a socially mediated process and that children depend on adults and more expert peers to acquire ways of thinking and behaving. While Vygotsky agreed with Piaget that children actively construct knowledge, he disagreed that children do this entirely on their own. Rather he posited that children construct knowledge through meaningful relationships. The “zone of proximal development” refers to knowledge the child cannot construct alone but can do with the help of a more skilled partner. This more skilled partner uses the process of “scaffolding” to adjust the support offered to fit the child’s current needs. In this manner, instruction is given a more central role in Vygotsky’s theory of cognitive development, as the role of the adult is highly interactive through scaffolding and assisted discovery.

The work of John Dewey is also essential when discussing theoretical foundations of preschool science education. Like Piaget, Dewey (1938) posited that all genuine learning comes
through experience; however, Dewey cautioned that not all experiences are “genuine or equally educative” (p. 25). Dewey advocated that the primary aim of education is the development of a capacity for learning through authentic and meaningful work related to real life problems. When problems occur, children use inquiry as an active quest for information and production of new ideas. The new facts and ideas then become the foundation for additional experiences, and new problems are encountered. This process is a continuous spiral as students examine and improve upon their scientific explanations created from their own inquiries. When children are provided with opportunities for this type of open-ended inquiry, they are able to successfully engage in scientific tasks such as direct observation and synthesis of prior knowledge (Barell, 2003).

Taken together Piaget, Vygotksy, and Dewey, with validation from neuroscience, provide a view of cognitive development that takes place in the context of the child’s interactions with others and with the environment. This leads to important implications for teaching early childhood science. Children need to be provided a stimulating environment for active exploration, with teachers who serve as partners in learning by guiding their explorations. Dewey’s theory adds that the explorations should be authentic and meaningful for children.

**From Theory to Practice: Best Practices in Preschool Science Education**

In a workshop on mathematical and scientific development in early childhood (NRC, 2005b), Karen Worth described an effective science program as one that builds on children’s prior experiences; draws on children’s curiosity and encourages children to pursue their own questions; engages children in in-depth exploration of a topic over time; encourages children to reflect on, represent, document, and share their ideas and experiences; is embedded in children’s work and play; is integrated with other domains; and provides access to science experiences for all children. These recommendations are in alignment with what is known about how young
children learn, as well as what will be expected of students once they transition to elementary school. The National Research Council (2007) states that in order for students to be successful in science they need “carefully structured experiences, instructional support from teachers, and opportunities for sustained engagement with the same set of ideas over weeks, months, and even years” (p. 3). As demonstrated in the following section, each of these recommendations for science education aligns with the aforementioned theoretical framework.

**Planning for Authentic and Meaningful Experiences (Dewey)**

Worth’s description of an effective science program (NRC, 2005b) consists of many components found in a constructive approach to science planning, which places an emphasis on building on what children already know and using topics that can be directly explored in the children’s immediate environment (Campbell, Jobling, & Howitt, 2015). Moreover, Worth describes an inquiry-based science program that recognizes children’s innate curiosity about the world (NRC, 2005b). The process of inquiry involves raising and trying to answer questions about the world. According to the Head Start ELOF (ACF, 2015) this includes observing and describing observable phenomena, engaging in scientific talk, and comparing and categorizing observable phenomena. Inquiry is a natural approach to learning that is driven by children’s interest, wonder, and curiosity. Dewey (1915) postulated that children demonstrate their inquiry through four different types of impulses or instincts including: social instincts, constructive impulse, instinct to investigate, and the expressive impulse. As a whole, these instincts and impulses translate into skills such as asking questions, gathering information and making predictions, planning and conducting investigations, analyzing results, drawing conclusions, and communicating results. Children intuitively ask information-seeking and explanatory questions when they have gaps in knowledge (Chouinard, 2007). Children’s questions are a significant
instrument for education because they indicate the child is ready for and interested in new information, which is important in terms of memory and cognitive organization. Adults tend to initially respond to questions with non-explanatory answers (e.g. “I don’t know”), but through continued back and forth exchanges, or feedback loops, these conversations shift to becoming causal and explanatory. Using a constructivist and inquiry-based approach, the educator’s role is to structure the environment for authentic and meaningful explorations based on children’s questions and support learning through scaffolding.

**Structuring the Learning Environment (Piaget)**

In structuring the learning environment for inquiry-based science exploration, teachers must consider space, materials, and time. The classroom layout should provide enough space for open-ended interactions and for discovery learning (Curtis & Carter, 2003). Likewise, materials should help children to learn about their world (e.g., authentic artifacts related to topic of study), explore their questions (e.g., scientific tools such as magnifying glasses) and communicate their thinking (e.g., clipboard, paper, and pencil). In addition to space and access to materials, children need time to explore, investigate, and solve problems (Harlan & Rivkin, 2008). Although investigations are possible during large and small group activities, research shows that children’s spontaneous play involves a form of intuitive experimentation that is designed to help them learn (Gopnik, 2012). While teacher-directed pedagogy can promote more efficient learning, it also narrows the opportunity for discovery and exploration of new information (Bonawitz et al., 2011). Therefore, providing children with ample time for exploratory and pretend play is the most effective way to prompt scientific thinking (Gopnik, 2012).
Scaffolding Learning Experiences (Vygotsky)

Although a carefully structured learning environment with ample time for free play is important, several studies have demonstrated that providing the environment and materials on their own does not necessarily lead to science learning opportunities. Baseline results from one study indicated that children and teachers rarely engage in activities in the designated science area of the classroom during free choice time (Nayfeld, Brenneman, & Gelman, 2011). An intervention was designed to “market” the science center by introducing children to a balance scale, which was a specific science tool in the center. Prior to the intervention, children did not know the name of the tool or its function, however, after two circle time discussions about the balance scale and how it can be used, children began to voluntarily spend more time in the science area compared to comparison classrooms. Fleer (2009) corroborates the importance of adult guidance for science learning with her finding that “without a mediational scientific framework for using materials in play-based contexts, children will generate their own imaginary, often non-scientific, narratives for making sense of the materials provide” (p. 1069). The Early Childhood STEM Working Group (2017) supports this notion with their first guiding principle in the Early STEM Matters policy report, “Children need adults to develop their ‘natural’ STEM inclinations” (p. 12). In other words, while children are inherently curious and ask questions about the world, children need adults to assist in their explorations, as well as guide and build on their interests to support science learning.

From a Vygotskian perspective, language is one of the most important tools for engaging children in higher-order thinking skills (Bodrova & Leong, 2007), which are integral to science learning. Vygotsky (1987) stated, “The development of scientific concepts begins with the verbal definition” (p.168). An important implication of this perspective for science teaching is the need
to focus on language within children’s explorations and consider how teachers can elicit and support children’s science discourse. The Early Childhood STEM Working Group (2017) also supports this notion with their second guiding principle in the *Early STEM Matters* policy report, “Representation and communication are central to STEM learning” (p. 14). These experts argue that communication via “discussion, visualization and other forms of representation (e.g., drawing, writing, graphing)” lead to active thinking and generalization of important STEM concepts and practices. Moreover, research has demonstrated that communication during science learning opportunities promotes children’s language and literacy development (French, 2004), which has important implications for integrated learning in preschool classrooms.

Given the importance of discourse for science learning, it is necessary to consider strategies that teachers can use to elicit children’s representations and communication about learning. One essential strategy is to ask children questions. According to Harlan and Rivkin (2008), there are two primary types of questions the can be helpful in generating communication about science learning. The first, convergent questions, are those with a single correct answer. Though research demonstrates that teachers tend to overuse these types of questions (Wittmer & Honig, 1991), Harlan and Rivkin (2008) argue that they can be suitable to promote learning by directing attention, recalling temporal order, and recalling prior conditions. The second type of questions, divergent questions, are open-ended and generate creative thinking and synthesizing information. Divergent questions are particularly important for science learning as they can instigate discovery, elicit predictions, probe for understanding, promote reasoning, spark interest in a problem, and encourage creative thinking and reflection. An important role for teachers in scaffolding children’s science learning is to understand how and when to ask the next question to promote these higher-order thinking skills.
Summary

Quality science education for preschool children should consist of carefully structured, integrated, in-depth explorations of meaningful topics drawn from children’s curiosity and interests that build on prior experiences and encourage children to pursue their own questions. Instructional support from teachers and other adults is essential in encouraging children to reflect on, represent, document, and share their ideas. The theoretical framework presented with tenets from Dewey, Piaget, and Vygotsky directly supports each of these best practices in early childhood science education. With a clear understanding of what should be taught (e.g. the Early Science Framework; Greenfield et al., 2017) and theoretically-based best practices of how early science should be taught, it is necessary to consider an integrated pedagogical approach that incorporates both of these ideals.

Emergent Curriculum

Despite the use of the term “curriculum”, emergent curriculum is not necessarily about what is being taught. Rather, it is a pedagogical approach that is constantly growing and evolving through a cycle that includes: observing and listening to children’s play and conversation, reflecting on and engaging in dialogue with colleagues about observations in order to make meaning and guide decision making, and planning in ways that support children’s ideas, questions, and thinking (Stacey, 2011). Through this process, teachers collaborate with children around their ideas, questions, and interests.

Two primary assumptions guide teachers using emergent curriculum (Stacey, 2009). First, emergent curriculum is child initiated and responsive to the child, allowing teachers to build upon existing interests. Second, teachers serve as facilitators by carefully observing and listening to children and providing opportunities for deep exploration of meaningful topics to
assist children in constructing their own knowledge. These practices embedded in emergent curriculum build upon the previously mentioned theories of Piaget, Vygotsky, and Dewey, which are related to best practices in preschool science education. This makes emergent curriculum an integrated pedagogical approach for teaching science using best practices derived from prominent early childhood theorists.

**The Project Approach**

The PA is a more prescribed version of emergent curriculum that involves an in-depth investigation of a topic that is either initiated by the teacher based on observations of children’s play and learning or initiated by children based on their interests (Helm & Katz, 2011). Projects progress through three phases, which include selecting a topic, investigating the topic, and communicating what was learned about the topic.

A possible topic emerges throughout the first phase, during which the teacher evaluates the suitability of a topic, anticipates needed resources and possible experiences, and identifies experts on the topic. The teacher completes an anticipatory planning web on the emerging topic, including possible questions, curriculum opportunities, and possible resources for experts and field site visits. The teacher then provides focusing activities and common experiences for the class to determine whether the topic is appropriate and practical. Topics with low interest that are not consistent with curriculum goals and are not practical are discarded, and the process of selecting a topic begins anew. If there is high interest in the topic and the topic is consistent with curriculum goals, the teacher creates a visual web (typically a drawn figure on a large poster board or white board) with children about concepts within the topic and their current understanding of these concepts. At the conclusion of this phase, teachers work with children to develop questions for investigation.
The primary focus of the second phase is investigation. This phase begins with the teacher reexamining both the anticipatory planning web and the children’s web for the topic to tie in specific skills and concepts. The teacher then arranges for experts to visit the classroom and field site visits related to the topic of interest. Families are often involved in this process as teachers ask parents and other family member to contribute artifacts and resources for children to study. Moreover, families help with identification of experts or field-sites. Through involving families in this phase, many opportunities arise for children to extend their learning about the topic of interest at home. It is important to differentiate field site visits from traditional field trips, which are usually taken at the end of a thematic unit and have a broader focus. In contrast, a field site visit is specifically designed to provide children with an opportunity to investigate and attempt to find answers to their own questions. During this time, children engage in critical thinking as they closely examine the site, equipment and materials, and interview experts at the site. In addition, children record their experiences through sketches, photographs, and videos. Upon returning to the classroom, children represent their learning through writing, drawing, construction, movement, and dramatic play. The teacher and children revisit the web and work together to determine what was learned and identify new questions. These new questions can lead to new investigations and a repetition of the second phase. Once children run out of questions and begin to tire of the topic, the teacher moves to the third and final phase.

During the third phase, the attention is on culminating the project and focusing on what was learned. The teacher works with children to think of ways they might share what they have learned with others. This often involves looking back at the web, as well as documented sketches, photographs, constructions, and video. Children are encouraged to write and draw everything they have learned about the topic and to think of ways they might remember the
project and what they learned. Culmination often includes making a book about the project, putting together a bulletin board, or sharing learning with a larger audience, such as parents or community members. The third phase concludes with an evaluation of the project and assessment of goals. This occurs through review of documentation throughout the project including individual portfolios, products, observations of progress and performance, child self-reflections, and narratives of learning experiences.

The use of project work in preschools is expanding. For instance, since 2001, over 1,000 teachers and 31,000 children in the greater Chicago area have been introduced to project work (Helm, 2015). Despite its implementation in childcare centers and schools, few empirical studies have been conducted on the PA to date, and none have examined the PA in relation to preschool science education. Considering the fact that the underlying elements of the PA align with theoretically-based best practices in early childhood science education (Figure 2), implementation of the PA may be one means of providing more and higher quality science learning opportunities in preschool classrooms. The PA could be particularly useful for both pre and in-service teachers due to the availability of established training and guides to support implementation (Helm & Katz, 2011; Perney, 2006). This study sought to explore the feasibility and efficacy of using the PA to promote high-quality science learning opportunities by addressing the following research questions:

1. How do teachers plan for authentic and meaningful experiences?
2. How do teachers structure the environment for science learning?
3. How do teachers interact with children when guiding explorations?
Figure 2. Theoretical framework
CHAPTER 3. METHODOLOGY

Research Design and Rationale

The purpose of this collective case study was to explore how preschool teachers in PA classrooms promote high-quality science learning opportunities. Although much has been written about theoretical best practices in preschool science education, few studies have empirically examined the specific strategies teachers use to promote preschool children’s science skills. A case study research design provided the opportunity to gain an in-depth understanding of the strategies preschool teachers use within the natural classroom context (Yin, 2014). An exploration of “strategies” in such a broad sense would be unwieldy, so propositions (Yin, 2014) were developed to narrow the focus of the study to specific categories of strategies. The propositions for this study were developed from theoretical tenets of Dewey, Piaget, and Vygotsky, and considered how teachers plans for authentic and meaningful experiences, structure the environment, and interact with children. A collective case study is grounded in theory and involves the exploration of multiple cases in order to understand a particular phenomenon (Stake, 1995). Multiple teachers were selected for this study to examine these theoretical-based propositions in different classroom settings and to provide the opportunity to search for commonalities in teaching strategies across cases.

One of the defining features of case study research is extensive data collection using multiple sources of information (Creswell, 2013). The data collected in the current study included structured observations, structured interviews, questionnaires, and audio recordings of large and small group activities. Using both qualitative and quantitative data provided greater depth of understanding and offered a more authentic representation of the true complexity of teaching strategies as they occurred in the preschool classroom. Moreover, just as the tenets of
this study are based on constructivist theories, the paradigm I most closely align with is constructivism. According to this paradigm, our understanding of the world is constructed from our own perspectives and experiences (Tashakkori & Teddlie, 2010). The use of multiple data sources offered more depth and richness in constructing my understanding of the specific teaching strategies, which led to a more accurate description (Tashakkori & Teddlie, 2010) of how teachers promote preschool children’s science skills.

**Participants**

A purposive, criterion sampling scheme was used to identify preschool teachers who were implementing the PA in their classrooms. A total of six teachers from a midwestern city were selected for this collective case study to increase replication logic across cases (Yin, 2014). The first two identified preschool teachers taught in a university child development laboratory school and were considered model early childhood teachers. Although the lab school encouraged applications from the broader community and used a lottery system for selection, many of the children in these classrooms were children of faculty members and other university staff. Four additional preschool teachers in community-based classrooms were identified to add more perspectives and increase confidence in the interpretation of findings. All of the teachers in this study were licensed and had completed at least a four-year degree in education. Table 1 outlines additional demographics and characteristics of these six teachers.

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Ethnicity</th>
<th>Age</th>
<th>Years of Preschool Teaching Experience</th>
<th>Approximate # of Projects Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>White</td>
<td>20-29</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>White</td>
<td>30-39</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>C</td>
<td>White</td>
<td>20-29</td>
<td>3</td>
<td>8</td>
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<tr>
<td>D</td>
<td>White</td>
<td>30-39</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>E</td>
<td>White</td>
<td>50-59</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>F</td>
<td>White</td>
<td>30-39</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>
Setting

Preschool classrooms were the setting for each case in the study. As previously stated, two teachers taught in the university child development laboratory school, while the other four teachers taught in a community-based preschool. All classrooms were located in the same midwestern city. The university child development laboratory school is located on campus and serves as a model early childhood program for pre-service teachers, administrators, and child and family specialists. The school, which also functions as a research site for the college and university, offers full-day year-round programs for infants, toddlers, and preschoolers. Both of the preschool classrooms are multi-age, each serving 18 children between the ages of 3-5 from 7:30 AM-5:30 PM.

The community-based preschool program is part of the school district and participates in the state’s Voluntary-Four-Year-Old Preschool Program. The program is a fully inclusive program serving both typically developing children and those with diverse abilities in each of its ten classrooms. This program offers half-day classes four days per week. The classrooms are multi-age, serving children between the ages of 3-5 in either a morning (8:15-11:15 AM) or afternoon (12:15-3:15 PM) class.

Both preschool settings are accredited by the National Association for the Education of Young Children. In addition to implementing the PA, both preschool settings implement the Creative Curriculum (Heroman et al., 2010) and assess students using Teaching Strategies GOLD (Heroman, Burts, Berke, & Bickart, 2010). This congruence in curricular methods but divergence in demographics between the two programs provided the opportunity to explore which teaching strategies could be replicated across programs.
Data Collection

Recruitment Process

There were several steps that needed to take place before data collection could begin. First, permission from both the university child development laboratory school and the community school district was required. A copy of the research proposal was presented to administrators of both programs and approved via a written letter of support. These letters of support were attached to an application to the university Institutional Review Board (IRB) along with the complete research proposal. After receiving IRB approval (Appendix A), a meeting was set up with the university lab school teachers to explain the study and obtain informed consent. A written description of the study and requested participation were provided to each teacher, in addition to a copy of the consent form. The principal of the community-based preschool was contacted, and the researcher was invited to discuss the study at the beginning of a professional development day. After follow-up emails answering questions about the study, four of the ten preschool teachers consented.

Procedure

After receiving written consent, each teacher was contacted via email to schedule a total of four data collection days. Observations in each classroom were conducted on two different days during the Investigation Phase of the PA. Structured observations on each day occurred during large and small group activities. Classrooms were observed for overall classroom quality and for the quality of science learning opportunities. The teacher was asked to wear the LENA language-recording device during these observations, as well as on two additional non-observation days to reduce the possibility of participant bias. The purpose of the language
recording device was to provide an in-depth analysis of the specific language that teachers use to promote scientific inquiry during their interactions with children.

At the end of the second observation day, a semi-structured interview (Appendix B) was conducted with each teacher to discuss the project the children were engaged in and to share documentation of the project planning process. Finally, each teacher completed an online questionnaire about their attitudes and beliefs toward science in preschool settings, as well as basic demographic information. As a form of compensation and appreciation for each teacher’s participation, an early childhood science picture book was donated to each classroom.

**Data Sources**

**Classroom observations.** Each classroom was observed on two separate days for overall classroom quality and for the quality of science learning opportunities using two established observation measures. Observational field notes were also collected during each classroom observation and were used to provide rich description of the classroom context.

**Classroom Assessment Scoring System (CLASS).** The CLASS (Pianta et al., 2008) is an observational tool that was developed to assess the interactions teachers have with children that impact learning and development. The CLASS is comprised of three domains (Emotional Support, Classroom Organization, and Instructional Support) and divided into ten dimensions. The Emotional Support dimensions include: Positive Climate (PC), Negative Climate (NC), Teacher Sensitivity (TS), and Regard for Student Perspectives (RSP). This domain assesses the interactions within the classroom, as well as the teacher’s responsiveness to student individual needs and the teacher’s emphasis on autonomy and choice. The Classroom Organization dimensions include: Behavior Management (BM), Productivity (PD), and Instructional Learning Formats (ILF). This domain assesses classroom and behavior management strategies, as well as
effective use of time and maintaining student interest and attention. The Instructional Support dimensions include: Concept Development (CD), Quality of Feedback (QF), and Language Modeling (LM). This domain assesses the techniques used to promote critical thinking skills, facilitate language development, and provide feedback. Internal consistency for the three domains are .89, .86, and .83 respectively (Pianta, La Paro, & Hamre, 2008). Although all of the CLASS domains were assessed in the current study, the Instructional Support domain was the focus of analyses and discussion.

According to CLASS protocol, observations should be conducted in 30-minute intervals with 20 minutes of observation followed by 10 minutes of live scoring. This protocol was adapted for the current study where classrooms were observed for the duration of large and small group activities, which ranged from 10 to 40 minutes. If time permitted between activities, the observations were scored directly after children had transitioned from the group setting. In classrooms where large and small group activities occurred consecutively, the observations were scored after the second activity had concluded. During this time, quality was rated on a scale of 1-7 for each dimension. A one or two indicates the classroom is low on that dimension, a three, four, or five indicates the classroom is mid-range, and a six or seven indicates the classroom is high on that dimension. Composite domain scores were calculated separately for large and small group activities by averaging the scores within each dimension across the two observations. An average domain score for Instructional Support and an average score for each of the three Instructional Support dimensions (i.e., Concept Development, Quality of Feedback, and Language Modeling) was calculated for each teacher for descriptive and cross-case analysis purposes.
The classroom observer in this study earned Pre-K CLASS certification through Teachstone. The certification process consisted of an intensive two-day in-person training, followed by completion of a reliability coding test online. To earn CLASS certification, observers must achieve an average interrater reliability of 87% with the master codes on the online reliability test.

**Science Teaching and Environment Rating Scale (STERS).** Quality of the science environment was measured using the STERS (Chalufour et al., 2009). The STERS uses a 1-4 rating to measure the quality of the science and teaching learning environment in eight domains: Physical Environment for Inquiry and Learning, Direct Experiences to Promote Conceptual Learning, Use of Scientific Inquiry, Collaborative Climate that Promotes Exploration and Understanding, Extended Conversations, Children’s Vocabulary, In-Depth Investigations, and Assessment of Children’s Learning. Each domain was rated using three sources of evidence through a combination of structured classroom observations and semi-structured teacher interview. Observational and interview field notes were entered into an evidence table for each teacher (Appendix D) and a domain score from (1) deficient to (4) exemplary was assigned to each domain. Internal consistency for the overall scale is estimated to be .94 (Greenfield, 2015). Ratings for the eight domains were averaged to create an overall average composite score for descriptive and cross-case analysis purposes.

**Large and small group audio recordings.** The LENA language recording device was used to audio record large and small group activities, as well as measure adult words spoken during these interactions. A recent study examined the reliability of using LENA in a preschool classroom (McCauley, Esposito, & Cook, 2011) and found it to be a reliable tool for measuring the language of adults and children in a preschool classroom. Typically, LENA reports include
counts of adult words spoken to and around a child wearing the LENA recorder (within a 6-foot radius), adult-child conversational interactions, and child vocalizations. However, since the unit of analysis in this study was the teachers, they were asked to wear the LENA recorder in the classroom and the only valid quantitative report was the counts of adult words. LENA recordings from the two observed large and small group activities in each classroom were transcribed to analyze science content during teacher-child interactions. This process is described in greater detail in the data analysis section of this paper.

**Semi-structured teacher interview.** A semi-structured interview (Appendix B) was conducted with each teacher as required by the STERS and to assess implementation fidelity to the PA. Although the PA is not a curriculum, there are specific elements that typically occur during a project. A checklist with elements typical of “deep project work” is included in Helm’s (2015) latest book on the PA. This checklist of 17 items was used to measure implementation fidelity to the PA. Observational and interview field notes were entered into an evidence table for each teacher (Appendix C) and each of the 17 items was assigned a score from 0-2, with 0 meaning the element was not present and 2 meaning the element was clearly present. Each classroom received a total implementation fidelity score ranging from 0-34 that was converted to a fidelity percentage for descriptive and cross-case analysis purposes.

**Teacher questionnaire.** Teacher characteristics were measured using a questionnaire consisting of a demographic survey and the Preschool Teacher Attitudes and Beliefs toward Science Teaching (P-TABS) (Maier et al., 2013). The demographic survey included questions about teacher age, race, educational background, teaching experience, and PA training. The P-TABS was developed to measure several aspects of preschool teachers’ attitudes and beliefs toward science teaching including: self-efficacy, cognitive aspects (e.g. perceived importance),
affective aspects (e.g. fear regarding science teaching), behavioral aspects (e.g. how currently intend to teach science), and contextual aspects (e.g. perceived resources). Teachers indicated their agreement with 35 statements on a scale from *strongly disagree* (1) to *strongly agree* (5). Previously established concurrent validity with observed practices and internal consistency for each factor—Teacher Comfort, Child Benefit, and Challenges to Science Teaching—was good (.71-.90; Maier et al., 2013).

**Data Analysis**

The analytical process occurred concurrently with data collection. Extensive field notes were collected during classroom observations, and CLASS domains were scored live directly following each large and small group activity. At the end of each observation day, notes regarding instructional support scores were extracted from the CLASS observation notes and entered into the case study database in MAXQDA (2018). Observational field notes were also entered into the case study database and were used to provide rich description of the classroom context. A semi-structured teacher interview was conducted on the last observation day. Immediately following each interview, observational field notes and interview notes were entered into an evidence table to assign STERS domain scores and implementation fidelity scores. The evidence tables were analyzed to answer the first two research questions regarding each teacher’s successful strategies for planning authentic and meaningful experiences and for structuring the environment. This was done by reviewing the indicators in each evidence table with the highest scores and noting the specific strategy that was utilized by the teacher.

Audio recordings on the LENA device were uploaded to the LENA online system for processing adult word counts. The audio recordings from the two observation days were transcribed and entered into MAXQDA (2018). Audio recordings from the two non-observation
days were reviewed and compared to transcripts from observation days to examine for possible participant bias. A paired-samples t-test was also conducted to compare average adult word counts on observation and non-observation days to test for observer bias or the Hawthorne effect. There was not a significant difference in adult word counts for observation ($M=8816.83$, $SD=2216.35$) and non-observation ($M=6965.58$, $SD=2151.22$) days; $t(5) = 1.97$, $p = .106$. These results suggest that observer bias did not influence the results of this study.

MAXQDA (2018) was used to code the transcripts of large and small group activities for children’s utterances related to the Head Start ELOF (ACF, 2015) science goals. Table 2 provides examples of coded utterances for each of these science goals. Frequency counts were conducted for the total number of coded utterances within each science goal and reported separately for large and small group activities in each classroom. Transcripts were then read through a second time and coded for specific instructional strategies that preceded children’s coded utterances. These instructional strategies were combined with the observational notes on instructional support to answer the third research question regarding how teachers interact with children to promote scientific inquiry, reasoning, and problem-solving.

The specific strategies elicited from each within-case analysis were entered into a conceptually clustered matrix (Miles, Huberman, & Saldana, 2014) to summarize the key data from each participant into a single matrix (Appendix E). The matrix was composed deductively based on the theoretical tenets that guided this study (i.e., planning for authentic and meaningful experiences, structuring the environment, and interacting with children). Reading down the rows of the matrix gives a “thumbnail profile of each participant” (Miles, Huberman, & Saldana, 2014, p. 178), and reading across the rows gives an overview of the strategies used across
classrooms related to each research question. This conceptually clustered matrix was examined for commonalities and general themes in teaching strategies used across classrooms.

Table 2
*Examples of coded child utterances for Head Start ELOF science goals*

<table>
<thead>
<tr>
<th>Head Start ELOF Goal</th>
<th>Child Utterance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child observes and describes observable phenomena</td>
<td>“The butterfly is big.”</td>
</tr>
<tr>
<td>Child engages in scientific talk</td>
<td>“They’re arachnids.”</td>
</tr>
<tr>
<td>Child compares and categorizes observable phenomena</td>
<td>“They’re all big, and they’re all small.”</td>
</tr>
<tr>
<td>Child asks a question, gathers information, and makes predictions</td>
<td>“How does chipmunks get warm?”</td>
</tr>
<tr>
<td>Child plans and conducts investigations and experiments</td>
<td>“First you have to go to the store and get the fishing thing.”</td>
</tr>
<tr>
<td>Child analyzes results, draws conclusions, and communicates results</td>
<td>“So when we see sap we can tell you we saw photosynthesis.”</td>
</tr>
</tbody>
</table>

**Verification Procedures**

When conducting case study analysis, it is essential to clearly delineate processes undertaken to verify that the results of the analysis are reliable and valid. Four criteria are commonly used to evaluate case studies in terms of their reliability and validity: construct validity, internal validity, external validity, and reliability (Merriam, 1998; Yin, 2014). Construct validity refers to the degree which data collection procedures accurately measure what they are intended to measure (2014). Yin (2014) recommends using multiple sources of evidence, as well as establishing a chain of evidence to demonstrate construct validity. This study utilized three types of data (classroom observations, audio recordings of large and small group activities, and
semi-structured teacher interviews) as evidence. The chain of evidence presented in Figure 3 delineates the specific data analyzed to answer each research question.

**Figure 3.** Within case analysis process

Internal validity refers to how congruent a study’s findings are with reality (Merriam, 1998) and often involves the process of member checking. Because internal validity is primarily concerned with the validity of inferences, it is not evaluated in descriptive studies. Teachers in this study were not asked for a member check because data analysis did not involve interpretation, and the findings were purely descriptive.

External validity refers to the overall generalizability of a study’s finding, but case studies are not statistically generalizable due to the small sample size (Yin, 2014). Rather, the goal of case study research is transferability, or “how (if at all) and in what ways understanding and knowledge can be applied in similar contexts and settings” (Bloomberg & Volpe, 2016, p.
External validity in case study research is typically established through rich, thick description of each case (Merriam, 1998) and replication logic across multiple cases (Yin, 2014). Individual cases in the current study are thoroughly described to provide depth of understanding, and then compared for replication of findings across cases.

Finally, reliability refers to the consistency and repeatability of findings. In case study research, this means that data collection procedures could be reproduced with the same results and is achieved through careful documentation and thorough record keeping. Yin (2014) recommends the development of a case study protocol and case study database. A case study protocol was developed for the current study including: case study questions, sources of information for each question, and data collection procedures. This case study protocol was followed for collecting data in each of the six classrooms. MAXQDA (2018) was used to develop a case study database, which includes the following data from each classroom: teacher demographic data from online questionnaire, observational field notes, CLASS scoring forms, examples of instructional support, notes from the semi-structured teacher interview, STERS evidence table, PA implementation fidelity evidence table, audio recordings of large and small group activities, and transcriptions of observed large and small group activities. In addition to using quantitative measures with established internal consistency, the reliability of observational data was improved by conducting repeated observations.

**Ethical Considerations**

As with any research involving human participants, intentional ethical measures were taken to protect participants. Informed consent and ensuring confidentiality were a priority throughout the research process, and participation in the study was completely voluntary. Each teacher was verbally informed of the purpose of the study, as well as the data collection
procedures, and provided with a physical copy of the consent. In addition, teachers were provided with a written description of the study and an outline of participant requirements. Teachers were given several weeks to decide if they would like to participate, and written informed consent was obtained from all participants prior to data collection. Because children were not direct participants in this study, no parental consent was required. However, teachers were provided with a letter to send to parents describing the classroom audio recording portion of the study with the option to dissent to their child being in the classroom during the audio recordings. No parent dissented across any of the six classrooms.

Multiple measures were taken to ensure that all collected information remained protected and confidential. Each teacher was assigned an identification number that was used throughout the data collection process. All teacher and child names were omitted during the transcription process, and pseudonyms were created for teachers in the written case study descriptions. Although the confidentiality of participant data was ensured, teachers were informed in the informed consent document that anonymity could not be guaranteed due to the small sample size of the study. Because of the lack of anonymity, this study employed a strengths-based approach and focused on the teaching strategies that were most successful for promoting high-quality science learning opportunities.
CHAPTER 4. FINDINGS

Overview

The purpose of this collective case study was to elicit strategies preschool teachers use when implementing the PA that promote science learning opportunities for children. This chapter presents the key findings obtained from observations, audio recordings, interviews, and questionnaires of six preschool teachers who were implementing the PA in their classrooms. Detailed individual case descriptions are presented first, followed by key themes that emerged from the cross-case analysis.

To fully understand each teacher’s context and the strategies she used to promote science learning opportunities, within-case analysis was conducted through “thick description” (Denzin & Lincoln, 2011) of each case. The within-case descriptions presented here utilize a strengths-based approach, outlining specific strategies that each teacher used to successfully promote science learning opportunities in her classroom. Each case description begins with information about the teacher, her classroom, and the project the class was engaged in at the time of the study. Then, the observed large and small group activities are briefly described. Finally, the specific strategies the teacher used to promote science learning opportunities are presented according to the theoretical framework underpinning this study. This chapter concludes with the results of the cross-case analysis, including descriptive quantitative data about the overall feasibility and efficacy of using the PA to promote science learning opportunities, as well as key strategies that emerged across all cases.
Case Study A

The Teacher

Amy earned her four-year degree in Early Childhood Education and had been a teacher for just two years total and a preschool teacher for one of those years. Indicating an age between 20-29 years on the demographic survey, she was one of the youngest and least experienced preschool teachers in this study. Amy was also one of two teachers in this study who never received formal training in the PA. Nevertheless, she received informal training and began implementing the PA in August 2016 along with the rest of the preschool center. By the time observations for this study began in May 2017, she had completed four projects. Despite her relative inexperience teaching, Amy’s responses on the P-TABS (Maier et al., 2013) questionnaire indicate that she saw great benefits of science for preschool children \( (M = 5, SD = 0) \) and was generally comfortable with teaching science \( (M = 4.4, SD = .5) \). Amy also perceived the least challenges to teaching science \( (M = 4.4, SD = 5) \) compared to the other teachers in this study.

The Classroom

Amy taught in one of the preschool classrooms in the community-based preschool program that functions as part of the state’s Voluntary-Four-Year-Old Preschool Program. The program offered half-day classes four days per week, and Amy taught one preschool class in the morning (8:15-11:15 AM). Her inclusive classroom consisted of 15 children between the ages of three and five, as well as two paraprofessionals. One of the paraprofessionals was a one to one aide for a nonverbal child on the Autism Spectrum.

Per the preschool center’s policy, Amy met her students in the foyer at 8:15 each morning and greeted families as children were dropped off. At 8:25, Amy and her students headed to the
classroom to check in, which consisted of hanging up backpacks and coats, washing hands, and responding to a daily sign in activity. Then all the children gathered on a large carpet in front of a whiteboard for the morning meeting, including songs, greetings, sharing time, a group activity, and reading the morning message together. After morning meeting, children ate snack before gathering back on the carpet for 15-20 minutes devoted to project study learning. The activity setting varied during this time between large and small groups depending on the specific focus of the activity. For example, if children were coming up with questions to investigate then they would be in small investigation groups. If there was an expert visitor, then that time was spent in a large group. After project study time, children spent an hour in free choice center time followed by 10-15 minutes in small groups focused on a specific curricular area, most often literacy or math. Each morning concluded with free play outdoors and then a closing meeting on the large carpet, which consisted of an interactive read aloud and saying goodbye to one another.

**The Project**

At the time of the observations, the children in Amy’s classroom were in the Investigation Phase (Phase 2) of a bug project. Children were divided into three investigation groups (butterflies, spiders, and ladybugs) based on the bug they wanted to learn more about. Prior to the observations, Amy had read aloud several books about each of these bugs and children had generated questions they wanted to investigate in their groups. They had also researched the habitats of each of these bugs on an iPad and sang songs during group times to learn the body parts of an insect. There were live caterpillars and spiders in the science center, and the children were preparing for an outdoor bug hunt to add to the classroom collection. During one of the observations, the children were preparing for a visit from the insect zoo by drawing representations of their questions for the experts. After the visit, they planned to draw
representations of the answers to their questions and create a book about bugs. According to Amy, she was beginning to think about the culminating event for the project and was considering a play that would integrate science and literacy by using Eric Carle books (e.g. *The Very Hungry Caterpillar* for the butterfly investigation group, *The Grouchy Ladybug* for the ladybug investigation group, and *The Very Busy Spider* for the spider investigation group).

**Observed large group activities.** Each large group followed the same general structure, which began with a song that involved the children moving around and doing a variety of different actions (e.g. “Going on a Bear Hunt). After the children settled into their spots on the large rug after the song, Amy provided clues so the children could guess the name of the super helper for the day. For example, “This person is shorter than most friends in class.” The children shouted out guesses and Amy continued to give clues until they were able to correctly deduce who the super helper was. Next, the children greeted each other for the day before participating in a short activity followed by reading the morning message. Large group ended with another short activity and a transition to snack.

On the first observation day, the activity after the greetings involved the children marking their favorite of three different butterflies and counting which butterfly had the most and least votes. Then, Amy had the children do another math activity where they estimated the number of magnifying glasses in a jar, while she wrote their estimates on the dry erase board. The whole class counted the magnifying glasses together to determine the actual number, and Amy worked with the children to determine which written number on the board matched the actual number. After the math activity, Amy read the morning message with the children: “Hello, (class)! We’re excited to hunt bugs tomorrow. Happy Birthday (child’s name)! I can say the first sound in a word. Love, Miss Amy”. Amy pointed to each word as she read the message and emphasized the
beginning “h” sounds because “h” was the letter of the day. The closing large group activity involved the children labeling the parts of a butterfly on a large piece of chart paper. Amy asked the children to point out different parts of the butterfly as she named them and called on children to come to the front and draw a line from the identified body part. Then she sounded out the body part and worked with the children to determine the beginning letter of the body part. Finally, she had another child come up and write that letter on the corresponding line. After the butterfly was labeled, the children transitioned to snack one at a time by writing the letter of the day on the white board.

On the second observation day, the activity after the morning greeting involved singing a song called “Caterpillars Creep” to the tune of “The Farmer in the Dell”. After the song, Amy read the morning message with the children: “Good morning! Today is Thursday. Miss (paraprofessional) caught a ladybug. I can find print in a book. Love, Miss Amy”. As they were reading the morning message, they asked the teacher aide where she caught the ladybug and Amy suggested using magnifying glasses during free choice to count the spots on the ladybugs. Amy also used the morning message to teach children about “meatball spaces” or the space between words. Then for the closing large group activity, Amy used a big book to model finding and “framing” a letter, a space between words, and a full word. Children transitioned to snack one at a time by showing Amy each of these in the book.

**Observed small group activities.** Children in Amy’s class participated in small groups twice during the day, once during project investigation time and again at the end of the day. For the purposes of this study, the project investigation small groups were observed. During this time, children would separate into their investigation groups to complete an activity specific to the bug they had selected to investigate. On the first observation day, children separated into
their investigation groups and then independently drew and labeled their bug. Each child was given a clipboard with paper and a pencil, and Amy or a teacher aide read from a nonfiction book specific to the group’s bug as children drew and labeled the parts of their bug. On the second observation day, children again separated into their investigation groups and independently drew a picture to help them remember the questions they had asked about their bug. For example, one child had a question about what spiders eat, so he drew a spider eating something to remind him of his question. Amy planned to have the children use these pictures the next day to ask their questions when the bug zoo came to visit.

**Strategies to Promote Children’s Science Learning Opportunities**

**Planning for authentic and meaningful experiences.** Amy’s score of 29 out of 34 on the PA fidelity checklist indicates that she implemented the bug project with 85% fidelity. When asked why she chose the topic of bugs for her class to investigate, Amy stated that she knew it needed to be “something they can hold or manipulate” and that the topic of bugs was “broad enough that we could each go off in different directions, but [also] focused enough.” Once she had chosen the topic, Amy considered the resources she would need to make the experience authentic and meaningful her students. She knew another teacher in her center had previously done a project on spiders, so Amy went to her first for general ideas and then began contacting other people in the community to see if there were any places her students could visit or if there were any experts willing to visit her students. Amy also considered how she could provide “hands on things for them to see”, so she ordered caterpillars for students to observe in the classroom, invited children to bring their own bug catchers for a bug hunt, and even caught some of her own bugs at home.
In addition to considering resources, Amy also thought carefully about how she could give her students “more ownership”, such as by “incorporat[ing] more of their drawing and writing.” One strategy Amy used to provide ownership was to offer students choice of which bug they would like to investigate for the duration of the project. She provided further ownership by having each group “work together to create a chart about what they want[ed] to know.” She also planned to invite the children’s families to the culminating event at the end of the project, so children would have the opportunity to share their learning with their family members.

Amy emphasized the importance of planning so that children have “recurring experiences, where they are seeing it in a different way.” She thought about how she could integrate the topic of bugs across curricular areas by looking at Teaching Strategies GOLD objectives while making an anticipatory web. She also looked at a variety of books to determine how she might integrate literacy and other content areas through shared reading experiences related to the topic of bugs. Amy was particularly interested in planning opportunities for children to build vocabulary and reinforce writing skills.

**Structuring the environment.** Amy’s desire to provide ownership for her students was evident in how she structured the learning environment, which received an average rating of 3 out of 4 on the STERS (Chalufour et al., 2009). One large chart on the wall listed children’s prior knowledge about bugs, including all of the bugs the children knew before starting the project. Each investigation group also had their own chart on the wall with a web of their questions for investigation. For example, some of the questions on the spider group’s web asked, “What are all the colors it can be?” “How they spin their web?” “How do spiders eat?” “How do spiders move up ceilings and walls?”
Amy provided authentic materials related to the project, such as live caterpillars in the science center so children could observe and document the process of metamorphosis. She also utilized the outdoor learning environment by taking the children outside to hunt for bugs that could be brought back into the classroom. In addition to authentic bugs, Amy placed plastic, anatomically correct bugs in the science center along with science tools that would prompt investigation, such as magnifying glasses. Amy also used magnifying glasses to integrate math during a large group activity by having her students estimate how many magnifying glasses were in a jar. She used this activity as an opportunity to both reinforce the purpose and use of magnifying glasses and to practice estimation and counting skills.

Amy’s use of books to promote science learning was evident throughout her classroom. The classroom library was full of both fiction and non-fiction books related to bugs. Amy also used books to provide science learning opportunities during large and small group activities:

Amy: Alright, I found this really cool bug book and it has a bunch of different bug songs in it. Not like "Itsy Bitsy Spider" because everyone knows that. These are new ones that I even have never heard of before. Yeah! This one is about the caterpillar's nap. And I make sure when I get to the end of one line, what do I do with my finger?

Child 1: You get it down to the next line.

Amy: I jump my finger down to the next one on this side. Okay?

Children: Okay!

Amy: To the tune of "The Farmer in the Dell". That's right, right. Okay, ready? It goes "Caterpillars creep, on tiny little feet. Caterpillars crawl on leaves, then eat and eat and eat." They do eat a lot, don't they?

Children: Yeah

Child 2: Until they get really big.

Amy: I think our caterpillars are going to get really big and fat

Children: Yeah
Child 3: Soon they’re gonna turn into the cocoons.

Amy: You think so? What’s another word for a cocoon?

Children: Chrysalis!

In this brief example, Amy was teaching her students concepts of print, specifically how to follow text on a page by reading from left to right and top to bottom. Although the focus of this activity was not science, she integrated science through the use of a book related to the project topic, which provided opportunities for children to discuss their science learning and reinforce some of the science vocabulary they had previously learned.

**Quality of instructional interactions.** Overall, Instructional Support was in the middle range in Amy’s classroom, with slightly higher quality interactions occurring during large group activities compared to small group activities (Table 3). Amy occasionally promoted concept development with why or how questions, but many of her questions and activities required a specific answer and left little room for analysis and reasoning. She also promoted concept development by linking activities to children’s previous learning (e.g. “Remember how we talked about the different body parts of insects?”) and relating concepts to children’s actual lives (e.g. “I wonder if [our butterfly] is going to look like that?”).

Although Amy engaged in feedback loops with children and intermittently asked them to explain their thinking, most of her feedback was perfunctory in the form of generic praise (e.g. “Awesome!”). Amy’s highest quality instructional interactions occurred through her use of language modeling. She frequently engaged in back and forth exchanges with children, often extended their responses, and introduced them to a variety of advanced words as demonstrated in the following exchange during a small group activity:

Amy: Let’s see how big ours are now. What do you notice about them?
Child: They big.

Amy: They are bigger than they were before.

Child: And web.

Amy: And it looks like there’s webbing in there doesn’t it. I wonder if that’s part of their exoskeleton shedding? That means the outside. When they get bigger, they shed their skin.

Table 3

Case study “A” Instructional Support scores across activity settings

<table>
<thead>
<tr>
<th>CLASS Domain/Dimension</th>
<th>Large Group</th>
<th>Small Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional Support composite</td>
<td>4</td>
<td>3.3</td>
</tr>
<tr>
<td>Concept Development</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Quality of Feedback</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Language Modeling</td>
<td>5</td>
<td>4</td>
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</tbody>
</table>

Quantity of science content during instructional interactions. Table 4 shows the total number of child utterances coded as scientific inquiry, reasoning, and problem solving as defined by the Head Start ELOF (ACF, 2015) during two observed large group activities and two observed small group activities. Across both activity settings, children’s scientific talk was heard most frequently. In addition to the aforementioned language modeling, one strategy Amy used to prompt children’s scientific talk was to read a book related to the topic of inquiry, stop at science content words, and have children fill in the blank (e.g. “Our caterpillar is making a special house called a…”). Amy also prompted children’s scientific talk by having them create representational drawings and then label the different parts of their drawings. After scientific talk, the next most frequent utterances involved children describing observable phenomena and representing observable phenomena with pictures. Although Amy prompted some observation through a combination of closed (e.g., “What does the caterpillar have on it?”) and open (e.g., “What do you notice?”) questions, most of the children’s utterances in this category were spontaneously prompted by the structure of the environment and activities. For example, one
child said, “There’s a leaf that he’s eating” while watching the caterpillars in the science center. The use of representational drawings also offered several opportunities for children to represent observable phenomena (e.g., “I did some dots on there, just like the chrysalis.”) The final category of utterances heard in Amy’s classroom related to the goal of asking questions and making predictions. Most of these utterances occurred during the small group activity when children were drawing representations of the questions they planned to ask when the bug zoo came to visit. Amy prompted the children to repeat the questions they had previously come up with and then think about what they could draw to help them remember their questions. The only prediction occurred during large group when one child predicted that the caterpillars in the science center would be “the butterfly lady”. This child based his prediction on a previous discussion during large group about the painted lady butterfly variety.

<table>
<thead>
<tr>
<th>Head Start ELOF Goal</th>
<th>Large Group (50 min)</th>
<th>Small Group (25 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child observes and describes observable phenomena</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>Child engages in scientific talk</td>
<td>11</td>
<td>15</td>
</tr>
<tr>
<td>Child compares and categorizes observable phenomena</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Child asks a question, gathers information, and makes predictions</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Child plans and conducts investigations and experiments</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Child analyzes results, draws conclusions, and communicates results</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Note. The time listed for each activity setting is the total amount of time across two observations.

Case Study B

The Teacher

Beth held a graduate degree in Instructional Design and had been a preschool teacher for nine years. She received two trainings in the PA, including an informal training in August 2014 and a formal training from one of the developers of the PA in summer 2016. By the time observations for this study began in May 2017, she estimated that she had completed nine
projects. Beth’s responses on the P-TABS (Maier et al., 2013) questionnaire indicate that she felt science is beneficial for preschool children ($M = 4.8, SD = .4$) and that she was generally comfortable with teaching science ($M = 4.5, SD = .5$). Beth perceived some challenges to teaching science ($M = 3.9, SD = 1.1$), primarily concerning having enough time in the day to teach science.

**The Classroom**

Beth taught in one of the preschool classrooms in the community-based preschool program that functions as part of the state’s Voluntary-Four-Year-Old Preschool Program. The program offered half-day classes four days per week, and Beth taught two preschool classes, one in the morning and one in the afternoon. In an attempt to maintain consistency in the number of observations across cases, only Beth’s afternoon class was observed in this study. Her inclusive afternoon class consisted of 14 children between the ages of three and five, as well as two paraprofessionals. One of the paraprofessionals was a one to one aide for a child on the Autism Spectrum, and another child in her classroom was on a behavior intervention plan.

Per the preschool center’s policy, Beth met her students in the foyer at 12:15 each afternoon and greeted families as children were dropped off. At 12:25, Beth and her students headed to the classroom to check in, which consisted of hanging up backpacks and coats, washing hands, and completing a brief arrival activity. Then, all the children gathered on a large carpet in front of a whiteboard for a group meeting, including songs, greetings, sharing time, reading the daily message together, and a group activity related to social emotional development from the *Second Steps* curriculum. After the group meeting, children ate snack before spending an hour in free choice center time. Next, children spent 10-15 minutes in small groups focused on a specific curricular area, most often literacy or math. Each afternoon concluded with free
play outdoors and then a closing meeting on the large carpet, which consisted of an interactive read aloud and group activity.

**The Project**

At the time of the observations, the children in Beth’s classroom were beginning the Investigation Phase (Phase 2) of an insect project. Prior to the observations, Beth had noticed children in both her morning and afternoon classes were interested in insects, so she brought in praying mantis egg sacs to pique children’s curiosity. She also ordered caterpillars for her classroom and created a concept web with her students about what children already knew about insects and questions they wanted to investigate. Relatedly, the children drew memories of places they had seen insects before and did some writing about their memories. During large group observations, the children added new insects to their project web as they learned about them and used a book to investigate the question, “What is an insect?” Beth had several additional activities planned for the investigation phase of this project including a visit from an insect zoo and an outdoor investigation where children would create observational drawings of insects they found. Beth noted that her students were particularly interested in the praying mantis, and she was brainstorming additional investigations her class could complete when the eggs hatched.

**Observed large group activities.** Children in Beth’s class participated in large groups twice during the day, once at the beginning of the afternoon for greeting and sharing time and again at the end of the day. For the purposes of this study, the end of day large groups were observed because Beth indicated that was the large group where she most often implemented project related activities. On the first observation day, Beth opened large group by playing a guessing game with her students where she gave clues about the name of an insect through
physical characteristics (e.g., “I am thinking of an insect that hops.”) and rhyming (e.g., “And it rhymes with mrassropper.”). After the guessing game, she introduced the book *Bugs, Bugs, Bugs* and told her students to listen for the names of bugs or insects to add to their project web. Before reading the book, she reviewed the names of the insects that the children had already included on the web. Then she reminded her students, “As we read today, listen for ones that aren’t on our web yet, and when we’re done with our book, we’ll add them up here.” After reading the book and adding new insects to the project web, the children transitioned to getting their bags and lining up to leave for the day.

On the second observation day, Beth began large group by saying, “I think we’re ready to investigate the question. Our question is, ‘What is an insect?’ Today, we’re going to use a book to try to find out the answer. Beth proceeded to read a page from the book *Bugs Are Insects* that stated the way to tell if something is an insect is to count its legs and how many parts make up its body. She continued reading the book to teach the children the names of the three body parts. Then, the class looked at a picture of an ant in the book and determined that the ant was an insect because it had six legs and three body parts. One child asked, “So that means a mantis is not an insect?” This sparked a class investigation to find the answer. Children helped Beth find a page in the book with a picture of a mantis and then the class counted the legs and body parts together. After determining that a mantis is an insect after all, the children transitioned from large group to get ready to go home.

**Observed small group activities.** The small group activities in Beth’s classroom were focused instruction for four to five children, often in the areas of math and literacy. During the first observation, children were given laminated paper cut outs of bug jars and plastic bugs to work through some math problems to meet the learning target “I can tell how many.” After
distributing the materials, Beth instructed students to select eight bugs to put “in” their jars. Then she told them “three more crawled in” and had them put three more bugs on the piece of paper before counting the total number of bugs “in” the jar. After the addition problem, Beth instructed students to select 13 bugs to put “in” their jars. Then she told them “five crawled out” and had them remove five bugs from the piece of paper before counting the remaining number of bugs “in” the jar. After children cleaned up their materials, they transitioned to get ready for outdoor play.

The second observation was literacy focused where the children practiced the letter “Y”. First, Beth introduced the letter and asked the children, “Do you know what sound Y represents?”. Then she had the children do a hand motion as they chanted “yuh, yuh, yuh”. Next, she demonstrated how to write both an uppercase and lowercase Y and distributed markers and papers so they could all practice writing it. Lastly, Beth distributed a worksheet with a variety of different letters all over the page. Each child selected a bingo dotter and was instructed to stamp all the letter Ys on the worksheet, saying the sound of the letter each time one was stamped. After children finished their worksheets with Beth’s approval, they cleaned up their materials and transitioned to get ready for outdoor play.

**Strategies to Promote Children’s Science Learning Opportunities**

**Planning for authentic and meaningful experiences.** Beth’s score of 24 out of 34 on the PA fidelity checklist indicates that she implemented the insect project with 71% fidelity. It is important to note that Beth was just beginning the investigation phase of the insect project, so although she did not discuss plans for a culminating event, it cannot be assumed that she would not provide one at the end of the project. When asked why she chose the topic of insects for her class to investigate, Beth said, “We have friends in the morning and afternoon that are really
interested in animals and bugs, and with it being Spring I knew we could make it hands on.” She also mentioned that she has a planning partner in the preschool center, so they needed a topic that both classes would be interested. Beth knew that her planning partner had a cockroach, so she suggested the topic of insects.

After agreeing on the topic, Beth and her planning partner spent time webbing everything they could think of related to the project, such as timelines for the three phases, different experiences they could provide, and questions the children might ask about insects. They also thought about how they could “incorporate GOLD objectives and connect” to them through the project topic. Beth mentioned that “writing has been a focus in our building this year, so getting some insect words in the classroom” was important. She also hoped to find songs to “try to link more of the arts.” In addition to creating the anticipatory web, Beth and her planning partner discussed resources for the classroom that would provide “opportunities to see the real stuff” as much as possible, such as STEM kits they already had that were insect related, ordering butterfly life cycle kits, and bringing in praying mantis egg sacs. They also brainstormed potential experts to visit the class or field sites the class might be able to visit. In planning activities for the project, Beth mentioned that she “uses children’s questions to guide planning” and that she was “really trying to work on getting them to be more independent in finding their own answers.”

**Structuring the environment.** Beth’s classroom received an average rating of 3.1 out of 4 on the STERS (Chalufour et al., 2009). One large chart on the whiteboard listed children’s prior knowledge about insects, including all of the insects that children knew before starting the project. There was also another chart that listed children’s questions about insects that they hoped to investigate, as well as some of the answers to their questions as they were discovered.
Beth frequently used books to promote science learning opportunities as evidenced by her large group activities. She referred to books “as a tool to find some of the answers” to children’s questions.

Beth: Today, we’re going to use a book to try to find out the answer. We’ve got a book called *Bugs are Insects* is the name of our book. We're not going to read the whole book today. But there’s a few pages that help us answer our question...And the back of the book, has a chart. And this chart is full of information about insects... and then it tells, can it fly? It puts yes or no. It tells about where it lives. It talks about how many legs it has. So, this is a way to share a lot of information about these insects and when we're trying to answer our questions we might use this book as a tool to find some of the answers.

Beth provided authentic materials related to the project, such as live caterpillars and praying mantis egg sacs in the science center to prompt children’s questions. She also planned to utilize the outdoor learning environment by taking the children outside to create observational drawings of live insects. In addition to authentic insects, Beth used plastic insects during one of her small group activities, which prompted some conversation about the names of different insects. For example, when children were choosing their insects for the math problem, one student exclaimed, “Look at this! I used this beetle. I picked this beetle.”

**Quality of instructional interactions.** Overall, Instructional Support differed greatly between large and small group activities in Beth’s classroom (Table 5). Much higher quality interactions occurred during large group activities, which scored in the middle-quality range, compared to small group activities, which scored in the low-quality range. The observed small group activities were heavily structured with one desired outcome, which left little room for concept development. Children were expected to work independently on their assigned activities during these groups, so little talk or language modeling occurred. In contrast, the large group activities were more open-ended, allowing for more discussion and sharing of ideas. Beth promoted concept development by repeating children’s why questions and encouraging
brainstorming by calling on many different children to respond without affirming a correct answer.

Child 1: I think um, that, why are they called, why are they called daddy long legs?
Beth: Why are those called daddy long legs? Hmm, does anybody have any ideas why?
Child 2: Um, because them look like daddies with the long legs.
Beth: They’ve got really long legs?
Child 3: They’re spiders.
Child 4: Yeah.
Beth: They’re a kind of spider?
Child 5: Spiders have 8 legs
Beth: Spiders have 8 legs? You guys are knowing a lot of things about bugs and spiders.

Beth also promoted concept development by integrating the large group activities with children’s previous knowledge (e.g., reviewing the project web) and connecting their learning to the real world. For example, one line in the book *Bugs, Bugs, Bugs* said, “A fuzzy caterpillar with tiny feet” and Beth connected that line to the real world by saying, “This morning one of our friends, we were wondering if our caterpillars in our caterpillar jar have feet.”

Beth’s highest-quality instructional interactions occurred through her quality of feedback, where she frequently engaged in scaffolding and back-and-forth exchanges with follow up questions that encouraged further investigation.

Child 1: Did you know that ants could have six legs and they have a little, um, little curvy ears with little dots and three bodies.
Beth: Three bodies? Three body parts? And I wonder what the little curvy things are called.
Child 1: They’re ears.
Child 2: I just know that they’re antennas.

Beth: Antennas? Hmm

Child 2: But they’re not ears.

Beth: They’re not ears.

Child 1: Yeah. Ants have ears that you can’t see.

Beth: Oh, that might be something we have to investigate more, too.

The strategies Beth used to promote concept development and quality of feedback also provided opportunities for language modeling. For example, repeating children’s responses back as questions and allowing opportunities for brainstorming resulted in frequent conversation and open-ended student responses.

<table>
<thead>
<tr>
<th>CLASS Domain/Dimension</th>
<th>Large Group</th>
<th>Small Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional Support composite</td>
<td>4.5</td>
<td>1.8</td>
</tr>
<tr>
<td>Concept Development</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Quality of Feedback</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Language Modeling</td>
<td>4.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**Table 5**

Case study “B” Instructional Support scores across activity settings

**Quantity of science content during instructional interactions.** Table 6 shows the total number of child utterances coded as scientific inquiry, reasoning, and problem solving as defined by the Head Start ELOF (ACF, 2015) during two observed large group activities and two observed small group activities. Due to the restrictive structure of the small group activities, very few child utterances were coded. In contrast, many utterances were coded during large group activities, particularly related to the HSELOF goals of observing and describing observable phenomena and engaging in scientific talk. The most prominent strategy Beth used to promote scientific talk was to read books related to the topic of inquiry. Sometimes the pictures in the books and Beth reading aloud would prompt a science comment from a child.
Beth (reading): Bees buzzing by flowers that smell so sweet. Child, do you have a question?

Child: Um, bees work so hard with flowers for the queen, for the queen bee. And the queen bee um, um has all the babies, and all the bees are her babies. But they grewed up.

Other times, Beth used a book to explicitly teach science content words (e.g., head, thorax, abdomen). She reinforced the science content words by having children repeat the words and then clap out their syllables. Another strategy Beth used to promote children’s scientific talk was to activate their prior knowledge. For example, reviewing the class project web of insects often sparked children’s comments (e.g., “Did you know that ants could have six legs and they have little, um, little curvy ears with little dots and three bodies”). Beth further promoted children’s scientific talk in this instance by replying, “I wonder what the little curvy things are called” and then calling on several children to discuss their knowledge.

After scientific talk, the next most frequent utterances involved children describing observable phenomena. Most of the children’s utterances in this category were spontaneously prompted by pictures in the books during the read alouds (e.g., “That’s a big ant”). Likewise, most of the children’s questions were also prompted by the read alouds.

Beth (reading): Friendly daddy long legs that never bite. Grasshoppers hop, hop, hopping out of sight.

Child: I think um, that, why are they called, why are they called daddy long legs?

After reading the book *Bugs are Insects* and learning how to tell if a bug is an insect, one child questioned, “So that means a mantis is not an insect?” Beth replied, “Well, we’re going to have to look at a picture of a mantis and see if we can figure it out,” which prompted another child to suggest looking through the *Bugs are Insects* book to see if they could find a page with a picture of a mantis up close. After finding a mantis is the book, Beth invited the child with the original
question to “come check it out” to investigate his question. The child went to the front of the group and pointed to each leg as he counted out loud.

Child 1: It has 1, 2, 3, 4
Beth: Yeah. 3, 4…
Child 2: That’s his arm things.
Child 3: No, no, those are legs. Them have, that’s one of the legs but them act like arms.
Beth: That’s right. We count them all together. So, if we kept counting…
Child 1: 1, 2, 3, 4, 5, 6

Beth then prompted the children to analyze the results of the investigation and draw a conclusion about whether or not a mantis is an insect.

Beth: Is it an insect?
Children: Yes!
Beth: It’s got six legs…
Child 3: It is an insect.
Beth: Let’s see if it has the three body parts. Does it have a head?
Children: Yes!
Beth (pointing to picture): Head. Does it have a thorax?
Children: Yeah!
Beth: Yeah. Does it have an abdomen?
Children: Yeah!
Beth: Yeah. From what we learned in this book, is it an insect?
Children: Yes!
Beth: Yes, it is!
Table 6
Case study “B” total number of child scientific utterances across activity settings

<table>
<thead>
<tr>
<th>Head Start ELOF Goal</th>
<th>Large Group (30 min)</th>
<th>Small Group (20 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child observes and describes observable phenomena</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>Child engages in scientific talk</td>
<td>22</td>
<td>2</td>
</tr>
<tr>
<td>Child compares and categorizes observable phenomena</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Child asks a question, gathers information, and makes predictions</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Child plans and conducts investigations and experiments</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Child analyzes results, draws conclusions, and communicates results</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Note. The time listed for each activity setting is the total amount of time across two observations.

Case Study C

The Teacher

Claire earned her four-year degree in Early Childhood Education and had been a preschool teacher for three years. Indicating an age between 20-29 years on the demographic survey, she was one of the youngest and second least experienced preschool teachers in this study. Claire received two trainings in the PA, including an informal training in August 2014 and a formal training at a multi-day institute from one of the developers of the PA in summer 2016. By the time observations for this study began in May 2017, she estimated that she had completed eight projects. Despite her relative inexperience teaching, Claire’s responses on the P-TABS (Maier et al., 2013) questionnaire indicate that she saw great benefits of science for preschool children (\( M = 5, SD = 0 \)) and was generally comfortable with teaching science (\( M = 4.5, SD = .7 \)). Claire also perceived fewer challenges to teaching science (\( M = 4.1, SD = 1.2 \)) compared to most other teachers in this study.

The Classroom

Claire taught in one of the preschool classrooms in the community-based preschool program that functions as part of the state’s Voluntary-Four-Year-Old Preschool Program. The program offered half-day classes four days per week, and Claire taught two preschool classes,
one in the morning and one in the afternoon. In an attempt to maintain consistency in the number of observations across cases, only Claire’s afternoon class was observed in this study. Her inclusive afternoon class consisted of 13 children between the ages of three and five, as well as two paraprofessionals. One of the paraprofessionals was a one to one aide for a child on the Autism Spectrum.

Per the preschool center’s policy, Claire met her students in the foyer at 12:15 each afternoon and greeted families as children were dropped off. At 12:25, Claire and her students headed to the classroom to check in, which consisted of hanging up backpacks and coats, and washing hands. Then all the children gathered on a large carpet in front of a whiteboard for an opening meeting, including songs, greetings, sharing time, a group activity, and reading the daily message together. After the group meeting, children spent a total of 25 minutes in three different small group rotations. Next, children went back to large rug for a large group activity with an interactive read aloud before going outside for recess. After coming inside, children ate snack and then spent the final hour of the day in free choice center time. Each afternoon concluded with a five-minute closing meeting on the large carpet, which consisted of singing a song or reading a book and saying goodbye to one another.

The Project

At the time of the observations, the children in Claire’s classroom were towards the end of the Investigation Phase (Phase 2) of a pet project and beginning preparations for concluding the project (Phase 3). Claire stated that she chose the topic of pets because she noticed that the children in her classroom were playing pet store in the dramatic play area, nonstop every day, so she read some books and played pet care videos to gauge their interest in a possible pet project. Prior to the observations, they made a class web about what they already knew about pets,
generated questions about what they wanted to learn about pets, learned about hermit crabs, and began learning how to take care of pets. The families served as the primary experts for this project as all the children were invited to share their pets with the class. Different families came in two to three days per week for about two months and shared about a variety of pets (e.g. dogs, cats, birds, quails, chickens, sheep). Then, Claire’s class broke into investigation groups based on a specific pet they wanted to investigate. Between the two observations in this study, Claire’s class took a trip to PETCO to learn more about the pet they had chosen to investigate. During one of the small group observations, the children spent time brainstorming information they would like to include in a book about their investigation. Claire was planning a culminating event where the children would create books and then use the books to teach other people about their pet. She planned to assemble the children’s memories and observational drawings and have them take their families on a tour to show the different things they did throughout the project and share what they learned.

**Observed large group activities.** Children in Claire’s class participated in a large group setting three times during the day, once at the beginning of the afternoon for greeting and sharing time, once after small groups for an interactive read aloud, and again at the end of the day for saying goodbye. For the purposes of this study, the beginning of the afternoon large groups were observed because Claire indicated that was the large group where she most often integrated project related activities. On the first observation day, Claire started large group by saying, “How was school on Friday? I wasn’t here. What did you guys do?” This led to ten minutes of spontaneous sharing time where Claire called on children one at a time to have a turn sharing something with the class. A few children talked about new shoes and clothes, one child talked about his birthday, another child showed some keys, and yet another child shared an adventure
map she had drawn. After Claire had given everyone a chance to share, she read the morning message with the children: “Hello (class), today is Monday. We will talk about authors and illustrators. Snack is graham crackers, peaches, and milk. Love, Miss Claire.” Next, Claire reviewed the letter of the day (Y) with the children and then had everyone move over to the science center to look at the class tadpole and see the new items she had added to the aquarium. She asked the children what they noticed was different about the tank, and the children discovered that Claire had added aquarium gravel, decorative plants, and a new filter. These additions led to an interactive discussion about the tadpole’s habitat. At the end of large group, each child was given the opportunity to look closely at the tadpole and the new additions to the aquarium before transitioning to small groups.

On the second observation day, large group began by the children singing a greeting song that they needed to practice for the upcoming end of year assembly. Next, Claire read the morning message with the children: “Hello (class). Today is Thursday. We will start our pet books. Snack is oranges and milk. Love, Miss Claire.” After reviewing the letter of the day (G) and class jobs for the day, Claire put the children into small groups of 2-3 for about five minutes of sharing time. During sharing time, the children talked with one another about what they saw during a class trip to PETCO the previous week. Large group concluded by the children practicing two more school songs for the end of year assembly.

**Observed small group activities.** Each small group followed the same general structure, with groups of four to five children rotating through three different small group activities during the 25 minutes. Claire led one small group activity, one of the paraprofessional’s led another activity, and the third activity involved playing the in dramatic play center and practicing social problem-solving skills. Claire set up an iPad to record the group in the dramatic play center, so
she could monitor children’s activities and use the video later for documentation of children’s social skills. After approximately eight minutes in an activity, the children would rotate to the next small group activity. For the purposes of this study, only Claire’s small group activities were observed because she was the lead teacher.

During the first observation, Claire’s small group activity was focused on reading. For each group of children, Claire used the same large book, *A Cat’s Day*, but she differentiated instruction based on the skill level of the group. The activity for the first two groups of children centered around concepts of print. The first group looked for spaces and periods in the book, while the second group focused on reading from left to right and using pictures to help figure out words. The third group worked on sounding out words and read short sentences from the book out loud with Claire.

On the second observation day, children in Claire’s small group began brainstorming for the project’s culminating activity, which was a pet book. Claire began small group by looking through pictures with the children that they had taken on iPads at PETCO and sharing what they saw there. Then, Claire facilitated a discussion with the children about what a pet owner would need to know or buy for the pets they had chosen to investigate. The children in the first group all investigated cats. The second group had a mix of investigations, including birds, guinea pigs, and dogs. The third group investigated reptiles, specifically snakes and bearded dragons. As the children discussed each pet, Claire recorded their responses on a large piece of chart paper that they would use later when they started writing their books.

**Strategies to Promote Children’s Science Learning Opportunities**

**Planning for authentic and meaningful experiences.** Claire’s score of 32 out of 34 on the PA fidelity checklist indicates that she implemented the pet project with 94% fidelity. When
asked why she chose the topic of pets for her class to investigate, Claire stated that she noticed her students had been playing pet store in dramatic play, nonstop every day. While her students “kind of introduced themselves to it through play,” Claire also read some pet books and played pet care videos to “get them thinking about what kinds of questions they had about pets.” After Claire determined that her students were interested in this topic for a project investigation, she used the PA Book, *Young Investigators* (Helm & Katz, 2011), to guide her preparation and planning. Claire thought specifically about what experiences she needed to provide and what skills her students would need before investigating because it “helps plan out what [she would] need to communicate” during the project. In terms of the skills she thought they would need, most of Claire’s learning goals for her students focused on “collaboration, being reflective, investigation skills, more of the skills behind learning about something or how you learn,” but she also mentioned “try[ing] to pull in literacy and math lessons… us[ing] books related to academic goals.” Although she had initial plans in mind, Claire used children’s responses and questions to guide future plans. “If they seem to grasp something or have a question about something, I use that in [planning] for the following week about what we need to go over again or what we need to extend.”

In planning experiences for her students related to pets, Claire considered resources that might be readily available. She knew one teacher had recently caught tadpoles in a pond, so she asked if her class could have one for the science center. She knew another classroom had a hermit crab that her class might be able to visit. Claire also realized that many of her students had pets at home, so she utilized families as experts for this project. “Anyone who wanted from our classes could share their pets with us. Families were experts. We had dogs, cats, birds, quails,
chickens, sheep…” Claire also utilized PETCO as a free location for a field site visit where students could investigate their selected pets.

At the time of the observations, the pet project was entering the culminating phase, and Claire was planning for how her students could summarize and present what they learned during the project. She planned to have her students write books about what a pet owner would need to know or buy for the pets they had chosen to investigate. She was also planning a culminating event where children would set up a tour of their memory drawings, observational drawings, and different things they did throughout the project to share with their families.

**Structuring the environment.** Claire’s classroom received an average rating of 3.8 out of 4 on the STERS (Chalufour et al., 2009). The science center in her classroom was near the door, which provided ample space for multiple students to observe the live tadpole in the aquarium, as evidenced during the large group activity when the entire class gathered in front of the aquarium. Claire integrated the project into other centers in her classroom, such as providing books about pets in the library area and setting up the dramatic play area as a pet store. Claire also integrated the project into a literacy focused small group by using the big book *A Cat’s Day* to teach reading skills. By using a book about a cat, Claire was able to facilitate a conversation about what cats do during the day and relate it to her students’ lives.

Claire: Let’s read it all together. Ready, go!

Claire and children (reading): *A Cat’s Day*

Claire: So, what do you think this book is going to be about?

Child 1: A cat’s day!

Claire: Yeah, maybe what they did during the day. What do you think the cat did during the day?
Child 2: Climbed

Claire: Yeah, climbed. Do you have any cats? Anybody have a cat?

Child 3: I do!

Claire: What does your cat do all day?

Child 3: Um, my cat goes up against my leg.

Claire: Yeah, cats are pretty well known to do that. What does your cat do?

Child 2: Um, she sits on my lap.

In addition to structuring the environment in the classroom, Claire also provided an environment for inquiry by arranging a field site visit to PETCO. She further facilitated the investigation by providing children with iPads to take pictures and videos to document their observations at the pet store and then later used those photos and videos to help the children reflect on their learning.

**Quality of instructional interactions.** Overall, Instructional Support was in the upper middle range in Claire’s classroom, with slightly higher quality interactions occurring during small group activities compared to large group activities (Table 7). Claire sometimes promoted concept development through asking analysis and reasoning questions, such as “Why do you think…?” or “What do you think will…?” but at other times her questions were closed and required a specific response. Likewise, Claire sometimes provided the children with opportunities for creating and brainstorming, such as when they were planning their pet books, but other times instruction was more structured and teacher-led. Claire promoted concept development most often by reminding children of prior knowledge and activities and making connections to the students’ lives. For example, she frequently referred to children’s pets at home and asked questions to help children connect what they were learning to their own pets.
Claire excelled at providing high quality feedback to her students. She consistently scaffolded student learning through extended feedback loops and often provided expansion on children’s responses.

Claire: What else? What do they need to survive and stay healthy?

Child: Food!

Claire: Food, that’s right. And what kind of food could we buy? There’s different kinds of food. What kind of food would we need?

Child: Cat food!

Claire: Mmhm, you said that there was two different kinds of cat food.

Child: Hard food and soft food.

Claire: The hard food and soft food. Do you remember what else, what other words we used to describe those? The hard food was dry and we called the soft food, what’s the opposite of dry? If you're not dry you're

Child: Cold

Claire: Yeah, you're cold because you're most likely, if it's raining outside and you get covered in rain water you become w-w-w-e

Children: Wet!

Claire: Wet, there we go that's right.

Claire’s high-quality feedback included strong language modeling. Through the extended feedback loops, Claire engaged in frequent conversation with the children and often repeated and elaborated on their responses. Not only did she engage in conversations with the children, but Claire also encouraged peer conversations and frequent sharing with one another, particularly during large group activities. Claire also modeled language by introducing a variety of new words to the children (e.g. pounce, litter, burrowing, omnivore, aquarium, filter), and she would often define these new words by connecting them to familiar ideas.
Claire: So, what does the bearded dragon need for its habitat? That's important for a new owner to know because just like your house that you have, you have heat in your house when it's cold, so you can stay warm. And you have an air conditioner so when it's really really really hot, you can stay cool. And you have a roof over your head to keep you dry and safe from storms. So, what does a bearded dragon need for their home, for their habitat to keep them safe?

Table 7
*Case study “C” Instructional Support scores across activity settings*

<table>
<thead>
<tr>
<th>CLASS Domain/Dimension</th>
<th>Large Group</th>
<th>Small Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional Support composite</td>
<td>5</td>
<td>5.3</td>
</tr>
<tr>
<td>Concept Development</td>
<td>4.5</td>
<td>4.5</td>
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<tr>
<td>Quality of Feedback</td>
<td>6</td>
<td>6.5</td>
</tr>
<tr>
<td>Language Modeling</td>
<td>4.5</td>
<td>5</td>
</tr>
</tbody>
</table>

**Quantity of science content during instructional interactions.** Table 8 shows the total number of child utterances coded as scientific inquiry, reasoning, and problem solving as defined by the Head Start ELOF (ACF, 2015) during two observed large group activities and two observed small group activities. Across both activity settings, the most frequent utterances involved children describing observable phenomena, with far more utterances occurring during small group compared to large group activities. In fact, utterances across all the Head Start science goals occurred more frequently during small group activities, which may be due to the fact that small groups consisted of rotations, so Claire had the opportunity to interact with each child in her class during small groups. This is not to say that observational utterances were entirely absent during large group activities. Several unprompted observational utterances occurred during the large group where the class sat in front of the aquarium as they made comments about the tadpole (e.g. “Look! He’s sticking his tongue out.”) While those utterances were spontaneous, most observational utterances occurred when Claire intentionally used a combination of the environment and questioning strategies. For example, while reading a book about cats during small group, Claire prompted children to talk about their observations of the cat in the book by modeling her own observations and then asking the children to share their
observations. “It looks like a little dog to me. What do you think?” Claire also used the photos and videos children had taken at PETCO to prompt children to talk about their observations at the pet store. Again, although providing the photos and videos resulted in some spontaneous observations, most of the observational utterances occurred due to Claire’s effective questioning while showing the pictures. For example, she would often ask “What do you see?” or “What do you notice”? Another effective strategy was to acknowledge each response and then follow up by asking the children to describe more (e.g. “What else do you see?” “What else do you notice?”).

After observational utterances, the next most frequent utterances involved children’s scientific talk. Claire prompted children’s scientific talk using both closed and open-ended questions. For example, occasionally she would ask a question looking for a specific science-related vocabulary word (e.g. “What do you call it when you’re an animal that likes to work and live with other animals?”) Other times, she would ask “how” or “why” questions (e.g., “How do they stay warm”? “Why do you have to use a thermometer?”). Most of the time, however, Claire prompted scientific talk by simply providing children with the opportunity to openly talk about what they learned (e.g., “What else did you learn about the bearded dragons that you want to share?” “Tell us about those logs.”)

When considering the strategies used to promote children asking questions and making predictions, again Claire used a combination of the environment and intentional questioning. Many children asked spontaneous questions while observing the tadpole in the aquarium (e.g., “Does he have feet yet?”) or looking at the pictures they had taken at PETCO (e.g., “What’s that?” “Is that snow?”). Claire prompted children to make predictions by frequently asking them about their thinking with open-ended questions.

Claire: yeah, what are you thinking (child)?
Child 1: I think, it’s a little bit (incoherent) maybe.
Claire: A what?
Child 1: I think it’s, I think it’s a little bit scared.
Claire: You know, I wondered the same thing too. And why do you think he’s scared?
Child 1: Because maybe like it’s (the filter) making a lot of noise.
Child 2: Maybe he wants family.
Claire: Yeah, so maybe it’s a little loud in here and it’s kind of scary or
Child 2: He wants his family.
Child 1: Maybe we’re scaring him.

Children in Claire’s classroom also talked about conducting investigations and discussed ways to communicate the results of their investigations. The children’s utterances related to the goal of investigating primarily involved using simple tools to observe, gather, and record data. For example, children noted the pictures they had taken during their investigation at the pet store (e.g. “I take a picture of a dog.”) During the large group in front of the aquarium, the children engaged in an extended conversation with Claire about the possibility of finding more tadpoles to add to the tank and articulated what they would need to do to get the tadpoles. Claire promoted this level of thinking by acknowledging children’s responses and then expanding on them.

Child 1: Maybe we could go on a hunt and we could find some more tadpoles
Claire: Oh, maybe we could try to go find some. We might actually be able to do that.
Child 1: First you have to go to the store and get the fishing thing
Claire: I bet we could make that happen.
Child 2: You mean the fishing pole. I have one.
Child 1: Yeah
Claire: We'll have to get probably a bus to take us there, but we could go to one of the ponds and see what we can catch. I'm up for trying that. Maybe we could add some stuff to this tank.

Child 2: Well we could catch a fish with a fishing pole.

Claire: Maybe with a fishing pole. Do you know how they caught these? They caught some fish too in Miss [t] and Miss [t] class. They used nets. They had big nets that they scooped into the water. Kind of like our net down here. Kind of like this but much bigger so it could get deeper into the water. And they caught a bunch of tadpoles. Um, I know they caught some fish even because they have some of the fish, Miss [t] has a bigger tank than this one, full of pond water and different pond animals.

Child 3: I got a idea. If we put the fishing thing with the food right there and dip in the water and somebody eat and pull it up very quick.

When discussing ways to communicate the results of their pet investigation, Claire again used intentional, open-ended questions to elicit children’s thoughts and conclusions (e.g., “What do you think is important to tell people about cats?” “What else might we need to tell people if they were going to own a pet cat? What would they need or what would they need to know?”)

Table 8

Case study “C” total number of child scientific utterances across activity settings

<table>
<thead>
<tr>
<th>Head Start ELOF Goal</th>
<th>Large Group (35 min)</th>
<th>Small Group (50 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child observes and describes observable phenomena</td>
<td>16</td>
<td>45</td>
</tr>
<tr>
<td>Child engages in scientific talk</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>Child compares and categorizes observable phenomena</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Child asks a question, gathers information, and makes predictions</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Child plans and conducts investigations and experiments</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Child analyzes results, draws conclusions, and communicates results</td>
<td>0</td>
<td>6</td>
</tr>
</tbody>
</table>

Note. The time listed for each activity setting is the total amount of time across two observations.

Case Study D

The Teacher

Dianne held a graduate degree in Educational Administration and had been a teacher for fifteen years, with ten of those years in a preschool classroom. Indicating an age between 30-39 years on the demographic survey, she was one of the most experienced preschool teachers in this
study. Dianne received two trainings in the PA, including an informal training in August 2014 and a formal training at a multi-day institute from one of the developers of the PA in summer 2016. By the time observations for this study began in May 2017, she estimated that she had completed twelve projects. Dianne’s responses on the P-TABS (Maier et al., 2013) questionnaire indicate that she saw great benefits of science for preschool children ($M = 5, SD = 0$) and was generally comfortable with teaching science ($M = 4.46, SD = .5$). Dianne perceived more challenges to teaching science ($M = 3.6, SD = 1.8$) compared to most other teachers in this study, primarily concerning having enough time and materials to prepare to teach science and having enough time in the day to teach science.

**The Classroom**

Dianne taught in one of the preschool classrooms in the community-based preschool program that functions as part of the state’s Voluntary-Four-Year-Old Preschool Program. The program offered half-day classes four days per week, and Dianne taught two preschool classes, one in the morning and one in the afternoon. In an attempt to maintain consistency in the number of observations across cases, only Dianne’s afternoon class was observed in this study. Her inclusive afternoon class consisted of 13 children between the ages of three and five, as well as two paraprofessionals.

Per the preschool center’s policy, Claire met her students in the foyer at 12:15 each afternoon and greeted families as children were dropped off. At 12:25, Claire and her students headed to the classroom to check in, which consisted of hanging up backpacks and coats, and washing hands. Then the children spent about 25 minutes rotating through small group learning stations where they would do different activities with each of the three teachers in the classroom. After small group learning stations, the children gathered on a large carpet in front of a
whiteboard for an opening meeting, including songs, reviewing the super helper, and a group activity, which was often literacy focused. Then, the children went outside for 15 minutes of outdoor play before coming in and eating snack. After snack, the children went back to the large rug for 15-20 minutes devoted to project study learning. This project meeting typically began as a large group and then children would separate into smaller groups to complete an assigned task with one of the three teachers. Once children had successfully completed their project task, they transitioned to center time, where they spent 45 minutes in free exploration. Each afternoon concluded with a large group read aloud, children checking their mailboxes and getting backpacks, and saying goodbye to one another.

**The Project**

The children in Dianne’s classroom were engaged in the Investigation Phase (Phase 2) of a flower project. Observations in her classroom occurred during the last few weeks of the school year, so Dianne mention that this project was on a shorter time frame of 4-5 weeks compared to her usual project timeframe of 6-8 weeks. According to Dianne, she tried to choose the topic based on children’s interests, but she also chose the flower topic due to accessibility in the short time frame. Prior to the observations, the children had engaged in an exploratory week where Dianne had transformed the dramatic play center into a garden center, and the children planted a seed that they took home. They also walked to a nearby garden and greenhouse supply store and made a web of what they already knew about flowers and a list of questions they still had about flowers. Dianne planned to use the children’s questions to form investigation teams like she had done for prior projects. She would have each team investigate the answer to their question and then come up with a way to teach the rest of the class about their investigation. She also planned to have each team make their own team web with more specific questions. The class had also
visited a local botanical garden, and Dianne was thinking about how she would have students represent their learning from the project.

**Observed large group activities.** Children in Dianne’s class participated in a large group setting three times during the day, once towards the beginning of the afternoon for greeting and a literacy focused activity, once after snack for a project meeting, and again at the end of the day for saying a read aloud and saying goodbye. For the purposes of this study, the project meetings were observed because Dianne indicated that was the large group where she most often integrated project related activities. On the first observation day, the children transitioned from snack to large group by listening and singing along to “The Itsy-Bitsy Spider”. This song sparked an extended exchange about spiders, which was a project topic the class had investigated earlier in the year. After the discussion about spiders, Dianne asked the children to share their memories from a recent trip to a local botanical garden. “Let’s take some turns telling what you remember about our trip. (Child), what do you remember?” Many children shared about the different sculptures they had seen in the garden before Dianne guided the children to discussing their memories of the flowers. Then she assigned children the task of creating a memory drawing about flowers. This drawing could be of anything the child remembered about flowers. The children then separated into three small groups to complete their drawings. After completing their drawing, children described their drawings to the teacher. Then, with a teacher’s assistance, children wrote about their drawings by sounding out the letters that they heard in their descriptions. For example, one child described her flower as a “rainbow flower”, so the teacher helped the child sound out the letters she heard in “rainbow” and “flower”. As she sounded out these words, the child phonetically spelled the words next to her drawing. As children completed their drawings, they transitioned to free choice time.
On the second observation day, Dianne began large group by saying, “Alright, today you have a job. We’re going to do some measuring. We’re going to measure some flower stems. Are you ready for me to show you what your job will be?” She then proceeded to demonstrate the measuring task. Children were asked to stamp three flowers on a piece of paper and draw a stem for each flower. Then they were instructed to measure the three stems and use a different item to measure each one. Children had the option of measuring with noodles, tickets, counting cubes, or a ruler. Finally, children were asked to place a sticker on the tallest flower. After Dianne demonstrated this process, including how to measure with a ruler, the children separated into three small groups to complete their measuring. Dianne checked each child’s measurements for accuracy and wrote the number of units for each stem on the papers. As soon as children had placed the sticker on the tallest flower, they transitioned to free choice time.

**Observed small group activities.** Small groups in Dianne’s classroom occurred during learning stations as soon as children arrived in the classroom. Each teacher worked with groups of four to five children, and as a child completed the activity at one group, that child transitioned to another activity at a different group. The children did not rotate all together as a group. Rather, each child rotated when she had completed her individual work at the learning station. For the purposes of this study, only Dianne’s learning station activities were observed because she was the lead teacher. During the first observation, Dianne’s learning station was focused on counting. Each child was given a worksheet with pictures of flowers with various numbers of seeds. Children were instructed to count the seeds in each flower and then write the number in the corresponding box. After Dianne checked each child’s paper for accuracy, the child would transition to a new learning station. As children from other stations rotated to her station, Dianne
would introduce each child to the counting activity and provide them with the necessary materials.

During the second observation, Dianne’s learning station was focused on categorizing. She provided each child with a laminated piece of paper with four different sections. A bag of mixed seeds and beans was placed on the table and Dianne instructed the children to sort the seeds. “Remember when we sort, we are putting things together somehow that they’re the same. Like if they’re all the same color or the same size or the same shape or the same kind.” The children worked on the sorting activity independently, and each child discussed his or her sorting method with Dianne. Once she approved a child’s first sorting method, Dianne challenged the child to sort the seeds a different way. As each child finished the sorting activity, he or she would transition to a new learning station. As children from other stations rotated to her station, Dianne would introduce each child to the sorting activity and provide them with the necessary materials.

**Strategies to Promote Children’s Science Learning Opportunities**

**Planning for authentic and meaningful experiences.** Dianne’s score of 29 out of 34 on the PA fidelity checklist indicates that she implemented the flower project with 85% fidelity. When asked why she chose the topic of flowers for her class to investigate, Dianne stated that she tries to choose topics based on students’ interests, but since it was the last few weeks of the school year, she needed to choose a topic that was accessible in a shorter time frame. She and her planning partner ended up choosing flowers because it was Spring, and they knew they could conduct the project in a few weeks using local resources. After Dianne and her planning partner chose the topic of flowers, they created “a teacher web first to kind of get [their] brains around what types of things might come up.” During this planning stage, they thought specifically about where they might want to go and what local field experiences would be available for the topic.
They also planned materials, talked about possible experts for the project, and informed parents to see if they could get parents involved.

In addition to considering resources, Dianne and her planning partner discussed learning goals for the project. Dianne mentioned that since attending the formal PA training the previous summer, her goals for children’s learning had shifted. “Before the training, it was, we are going to teach them all about the content, but now it’s about the process.” Therefore, Dianne’s primary learning goals for her students revolved around the process of learning, such as “How to be curious about things. How to investigate and find answers.” Dianne also stated that she tries to integrate the curriculum with the project, such as by having her small group learning stations relate to the project topic. For example, Dianne integrated math with the project by using pictures of flowers for counting and measuring and by using seeds for categorizing.

Dianne’s planning process relied on both formal and informal assessments. She stated that sometimes should would “take data from the last time [she] collected [it] to form their groups.” When she did this, she would create ability groups based on the learning objective so that she could make the activity “more specific to their skill.” At other times, she used student’s questions about the topic to form investigation teams. “So, if a lot of kids ask about the parts of the flower, I would have them investigate and come up with a way to teach the rest of the class about that.” At the time of the observations, the flower project was still in the investigation phase, so Dianne was just beginning to plan for how students would represent their learning in a culminating event.

**Structuring the environment.** Dianne’s classroom received an average rating of 2.8 out of 4 on the STERS (Chalufour et al., 2009). Dianne integrated the project into other centers in her classroom, such as providing books about flowers in the library area and setting up the
dramatic play area as a garden center. Dianne also integrated the project into her small group learning stations by using materials related to the project topic. For instance, the small group activity focused on counting involved counting the number of seeds on a picture of a flower, and the sorting activity involved categorizing different types of seeds. By using actual seeds during the sorting activity, Dianne was able to keep children engaged and sparked children’s curiosity.

Child: Look what I found. Miss Dianne, look what I found!

Dianne: Do you know what kind of seed that is?

Child: Yeah, it’s a flower.

Dianne: A sunflower seed. You’re correct.

Child: What’s this one?

Dianne: That one is a watermelon seed. We’re going to sort some seeds.

Child: What is this one?

Dianne: That one is a bean seed.

Child: What is this one?

Dianne: That one is a pea. Remember like when we had peas for snack the other day, and we opened our pea pods.

Child: What’s this one?

Dianne: That one’s a pea

Child: Too?

Dianne: Mmhm, yeah.

Child: How about this one?

Dianne: That one is corn. I can’t wait to hear about how you’re sorting.
In addition to structuring the environment in the classroom, Dianne also provided an
environment for inquiry by arranging field site visits to a local garden supply store and a local
botanical garden.

**Quality of instructional interactions.** Overall, Instructional Support was in the middle
range in Dianne’s classroom, with slightly higher quality interactions occurring during large
group activities compared to small group activities (Table 9). The quality of concept
development in Dianne’s classroom often depended on the structure of the specific activity. For
example, Dianne’s counting small group activity was teacher-directed and focused on a discrete
skill with little opportunity for analysis and reasoning, whereas her categorizing small group
activity provided many opportunities for children to compare and classify. Likewise, the large
group activity that was focused on measuring provided few opportunities for analysis and
reasoning or creating, whereas the large group activity that involved drawing a memory of
flowers provided ample opportunities for children to brainstorm, create, and connect their
learning to previous experiences.

Dianne’s highest-quality instructional interactions occurred through her quality of
feedback, where she frequently engaged in scaffolding and back-and-forth exchanges with
follow up questions. These exchanges were particularly evident during small group activities
when she would work with individual children. This one on one time with each child provided
her with many opportunities for differentiating and scaffolding instruction. For example, during
the counting activity, Dianne had some children counting smaller numbers (e.g., 1-5), while
other children counted larger numbers (e.g., 1-10). During the sorting seeds activity, some
children were able to sort independently, while other children needed specific guidance. For one
child, Dianne scaffolded the activity by first sorting a few of the seeds and then having the child sort the remaining seeds into the categories she had provided.

    Dianne: Okay, I want to help you here. So, I see these. Where would this one go?
    Child: Here
    Dianne: Okay, where would this one go?
    Child: Here
    Dianne: Okay, try to sort a few more.

For another child, Dianne engaged in a feedback loop to help the child explain his sorting, and then she extended the activity by asking him to sort the seeds another way.

    Dianne: Tell me about how you’re sorting.
    Child: I just did this and this and this.
    Dianne: Okay, so what makes these all the same?
    Child: They’re black.
    Dianne: Okay and what makes these all the same?
    Child: Because they’re green.
    Dianne: And these?
    Child: They’re all white.
    Dianne: And these are?
    Child: They’re all brown:

    Dianne: So, you’re sorting by color, aren’t you? You sorted because you put the colors together. So, I’m going to slide this off, and I want to see if you can sort by a different way. Okay? See if you can do something different like size or shape or kind.
Dianne engaged in language modeling for her students through repeating and expanding on student responses and engaging in self talk where she would map her actions by describing what she was doing as she was doing it.

“So, I think the first one, I’m going to measure with blocks. So, then I need to get out a bunch of blocks, and I’m going to measure my stem. So, I will be sure to start at the bottom of my stem and just measure all the way to the top.”

Table 9

<table>
<thead>
<tr>
<th>CLASS Domain/Dimension</th>
<th>Large Group</th>
<th>Small Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional Support composite</td>
<td>4</td>
<td>3.5</td>
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<td>Concept Development</td>
<td>3.5</td>
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<tr>
<td>Quality of Feedback</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Language Modeling</td>
<td>3.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

**Quantity of science content during instructional interactions.** Table 10 shows the total number of child utterances coded as scientific inquiry, reasoning, and problem solving as defined by the Head Start ELOF (ACF, 2015) during two observed large group activities and two observed small group activities. Across both activity settings, the most frequent utterances involved children comparing and categorizing observable phenomena, with far more utterances occurring during small group compared to large group activities. In fact, utterances across all the Head Start science goals occurred more frequently during small group activities, which may be due to small group rotations where Dianne had the opportunity to interact with each child in her class. Most of the utterances involved comparing and categorizing due to the structure of the activity. For instance, during the large group activity where children were measuring flower stems, children used measurement tools to quantify similarities and differences in the length of the stems.

Child: These are all long and this one is too long.
Dianne: Well, let’s try. How many tickets tall is this one?

Child: Uh, 1, 2, 3, 4

Dianne: So, this one is four tickets. Let’s write “4 tickets”. Okay, how tall is this one?

Child: 1, 2, 3, 4

Dianne: Four tickets too? So, which one is bigger?

Child: Both of them.

Dianne: They’re the same, or equal, aren’t they?

Child: Yeah

Likewise, during the small group sorting activity, children categorized seeds based on observable characteristics, such as type of seed, color, size, or shape. Dianne prompted children’s utterances related to comparing and categorizing by asking children to explain how they sorted the seeds.

Dianne: Okay, then I want to hear about how you sorted this time.

Child: I put all the beans right here.

Dianne: Okay

Child: And all of the corn here.

Dianne: Okay, why did you put these seeds in the same box?

Child: Because they the same.

Dianne: What’s the same about them?

After utterances involving comparing and categorizing, the next most frequent utterances involved observing and describing observable phenomena and asking questions. Children repeatedly described the seeds (e.g., color, type, shape) as they sorted them into different categories, and they also described the seeds when prompted by Dianne to explain how they sorted them. The children were interested in the different types of seeds during the sorting
activity, as evidenced by the number of questions they asked (e.g., “What is this seed?” “How about this one?”). They were also interested in what was inside the seeds and frequently asked if they could open the seeds to look inside. By using authentic materials, such as the seeds, Dianne provided many opportunities for children to express their curiosity and ask questions.

Table 10
Case study “D” total number of child scientific utterances across activity settings

<table>
<thead>
<tr>
<th>Head Start ELOF Goal</th>
<th>Large Group (50 min)</th>
<th>Small Group (60 min)</th>
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<tbody>
<tr>
<td>Child observes and describes observable phenomena</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>Child engages in scientific talk</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Child compares and categorizes observable phenomena</td>
<td>12</td>
<td>42</td>
</tr>
<tr>
<td>Child asks a question, gathers information, and makes predictions</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>Child plans and conducts investigations and experiments</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Child analyzes results, draws conclusions, and communicates results</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Note. The time listed for each activity setting is the total amount of time across two observations.

Case Study E

The Teacher

Elaine held a graduate degree in English as a Second Language and had been a teacher for 36 years, with 6 of those years in a preschool classroom. Indicating an age between 50-59 years on the demographic survey, she was one of oldest teachers in this study and had the most overall classroom experience. Elaine received formal training in the PA from one of the developers (Sylvia Chard) at a multi-day institute, and she began implementing the PA in her classroom in September 2016. By the time observations for this study began in September 2017, she estimated that she had completed four projects. Elaine’s responses on the P-TABS (Maier et al., 2013) questionnaire indicate that she saw great benefits of science for preschool children ($M = 4.9, SD = 0.3$) and was generally comfortable with teaching science ($M = 4.6, SD = .6$). Elaine perceived some challenges to teaching science ($M = 3.9, SD = 1.7$), primarily concerning the
amount of preparation time needed to teach science compared to other subjects and difficulty in planning hands-on science activities.

**The Classroom**

Elaine taught in one of the preschool classrooms in the university child development laboratory school that serves as a model early childhood program and functions as a research site for the university. The program offered full-day preschool classes (7:30 AM-5:30 PM) five days per week with two licensed teachers in each classroom. In an attempt to maintain consistency in the time spent in observations across cases, only the morning activities (9 AM-12 PM) were observed in this study. At the time of the observations for this study in September, Elaine’s class consisted of 18 children between the ages of three and four, as well as one co-teacher.

Children in Elaine’s class would begin arriving as early as 7:30 AM and continue to arrive up until 9:45 AM. During this time, children engaged in free play and exploration at various centers throughout the room. After free play time, children cleaned up and gathered on a large rug for a story before transitioning to snack. Then, the children gathered back on the large rug for twenty minutes of large group, which involved songs, stories, and a group activity. After large group, the children separated into groups of six to eight for twenty minutes of a small group activity with one of the teachers. These small group activities often focused on specific learning goals, like cutting, writing, or counting. Next, children transitioned from small group to outdoor time where they spent forty minutes in outdoor free play before coming back inside and spending an additional thirty minutes in self-selection time. During this time, children chose from manipulatives, the art area, or the writing and book center. After self-selection time, children cleaned up, washed their hands, and transitioned to lunch.
The Project

The children in Elaine’s classroom were engaged in the Investigation Phase (Phase 2) of a backyard wildlife project. At the time of the observations, they were specifically focusing on chipmunks. According to Elaine, the project topic had evolved over the summer from children’s interests. The project initially began with children expressing an interest in wildlife they were seeing on the playground, so Elaine and the children created a list about what they already knew about birds, chipmunks, squirrels, and rabbits. Elaine stated that the children were particularly interested in watching birds at the bird feeder and asked many questions about birds. After spending some time studying and observing birds over the summer, children noticed that when the birds dropped their seeds while eating, the chipmunks would come to get the seeds. This sparked children’s interest in chipmunks, so Elaine took the children to see a chipmunk burrow outside their classroom.

Prior to the observations, the children had studied a lot about what chipmunks eat, as well as their habitats. Elaine would elicit suggestions from her students about what types of food to place outside for the chipmunks, and then they would observe to see if the chipmunks ate the food. They also completed observational drawings of different foods during a small group activity, and they looked at a number of books that showed chipmunk habitats. During one observation, Elaine brainstormed with the children about how they could use cardboard to create a chipmunk burrow for the dramatic play center. Elaine was planning to help children map out where the chipmunks live on the playground, and she was still searching for an expert visitor for the project. Elaine also planned to have each child contribute a page to a book that she would keep on the shelf in the library.
**Observed large group activities.** Children in Elaine’s class participated in a large group setting twice during the morning, once after free choice time for a morning meeting and story and again after snack for a large group activity. For the purposes of this study, the large group activities that occurred after snack were observed because Elaine indicated that was the large group where she most often integrated project related activities. On the first observation day, Elaine began large group by pulling items out of a bag of materials the library had sent for the class. “Okay, what I have here is not about chipmunks, but I asked the library to see if they could send me something about some other small animals that are kind of like chipmunks.” The bag included two little field mice puppets, four books about mice, and a DVD with stories about Peter Rabbit. After looking through the materials, Elaine read aloud the book *Mouse Count* by Ellen Stoll Walsh, which was one of the books in the library bag. Next, Elaine showed children some acorn shells and tomato shells that she had found outside in the area where the class had been leaving food for a chipmunk and led a discussion about why they thought the chipmunk did not eat the shells. Elaine also discussed with the children the possibility of going for a walk and looking for oak trees to find some more acorns. Large group concluded with a scripted social-emotional lesson using a puppet about how to ask nicely for help.

On the second observation day, Elaine began large group showing children pictures of chipmunk burrows in various books. Then she said, “I have these things. I have a smaller box. I have a bigger box. I have a long, long tube. And I was thinking we could make something for our dramatic play center.” The rest of the large group time was spent brainstorming how the class could use those three items to make a chipmunk burrow for the dramatic play center. This activity led to many questions about how a chipmunk stays warm in its burrow and how the class could make paper straw to put in the burrow.
**Observed small group activities.** The small group activities in Elaine’s classroom were focused instruction on specific learning goals for groups of six to eight children. During the first observation, children were given a piece of paper with a roughly drawn circle and triangle. Elaine modeled how to properly hold scissors to cut the paper. “Look at my fingers. I have one thumb in the thumb hole. That’s the circle one. You see that? And I have two fingers in the two-finger hole. You might have three fingers in it. Your hands are a little bit smaller than mine. Okay? My thumb stays on top and watch me cut.” Children were then instructed to cut out the circle and triangle and write their names on each shape.

On the second observation day, Elaine played a game of memory with the children in her small group. Using a memory game with pictures of children from around the world, Elaine placed 18 cards on the floor and had the children sit in a circle and take turns flipping two cards over to search for the nine pairs. After the children had found all of the matches, Elaine mixed up the cards, and they played again.

**Strategies to Promote Children’s Science Learning Opportunities**

**Planning for authentic and meaningful experiences.** Elaine’s score of 23 out of 34 on the PA fidelity checklist indicates that she implemented the chipmunk project with 68% fidelity. It is important to note that Elaine’s class was just beginning the investigation phase of the chipmunk project, so although she did not yet have plans for a field site visit or an expert visitor, it cannot be assumed that she would not provide these experiences before the project culmination. When asked why she chose the topic of chipmunks for her class to investigate, Elaine mentioned that children had been interested in the wildlife on the playground and while studying birds, children noticed that when birds dropped their seeds, then chipmunks would come. This sparked curiosity about other foods that chipmunks eat. Elaine also mentioned that in
addition to children expressing an interest in a topic, it was important that she had an interest in the topic as well. Elaine stated that she was particularly interested in the topic of wildlife because one of her overall goals as a teacher is to help children “learn about their environment and learn to love their environment so they can take care of the planet.”

When planning for the chipmunk project, Elaine discussed how she begins planning for every project by brainstorming how she thinks the project will progress and considering the Teaching Strategies Gold learning goals that she might be able to integrate. If she thinks she will not able to integrate the learning goals or that the project will be short lived, then she decides that the topic is “not something worth pursuing.” Once she determined that the chipmunk project was worth pursuing, Elaine began to look for materials. She talked about going for walks around the campus grounds to look for acorns and other things that chipmunks might eat or use in their burrows. Elaine also mentioned searching for children’s books related to the project topic, and she requested that the local library put together a bag of materials for the project. In addition to discussing these material resources, Elaine stated that she needs to “get better at finding people” to be expert visitors. She planned to search in the directory for an expert visitor for the chipmunk project. An important aspect of Elaine’s planning process involved thinking carefully about how she could integrate [the project topic] into a normal classroom day and give children opportunities throughout the day to be curious and “think like a scientist.” She also discussed the importance of asking open ended questions to “really bring it back to getting them to use those thinking skills and being curious.”

**Structuring the environment.** Elaine’s classroom received an average rating of 2.9 out of 4 on the STERS (Chalufour et al., 2009). Four large pieces of chart paper hung on the wall at children’s eye level. One chart listed children’s prior knowledge about birds, squirrels,
chipmunks, and rabbits, as well as some of the children’s questions. Another chart compared theour animals as children learned new information. Under each animal heading, Elaine had
written how the animal moves from place to place (e.g., fly, walk, hop, run), the types of food
the animal ate, what the animal’s babies looked like, where the animal lived, and what the animal
does during the winter (e.g., fly away, hibernate). A third chart had a photocopied cover of the
book *Chipmunk at Hollow Tree Lane* and the words “What did we learn?” On this chart Elaine
had written all the different foods that the chipmunk had eaten that she had placed outside (e.g.,
fruit, acorns, corn, berries). The final chart listed new foods that the children wanted Elaine to
place outside for the chipmunk.

The science center in Elaine’s classroom was in the back corner of the room, near two
large windows. Directly outside one of the window was a concrete ledge where Elaine would
place the food for the chipmunk. Children were able to look out the window throughout the day
and observe “Chippy” eating the food or taking it away to his burrow. In addition to the
opportunities to observe a chipmunk, the science center also included authentic materials related
to the project, such as a tray of corn cobs and some nest material.

The project topic was also integrated into other areas of the classroom. During one large
group observation, Elaine and the children brainstormed how they could turn two cardboard
boxes and a tube into a burrow for the dramatic play center, and the library center was stocked
with books related to the project topic. Elaine also used books to help build children’s prior
knowledge or to connect concepts. For example, when she wanted the children to think about
how to make a burrow for the dramatic play center, Elaine first refreshed their memory about
burrows with pictures from books they had read.

Child: Read it! Read it!
Elaine: We’re just going to look at some pictures because I want you to be thinking. And I have another book because I want you to be thinking about this. It’s got some more pictures of those burrow holes.

Child: Can you read that book?

Elaine: Well, I want to show some pictures from it. Oh, look. Do you see this small hole? And it’s going down. Now, I also have some more pictures in here, and I need to find the great big picture because I want you to put this into your mind.

In addition to structuring the environment inside the classroom, Elaine planned to utilize the outdoor learning environment. She discussed taking the children on a walk to search for acorns to give to the chipmunk and planning an activity where the children would map out where the chipmunks lived on the playground.

Quality of instructional interactions. Overall, Instructional Support differed greatly between large and small group activities in Elaine’s classroom (Table 11). Much higher quality interactions occurred during large group activities, which scored in the middle-quality range, compared to small group activities, which scored in the low-quality range. The observed small group activities were heavily structured with one desired outcome, which left little room for concept development. In contrast, the large group activities were open-ended, allowing for more discussion and sharing of ideas. Elaine highest-quality instructional interactions revolved around concept development, which she promoted during the large group activity when she asked the class to think about how they could turn the two boxes and cardboard tube into something for the dramatic play center.

Elaine: Alright, so I want you to raise a quiet hand if you have any ideas for our dramatic play center when it comes to these boxes and the tube and what we’re looking at here. Any ideas out there?

Child 1: Um, we could tape it together

Elaine: And what would we make?
Child 1: Um, a burrow

Elaine: Do you think we could make a burrow with those things?

Child 1: Mmhm. A burrow and a hole.

Elaine: Do you think that one of those boxes might be big enough for one person to sit in if they got really small?

Child 2: They! This one’s bigger.

Elaine: That one is bigger.

Child 2: Maybe it could fit one people.

Elaine: I think maybe one person. I think that’s true. What do you think, (child’s name)?

Child 3: Maybe we could paint it.

Elaine: Oh, you think painting it. What color would we paint it?
Child 3: Maybe brown

Child 4: Blue, yellow, and green, and all the colors in the rainbow!

Elaine: But where are burrows at?

Child 1: Um, they’re in the ground, and I think we could make a tube and then we could have the tube right here, so we could all go places.

Elaine: Oh, if you were a chipmunk size, could you go both places in that tube?

Children: Yeah!

Elaine: Yeah, I knew that tube was going to come in handy when I saw it this year. (Child’s name), what’s your idea?

Child 5: Um, we could turn ourselves into chipmunks maybe.

Elaine: Well, maybe we could make some chipmunk hats that we could put on in dramatic play and then we could turn ourselves into chipmunks and sit inside. I think that’s a wonderful idea.

As demonstrated in the previous example, this large group activity provided ample opportunities for children to brainstorm ideas and create a plan for the dramatic play center. Elaine further
promoted children’s concept development by relating their ideas back to what they had learned about burrows and connecting to the real world by suggesting a way to pretend to turn into chipmunks. With regard to quality of feedback, Elaine often expanded student responses to extend their understanding, and she could frequently be heard offering specific praise and encouragement for children’s ideas and efforts. She occasionally engaged in feedback loops with children and questioned children’s responses if they were factually incorrect as demonstrated in the following example:

Elaine: Now, why would these mice be watching for snakes?
Child 1: Because they could eat them.
Child 2: They might eat them.
Elaine: The mice eat snakes?
Child 1: Yeah
Elaine: How could a little tiny mouse gobble up a snake?
Child 3: No way!
Elaine: Or does the snake eat the mice?
Children: Snake eat the mice!

Although frequent conversations could be heard throughout the classroom, particularly amongst children, Elaine primarily engaged in language modeling for her students through asking open-ended questions and repeating and expanding on student responses.

Elaine: We’re going to look and see if we can find some oak trees along our way. And then, if we do, on the way back, if they’re easy to get to, we’ll see if we can collect something. What do you think that we might want to collect?
Child 1: Leaves
Elaine: Um, yeah, the leaves. We could.
Child 2: Um, I think maybe acorns.

Elaine: Oh, the acorns. I think that that’s what we’ll do.

Child 3: Or some chipmunks

Elaine: Well, I think if we had some acorns, we could probably find chipmunks.

Table 11
Case study “E” Instructional Support scores across activity settings

<table>
<thead>
<tr>
<th>CLASS Domain/Dimension</th>
<th>Large Group</th>
<th>Small Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional Support composite</td>
<td>4.3</td>
<td>2</td>
</tr>
<tr>
<td>Concept Development</td>
<td>5</td>
<td>1.5</td>
</tr>
<tr>
<td>Quality of Feedback</td>
<td>4</td>
<td>2.5</td>
</tr>
<tr>
<td>Language Modeling</td>
<td>4</td>
<td>2</td>
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</tbody>
</table>

**Quantity of science content during instructional interactions.** Table 12 shows the total number of child utterances coded as scientific inquiry, reasoning, and problem solving as defined by the Head Start ELOF (ACF, 2015) during two observed large group activities and two observed small group activities. Utterances across all the Head Start science goals occurred more frequently during large group activities, which may be due to the fact that the small group activities were heavily teacher-directed. Across the two activity settings, children’s scientific talk during large group was the most frequently coded utterance. Sometimes the utterances were unprompted and occurred spontaneously in response to the environment. For instance, while reading the book *Mouse Count* by Ellen Stoll Walsh, one child said, “And did you know that snakes—there’s boa snakes that can eat another snake.” Most scientific talk occurred when Elaine intentionally used a combination of the environment, questioning strategies, and follow up responses.

Elaine: What do we know about chipmunks? Where do they like to live?

Children: Underground!

Elaine: Underground. Yeah, they really like it when it’s underground. I wonder if it feels very warm to them or very cool to them.
Child 1: No, they need them warm.

Elaine: Oh, you think it’s warm in the winter time down there?

Child 1: No


Elaine: What about their burrows that makes it warm in the winter time for them? I’ll hold up some pictures.

Child 3: Um, they can eat and while they’re sleeping, um, because you can make a house because, um, when they made a house under like the snow and then the chipmunk could not go in his house and the house was really cold.

Elaine: Okay. That’s a good idea. You talked about snow, and you talked about winter, and you talked about how he could store his food in there and eat and stay warm. One of the reasons why he can stay warm is if he’s under the ground, there’s not something blowing on him. What isn’t blowing on him if he’s underground?

Child 1: Wind

Elaine: Wind, that’s right.

Child 4: But the tunnels are open. Will he get cold or not?

Elaine: Oh, now that’s a really interesting idea. Let’s look at this picture of that tunnel, and I think I noticed something. Is it, look, what’s the first tunnel? What does the tunnel come to first?

Child 4: Um, it comes to the burrow and then the animals go under.

Elaine: Uh huh, so, on top where it might be closer to where the opening is, is where the food is.

Child 2: But in the spring they come out!

In the previous example, Elaine began the conversation by asking a close-ended question about where chipmunks like to live. She then followed up by using self-talk and describing one of her own curiosities about chipmunk burrows, which led to a conversation about whether or not a chipmunk’s burrow is warm. Another strategy Elaine used here to promote further scientific talk
was to repeat children’s responses, extend them, and then ask a follow up question to prompt children to continuing talking.

After children’s scientific talk, the next most frequent utterances involved observing and describing observable phenomena and asking questions or making predictions. Some of the descriptive utterances occurred as children described the pictures on the cards while playing memory during one of the small group activities, however, most of the observational utterances occurred during large group when Elaine would read a book or show a picture and children would make comments about what they were seeing.

Most of the questions and predictions also occurred during the large group activity where the children were planning how to create a burrow for the dramatic play center. After the conversation about whether or not chipmunk burrows are warm, children had many follow up questions. For example, one child asked, “How do chipmunks get warm?” and another child asked, “Is there grass in their nest?” As children asked these questions, Elaine acknowledged each question and wrote it on a large chart paper, which seemed to elicit additional questions from the children. Elaine also promoted these questions by using wait time and allowing children the opportunity to voice their wonderings about the topic.

The children’s utterances related to the goal of investigating primarily involved articulating the steps to be taken and the list of materials needed to create the burrow for the dramatic play center. Although this particular activity was not an investigation, it did involve some higher-level thinking skills related to planning. For example, one child talked about how they would need to cut a hole in the box to “make it enter and exit,” and another child shared possible locations to tape the cardboard tube, so the chipmunks could get to all the different areas
in the burrow. Elaine promoted these planning skills by simply providing materials and facilitating a brainstorming session of children’s ideas.

<table>
<thead>
<tr>
<th>Head Start ELOF Goal</th>
<th>Large Group (45 min)</th>
<th>Small Group (45 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child observes and describes observable phenomena</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>Child engages in scientific talk</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Child compares and categorizes observable phenomena</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Child asks a question, gathers information, and makes predictions</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>Child plans and conducts investigations and experiments</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Child analyzes results, draws conclusions, and communicates results</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Note. The time listed for each activity setting is the total amount of time across two observations.*

**Case Study F**

**The Teacher**

Francine held a graduate degree in Early Childhood Education and had been a teacher for ten years, with seven of those years in a preschool classroom. Francine received informal training in the PA from a previous co-teacher in the classroom who had received formal training at a multi-day institute, and she began implementing the PA in her classroom in August 2015. By the time observations for this study began in November 2017, she estimated that she had completed six projects. Francine’s responses on the P-TABS (Maier et al., 2013) questionnaire indicate that she saw great benefits of science for preschool children ($M = 4.8$, $SD = 0.4$) and was generally comfortable with teaching science ($M = 4.7$, $SD = .5$). Francine perceived some challenges to teaching science ($M = 3.6$, $SD = 1.1$), primarily concerning her confidence in talking with young children about the scientific method.

**The Classroom**

Francine taught in one of the preschool classrooms in the university child development laboratory school that serves as a model early childhood program and functions as a research site.
for the university. The program offered full-day preschool classes (7:30 AM-5:30 PM) five days per week with two licensed teachers in each classroom. In an attempt to maintain consistency in the time spent in observations across cases, only the morning activities (9 AM-12 PM) were observed in this study. At the time of the observations for this study in November, Francine’s class consisted of 18 children between the ages of three and four, as well as one co-teacher.

Children in Francine’s class would begin arriving as early as 7:30 AM and continue to arrive up until 9:30 AM. During this time, children engaged in free play and exploration at various centers throughout the room. After free play time, children cleaned up and gathered on a large rug in the center of the room for an opening meeting, which consisted of greeting one another, going over classroom jobs, and sharing time for the “Star of the Week”. Then, the children transitioned to snack before gathering back on the large rug for twenty minutes of large group. After large group, the children separated into groups of six to eight for twenty minutes of a small group activity with one of the teachers. These small group activities often focused on specific learning goals. Next, children transitioned from small group to outdoor time where they spent fifty-five minutes in outdoor free play. Children then returned to the classroom to listen to a read aloud or sing songs before washing hands and transitioning to lunch.

The Project

At the time of the observations, the children in Francine’s classroom were transitioning from the Investigation Phase (Phase 2) to the Culminating Phase (Phase 3) of a tree project. Francine stated that the project had started in early October and that she had chosen the topic of trees because she wanted to study “something that was of interest to the children and that children could notice changes.” She introduced the children to the project by taking them outside and having them complete observational drawings. Then, Francine took the children on a
scavenger hunt to find some of the things they had drawn in their observational drawings. After the scavenger hunt, Francine placed the items in the sensory table for the children to explore during free choice time.

In small groups, the children generated questions they had about trees in preparation for an expert visitor from the ecology department who was “somewhat of a leaf expert.” During one of the observed large group activities, the children reflected on what they had learned from the expert visitor. At another point in the project, the class had conducted and experiment involving placing a coffee filter and a leaf into colored water to observe the process of absorption. In addition to the expert visitors and the experiment, the children sang songs, read books, and watched videos about trees. One of the observed small group activities involved the children creating their own representation of a tree using a variety of materials. Francine planned to use the children’s 3D trees as one of the exhibits for a Family Night culminating project. Other exhibits she planned for the family night included: songs on the wall, observational drawings, pictures taken throughout the project, charts listing what they learned, and the tree on the wall, and a tree they had created for dramatic play. Francine also mentioned that the “children wanted to create tree decorations for the room, so now the room has trees hanging everywhere!”

**Observed large group activities.** Children in Francine’s class participated in a large group setting three times during the morning, once after free choice time for a morning meeting, once after snack for a large group activity, and again after outdoor play for a story and songs. For the purposes of this study, the large group activities that occurred after snack were observed because Francine indicated that was the large group where she most often integrated project related activities. Francine began each large group with what she called the “exercise coach”, which was one of the classroom jobs. The exercise coach had the option of a rolling a dice with
suggested exercises or the coach could create his or her own exercise. Then the coach rolled a six-sided die to determine how long the class would do each exercise. After completing two exercises selected by the exercise coach, the class would participate in a large group activity.

On the first observation day, Francine had the children move from the large group area to a large paper tree that was on the wall between the dramatic play center and the science center. Once the children were gathered “under” the tree, Francine facilitated a reflection and discussion of what the children had learned from the expert visitor who came to talk to them about trees the previous week. Then, Francine and the children sang a song about the parts of a tree to the tune of “Head, Shoulders, Knees, and Toes” that included leaves, branches, trunk, and roots. Francine spent the last five minutes of large group reviewing the questions the children had asked about trees and updating the paper tree with new knowledge. Some of the questions and answers discussed were: How do we make paper out of trees? Why do trees grow? What do trees need to grow? The children transitioned back to the large group area by pretending to be leaves and blowing to their name spots when Francine blew on them.

On the second observation day, Francine began large group by introducing children to the word “photosynthesis” and explained, “That is how plants make food.” She then led the children in a song about photosynthesis to the tune of “The Addams Family”:

Plants need food but can’t take it. Instead they have to bake it. It’s in their leaves they make it. In photosynthesis. In the leaves you cannot see, the chloroplasts so tiny, making food for energy, and here’s their recipe. Sunlight (snap, snap), carbon dioxide (snap, snap) and water. When it’s finally done, there sugar and oxygen. From water, air, and sun. That’s photosynthesis.
At the children’s request, they repeated the song a second time, and then Francine reviewed the word “absorption” and led the children in a discussion about how trees get water for photosynthesis. Then, Francine played a video on an iPad that showed how plants get water and the process of photosynthesis. After playing the video a second time, Francine closed large group by explaining that the children would be creating their own trees during small groups that day.

**Observed small group activities.** During the first observation, children were given a piece of paper, a clipboard, and a pen and were instructed to complete an observational drawing of the paper tree between the dramatic play center and the science center. Francine worked with children to only draw what they saw and not something they imagined because these were observational drawings. Francine repeated, “Draw the tree that you see” several times to remind the children to draw only what they could see.

On the second observation day, Francine provided children with a variety of materials (e.g., different sized boxes, pipe cleaners, feathers, stickers, pom pom balls, etc.) and instructed the children to make their own tree. “Okay, you are going to take the materials provided, knowing what you know now about trees, you get to go make your own tree.” The children were given complete freedom to create their trees however they would like, using any of the materials.

**Strategies to Promote Children’s Science Learning Opportunities**

**Planning for authentic and meaningful experiences.** Francine’s score of 32 out of 34 on the PA fidelity checklist indicates that she implemented the tree project with 94% fidelity. When asked why she chose the topic of trees for her class to investigate, Francine said that she took the children outside and did observational drawings because she “wanted to notice what they saw and what was of interest to them.” She collected the observational drawings and tallied the concepts within them and decided to focus an investigation on trees. She also thought trees
would be a good topic because it was autumn, so children would be able to notice and observe changes.

Francine discussed how she used the *Young Investigators* (Helm & Katz, 2011) book to guide her preparation and planning for the project and as a tool to have “a lot of discussions with [her] new co-teacher” because her co-teacher had no experience with the PA. Together, Francine and her co-teacher created an anticipatory planning web of the different directions a project about trees might lead, and they talked about the materials and resources they might utilize for the project. Francine mentioned that for this particular project the “materials [were] pretty much already provided because [the topic] was nature-based, and then nature took its course.” To find an expert visitor for the project, Francine reached out to networks on campus to see if she could find a” scientist who studies trees or things that relate to trees.” When discussing her project planning, Francine stated, “You follow the process, but then based on their interests, you follow their lead. As I saw what they were interested in, I just went with that. It’s all child led.” Francine also talked about her goals for children’s learning, which she said was about “understanding the process of what we do” during investigations. Francine hoped to encourage more scientific inquiry and work with children to conduct focused observations.

**Structuring the environment.** Francine’s classroom received an average rating of 3.8 out of 4 on the STERS (Chalufour et al., 2009). Located between the dramatic play center and the library areas, the science center had two tables set up with materials related to the project topic. On one table, there was a basket with some bark and a few branches placed strategically next to a large magnifying glass. On the other table there was a light viewer with a basket of leaves pressed in contact paper. When the contact paper was placed on the light viewer, children
were able to see through the leaves. Pictures of various science tools were posted on the wall, with a sign that reads, “Name that science tool!”

The wall between the science center and dramatic play center was covered in a large paper tree, and children’s questions about trees were written on the leaves. Lyrics to the two songs that children had learned about photosynthesis and fungus were posted on chart paper next to the paper tree. An entire wall near the science center was dedicated to project investigations. Under the “Phase 1” heading, there was an anticipatory planning web with the Francine’s ideas about different directions the project might lead. Under the “Phase 2” heading were pictures of children engaged with the expert visitor, as well as children’s observational drawings. The project topic was also integrated into other areas of the classroom. There were many books about trees in the library center, and the sensory table contained items from the children’s outdoor scavenger hunt.

**Quality of instructional interactions.** Overall, Instructional Support was in the middle range in Francine’s classroom, with higher quality interactions occurring during large group activities compared to small group activities (Table 13). Francine promoted concept development most often by providing children with opportunities to connect concepts with their prior knowledge and providing examples that are relevant to children’s lives. For example, during one large group activity, Francine facilitated a discussion about what the children had learned from the expert visitor and connected the concepts back to the children’s initial questions about trees. Francine’s highest-quality instructional interactions revolved around the quality of feedback she provided her students. She excelled at engaging in feedback loops and scaffolding student responses.

Francine: So, we found out what trees need to grow. They need five things. Hold up your hand. Who knows one thing trees need to grow?
Child 1: Seeds!
Francine: Well, they start out as a seed.
Child 2: Leaves!
Francine: They will grow the leaves, but what is something they need to grow?
Child 3: Branches!
Francine: Ooh, let’s start down low.
Child 4: Sun!
Francine (laughs): Okay, we’ll start up high. Sun. What else do trees need to grow?
Child 5: Ground
Child 6: Rain
Francine: Rain! Rain, they need water.
Child 5: And um
Francine: It’s something in the dirt that they can get
Child 1: Worms!
Francine: Well, the worms help spread this around. They’re called nutrients. So, put up a three. We’ve got water, sun, nutrients.
Child 2: Fiber
Francine: Oh, the fiber is what’s inside the trees. And then they need air. Just like we do. And then the nutrients are inside the soil. There are five things, so here’s one of our answers.

In the previous example, Francine acknowledged each child’s response, even when it was incorrect, but then she followed up with clarification or expansion on the child’s response.
Francine also provided quality feedback during small group activities. During the small group activity that involved completing an observational drawing, one child complained, “I cannot make a tree.” Francine responded, “Hmm, so what shape does the trunk look like? Does it look
like a rectangle, a triangle, or a circle?” In this manner, Francine provided the child with a starting point to begin drawing the tree.

Frequent conversations could be heard throughout the classroom, particularly amongst children, and Francine frequently asked questions to elicit children’s responses. Francine’s highest-quality language modeling occurred when she introduced advanced language to her students. For example, when they were singing the song about photosynthesis during large group, Francine talked about carbon dioxide.

Francine: Carbon dioxide (inhales and exhales), is right there.

Child 1: Breathe

Francine: When you breathe out, that’s carbon dioxide that you’re exhaling.

Child 2: Breathing

Francine: Well, it’s exhaling for us. So, when we breath in (inhales), we breathe in the oxygen. Plants need oxygen too, but they also need what we breathe out (exhales), carbon dioxide.

Child 3: It’s air

Francine: It’s in the air. So, can you see carbon dioxide?

Children: No!

Francine: Put your hand in front of you.

Francine and children breathe on their hands

Francine: Could you feel it?

Child 4: I feel it!

Child 5: Me too!

In this example, Francine introduced her students to a complex concept and made it relatable for children by connecting it with concepts that the children were familiar with (e.g., breathing). She
also made the concept more concrete by having children breathe on their hands to demonstrate that you cannot see carbon dioxide, but you can feel it.

Table 13

<table>
<thead>
<tr>
<th>CLASS Domain/Dimension</th>
<th>Large Group</th>
<th>Small Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional Support composite</td>
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<td>3.7</td>
</tr>
<tr>
<td>Concept Development</td>
<td>5</td>
<td>4.5</td>
</tr>
<tr>
<td>Quality of Feedback</td>
<td>5.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Language Modeling</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

Quantity of science content during instructional interactions. Table 14 shows the total number of child utterances coded as scientific inquiry, reasoning, and problem solving as defined by the Head Start ELOF (ACF, 2015) during two observed large group activities and two observed small group activities. Across the two activity settings, children’s scientific talk was one of the most frequently coded utterance types. During both small group activities, children were actively engaged in creating representations of their learning: one in the form of observational drawings and the other in the form of a 3D model of a tree. As children worked on these representations, they frequently and spontaneously used scientific talk when describing what they were doing as they worked (e.g., “Teacher, I’m getting—this is the bark,” “Now I need leaves,” “Teacher—this is—the glue is photosynthesis.”) When a child seemed lost or didn’t know where to start, Francine would provide an open-ended prompt (e.g., “What are some things that could draw”), which led to more scientific talk. Francine would also prompt children to describe their work (e.g., “What is all of that on your tree? What are you making?) if they weren’t already doing so. Another aspect of Francine’s planning that promoted scientific talk was finding songs related to the project topic. For example, as children sang the “Roots, Trunk, Branches, Leaves” song, they engaged in scientific talk as they named the different parts of a tree. Children could also be heard engaging in scientific talk while watching the tree video no the
iPad. While some of the science utterances occurred as a result of planning and the environment, other utterances occurred through Francine’s use of language modeling and scaffolding. For example, when she introduced the word “photosynthesis”, Francine had the children repeat it after her. Francine also prompted scientific talk when she would directly ask children questions that required a specific response and then engage in a feedback loop until children arrived at the correct answer.

Francine: How do leaves get the water? Or how do the trees get the water?

Child 1: Rain!

Francine: It’s the rain, but what do they do to pull the water up? What was that big word?

Child 2: Straw!

Francine: It’s like a straw.

Children: Photosynthesis!

Francine: Oh, that’s how they make food. (Sounding out word) Ah-b

Children: Absorbing!

Francine: Absorbing! Absorption! Absorb. It has to absorb the water.

After children’s scientific talk, the next most frequent utterances involved observing and describing observable phenomena during small group activities. The comments children made as they were creating their representation were double coded as both scientific talk and describing because children were specifically describing parts of the tree as they “represented observable phenomena with pictures, diagrams, and 3-D models” (ACF, 2015). Francine promoted this science goal by simply providing children with the time, space, and materials to represent their knowledge of trees.
While the small group activities offered many opportunities to describe and represent, the large group activities provided children with opportunities to “draw conclusions, construct explanations, and verbalize cause and effect relationships” (ACF, 2015). Francine facilitated a discussion and reflection on what the class had learned from the expert visitor by repeating some of children’s initial questions and then prompting children to share what they had learned.

Francine: How do we make paper out of trees? Who remembers?

Child 1: I know! I know!

Child 2: Water!

Francine: Hold on. What do we have to do first?

Child 3: Um, first we need to, um, chop.

Francine: Chop down the tree.

Child 4: Then we need to cut it just a little bit.

Francine: Yeah, they had to shred it because inside trees is what? (Sounding out) f-i-b

Child 1: Fiber!

Francine: Fiber, that’s right! And then somebody said water. What did they do with the water?

Child 2: They soak it, and then they do it into tiny pieces.

Francine: That’s right.

Child 3: And then that’s how they make paper.

Francine: That’s right. And so, when it was chopped into little pieces and they had all the water and they would spread out the fibers once it dries.

Child 4: They comed apart and then put it together.
In the previous example, Francine again engaged in feedback loops to prompt children’s utterances and scaffold children’s explanation of how paper is made from trees. Providing children with opportunities to reflect on their learning also prompted them to ask new questions. For example, after reviewing how paper is made from trees, one child asked, “How do they make the hard paper?” Later, during a discussion about leaves falling to the ground and turning to mulch another child asked, “How does that happen?”

Table 14

<table>
<thead>
<tr>
<th>Head Start ELOF Goal</th>
<th>Large Group (40 min)</th>
<th>Small Group (37 min)</th>
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<tr>
<td>Child observes and describes observable phenomena</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>Child engages in scientific talk</td>
<td>23</td>
<td>21</td>
</tr>
<tr>
<td>Child compares and categorizes observable phenomena</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Child asks a question, gathers information, and makes predictions</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Child plans and conducts investigations and experiments</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Child analyzes results, draws conclusions, and communicates results</td>
<td>12</td>
<td>0</td>
</tr>
</tbody>
</table>

*Note.* The time listed for each activity setting is the total amount of time across two observations.

**Cross Case Analysis**

This section begins with a contextual comparison of the teachers, classrooms, and projects in this study. Then, the quantitative data and key themes that emerged across all cases are presented for each research question. This section concludes with specific strategies teachers used to promote children’s scientific inquiry, reasoning, and problem-solving skills as defined by the Head Start ELOF (ACF, 2015).

**The Teachers**

Overall, the teachers in this study were highly educated, with four out of six participants holding a graduate degree. Their experiences in the classroom varied widely, with one having as few as two years teaching experience and another having thirty-six years of total experience. Likewise, their experience as a lead preschool teacher varied from one year to ten years. Most of
the teachers in this study had received formal training at a multi-day institute, and the number of projects teachers had completed by the time observations began ranged from four to twelve. As indicated in Table 15, all of the teachers saw great benefits of teaching science in preschool, and they were generally comfortable teaching it. A few of the teachers perceived challenges, primarily related to the amount of time it takes to plan science experiences and having enough time in the day to teach science.

**The Classrooms**

Four of the classrooms in this study were located in a half-day community-based preschool program, while the other two classrooms were in a full-day university child development laboratory school. The classrooms in the community-based program all had one lead teacher and two to three paraprofessionals. In contrast, the classrooms in the university child development laboratory school each had two fully licensed teachers. Another difference between the two settings is that the community-based program was fully inclusive, and each classroom had anywhere from one to three children on the Autism Spectrum or with a behavioral intervention plan. The class sizes at both programs were similar with about 13-15 children in each community-based classroom and 18 children in the lab school classrooms.

All of the classrooms in this study followed a similar daily schedule with an average of 25 minutes spent in each large group and small group activity. Each classroom also had at least one hour devoted to free play, as well as time spent playing outside. Although not a focus of this study, it is important to note that the overall quality of all the classrooms in this study was high. Consistent with other research using the CLASS (LoCasale-Crouch et al., 2007), the classrooms were highest in quality in emotional support and classroom organization, and lower in instructional support. Average scores on emotional support ranged from 5.9-6.6, and average
scores on classroom organization ranged from 5.8-6.6. Average scores on instructional support are reported in Table 15 and discussed in the teacher interaction portion of this analysis.

The Projects

All of the projects in this study were nature-based and often related to the season at the time of the project. For example, the projects in the spring included bugs, insects, flowers, and pets. Likewise, the projects in the fall focused on trees and chipmunks. All of the projects were in the Investigation Phase (Phase 2) of the PA at the time of observations, but some classrooms were just beginning this phase while others were making plans to transition to the Culminating Phase (Phase 3).

Strategies to Promote Children’s Science Learning Opportunities

How do teachers plan for authentic and meaningful experiences? Teachers varied greatly in how accurately they implemented the PA, with scores ranging from 71%-94% on the fidelity checklist. Despite these differences in implementation, three themes emerged across cases as key strategies for planning authentic and meaningful experiences.

Theme 1: Children’s interests and questions guided the planning process. All of the teachers mentioned choosing their project topic based on observations of children’s interests, such as hearing children begin to talk about bugs outside or seeing children playing pet store in the dramatic play center. After determining an initial project topic based on children’s interests, all of the teachers planned specific focusing events to introduce children to the project topics and to gauge the children’s continued interest in the topic. They also all assessed and recorded children’s prior knowledge on the topic in the form of a web or a list that was posted on the classroom wall, and they worked with children to formulate questions for investigations. Some teachers split children into investigation teams, whereas others focused on the questions of the
group as a whole. Regardless of their specific method for helping children formulate questions, all of the teachers talked about how the children’s questions guided their planning for the project.

**Theme 2: Teachers engaged in an anticipatory planning process.** All of the teachers discussed some form of anticipatory planning, and the two teachers with the highest implementation fidelity scores stated that they used the *Young Investigators* book (Helm & Katz, 2011) to guide their planning. Several of the teachers mentioned that they planned with another teacher or they consulted another teacher while planning. Another commonality across teachers was their focus on inquiry and science process learning goals, as well as their intentions to integrate Teaching Strategies GOLD (Heroman et al., 2010) objectives into the project. Many teachers specifically mentioned creating an anticipatory planning web to explicitly link project activities to student learning objectives.

**Theme 3: Teachers considered the availability of authentic resources.** A key aspect of the planning process for all the teachers was considering the resources they would need for the project, both in terms of materials and possible expert visitors or field site visit locations. Many teachers discussed searching specifically for books related to the project topic and materials that children could hold and manipulate. When considering resources for expert visitors or field site visit locations, the teachers talked about networking locally. Teachers at both the community-based preschool and the lab school utilized the university by inviting expert visitors related to their projects. Teachers also utilized local stores as free field site visit locations, such as the pet store and the garden supply store.

**How do teachers structure the environment?** The quality of the science environment in classrooms in this study ranged from 2.8 to 3.8 out of 4 on the STERS (Chalufour et al., 2009).
Three themes emerged across cases as successful strategies for structuring a high-quality science environment.

**Theme 1: Teachers provided children with authentic materials and resources.** All of the classrooms had at least some authentic materials related to the project for children to either explore or observe. These materials included both living organisms (e.g., caterpillars, praying mantis, tadpole) and items that could be manipulated (e.g., seeds, corn cobs, leaves). Teachers also provided children with authentic environments for exploration in the form of field site visits, such as a visit to a local pet store or garden supply center. Other teachers provided authentic resources in the form of expert visitors, such as the university bug zoo.

**Theme 2: Teachers integrated project-related books.** Many teachers mentioned project-related books as an essential resource in their classrooms. Most teachers read aloud books related to the project during large and small group activities. For example, one class read *Bugs are Insects* (by Anne Rockwell and Steve Jenkins) during an end of the day interactive read aloud, and another class read *A Cat’s Day* during a literacy-focused small group activity. Many more books related to the project topic were located in each classroom’s library area for children to explore during free choice time.

**Theme 3: Teachers posted charts with children’s prior knowledge and questions.** All of the classrooms had charts on the wall that listed children’s prior knowledge, as well as their questions about the project topic. Some of the prior knowledge charts were written in the form of lists, while others were webs of children’s knowledge. Some of the classrooms included question charts that were based on questions from the class as a whole, while other classrooms included several individual charts with questions from each investigation group.
Which teacher interaction strategies lead to high quality instructional support? The overall quality of instructional support across all observed large and small group activities in these classrooms ranged from 3.2 to 5.6 on a 7-point scale. Three key themes emerged across cases as successful strategies for providing high-quality instructional support.

**Theme 1: Teachers connected concepts to children’s prior knowledge and to their lives.**
Teachers in this study could frequently be heard relating the current activity to children’s prior knowledge. For example, while children were brainstorming ideas to create a burrow for the dramatic play area, one teacher related their suggestions back to what they had learned about burrows. Teachers also consistently related concepts to children’s experiences at school. While looking at a picture of a butterfly in a book, one teacher questioned, “I wonder if [our butterfly] is going to look like that?” Similarly, during a discussion about caterpillar feet during large group, one teacher said, “This morning one of our friends—we were wondering if our caterpillars in our caterpillar jar have feet.” In addition to connecting concepts to children’s school experiences, teachers also connected to children’s home lives. For example, during a pet project, one teacher referred to children’s pets at home and asked questions to help children connect their learning to their own pets.

**Theme 2: Teachers scaffolded children’s learning through extended feedback loops.**
Most teachers in this study provided the highest quality instructional interactions through their quality of feedback. Teachers consistently challenged children’s incorrect responses and scaffolded them to the correct answer by asking follow-up questions. For example, when asking children how trees get water, one child responded, “Rain!” The teacher followed up that response by saying, “It’s the rain, but what do they do to pull the water up? What was that big word?” Rather than simply providing the child with the answer, the teacher engaged the child in an
extended feedback loop that involved a back and forth conversation until the child arrived at the word “absorption”. Teachers also engaged in extended feedback loops by clarifying children’s responses. For example, when talking about food to buy for a pet, one teacher asked children, “What kind of food would we need?” After one child said, “Cat food”, the teacher asked the child to clarify the two different kinds of cat food. When the child responded, “Hard and soft food,” the teacher asked follow-up questions to clarify the child’s response until the child said, “dry and wet food.”

**Theme 3: Teachers repeated and extended children’s responses.** Teachers consistently repeated children’s responses, both during large group activities and during individual interactions. One teacher used the strategy of repeating children’s responses to encourage further discussion. For example, when a child asked, “Why are they called daddy long legs?”, the teacher responded by repeating the child’s question and then asking the other children for their ideas. She then repeated each subsequent idea, without affirming a correct response, which led to even more discussion. Teachers also expanded children’s responses to include more language. When one teacher asked children what they might want to collect on a walk, one child responded, “Some chipmunks.” The teacher expanded this child’s response by saying, “Well, I think if we had some acorns, we could probably find chipmunks.

**Which teacher interaction strategies lead to children’s scientific utterances?** The total number of child utterances coded within each Head Start ELOF (ACF, 2015) science inquiry goals varied greatly between classrooms and activity settings. For each science goal, the cases with the highest number of utterances were analyzed to determine the most effective strategies for eliciting children’s utterances with regards to that specific goal.
**Goal P-SCI 1: Child observes and describes observable phenomena.** Teachers used a combination of environmental and intentional interaction strategies to elicit children’s descriptive and observational utterances. By providing children with time, space, and materials to represent their knowledge, teachers afforded children opportunities to “represent observable phenomena with pictures, diagrams, and 3D models” (ACF, 2015, p.62) and to talk about their learning. Teachers’ use of authentic materials and books related to project topics also prompted many spontaneous observational or descriptive utterances. Teachers elicited the most utterances when they used intentional interaction strategies in combination with the environment. One successful strategy was to use self-talk to model observations (e.g., “I think it looks like…”) and then ask children to share their thoughts (e.g., “What do you think?”). Another successful strategy to elicit these types of utterances was to show children photos or videos related to the project topic and prompt children to share their observations (e.g., “What do you see?”, “What do you notice?”). One teacher elicited even more utterances by acknowledging each child’s response and asking the child to describe more (e.g., “What else do you see?”, “What else do you notice?”).

**Goal P-SCI 2: Child engages in scientific talk.** Teachers used a combination of closed and open-ended questions to elicit children’s scientific talk. Several teachers specifically asked closed-questions when attempting to elicit science or project-related vocabulary words (e.g., “What do you call it…?”). If children did not provide the correct word, teachers would engage in extended feedback loops to scaffold children to the correct answer. Teachers also used open-ended questions to engage children in scientific talk around science topics or processes (e.g., “How do they stay warm?”). The most successful strategy teachers used to elicit children’s
scientific talk was to simply prompt children to talk about what they had learned (e.g., “Tell us about…”).

**Goal P-SCI 3: Child compares and categorizes observable phenomena.** Children’s utterances related to comparing and categorizing were primarily elicited through the structure of the activity. For example, children quantified similarities and differences during an activity when they were instructed to measure flower stems and determine which stem was the tallest. Likewise, children “sorted observable phenomena into groups” (ACF, 2015, p.63) when they were instructed to categorize seeds. An important strategy the teacher used in both of these activities was to query children’s thinking by asking them to explain how they sorted seeds or how they determined which flower stem was the tallest. By querying children’s thinking about their comparisons and categorizations, the teacher specifically elicited utterances related to this goal.

**Goal P-SCI 4: Child asks a question, gathers information, and makes predictions.**

Many of the children’s utterances related to this goal were spontaneous in response to the availability of authentic materials. For example, children asked questions about the live organisms in their classrooms, and they had many questions about the seeds they were sorting. Teachers were able to elicit additional questions by providing children with opportunities to voice their wonderings and using wait time to ensure children had enough time to process and verbalize their thinking. One teacher acknowledged children’s questions by writing them down on chart paper for everyone to see, which seemed to encourage children to ask more questions. Teachers primarily elicited children’s predictions by directly asking, “What do you think is going to happen?” These types of questions were most common during read alouds.
**Goal P-SCI 5: Child plans and conducts investigations and experiments.** One teacher elicited children’s utterances related to this goal by providing children with opportunities to “use tools to observe, gather, and record data.” This teacher provided children with iPads to take pictures and videos while investigating pets at a local pet store. Another teacher elicited utterances related to planning by providing children with opportunities for brainstorming and sharing their ideas about how to create a chipmunk burrow.

**Goal P-SCI 6: Child analyzes results, draws conclusions, and communicates results.** Teachers primarily elicited children’s utterances related to this goal by providing children with opportunities to discuss and reflect on their learning. For example, several teachers facilitated large group discussions after field site visits or visits from experts. By asking open-ended questions during these discussions (e.g., “What would be important to tell someone about…?”), teachers prompted children to communicate their thoughts about the results of their investigations. Another successfully strategy one teacher used was to review children’s initial questions with them and then prompt children to discuss what they had learned about each question. By reminding children of their initial questions, this teacher helped children to link the beginning and end of the inquiry cycle.

<table>
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<tr>
<th>Case</th>
<th>P-TABS: Benefit</th>
<th>P-TABS: Comfort</th>
<th>P-TABS: Challenges</th>
<th>CLASS: Instructional Support</th>
<th>STERS</th>
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<td>Overall</td>
<td>4.9 (0.1)</td>
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<td>3.9 (0.8)</td>
<td>3.2 (0.5)</td>
<td>80% (11%)</td>
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*Note. CLASS mean scores are across all observed large and small group activities*
CHAPTER 5. DISCUSSION

This collective case study explored how six teachers in PA classrooms promoted science learning opportunities for preschool children. Guided by theoretical tenets from Dewey, Piaget, and Vygotsky, the main purpose of this research was to examine how the teachers planned for authentic and meaningful experiences, how they structured the environment, and how they interacted with children when guiding explorations. Data from classroom observations, audio recordings of large and small group activities, and teacher interviews and questionnaires were analyzed to determine specific strategies teachers used while implementing the PA to promote preschool children’s scientific inquiry, reasoning, and problem-solving skills. Each case was analyzed and described individually to develop a thorough understanding of each teacher’s context and to provide “thick description” (Denzin & Lincoln, 2011) of the specific strategies that each teacher successfully used to promote science learning opportunities in her classroom. The detailed within-case analyses provided specific examples of these strategies as they occurred within the natural classroom context. A cross case analysis was conducted to examine the transferability (Bloomberg & Volpe, 2016) of successful teaching strategies in similar contexts and to determine which strategies were most successful for promoting preschool children’s science learning opportunities. Data were also analyzed across cases to explore the overall feasibility and effectiveness of implementing the PA to promote children’s early science skills.

This chapter begins with a discussion of the overall quantitative findings from the cross-case analysis, followed by specific recommendations for preschool teachers to promote high-quality science learning opportunities for their students. The chapter concludes with a discussion of limitations of this study and implications for future research.
Feasibility and Effectiveness of Implementing the PA to Promote Science Learning Opportunities

The developers of the PA recognize that “learning how to guide projects is a journey, often a long journey” (Helm, 2015, p. 1). The teachers in this study were at the beginning of this journey, with just one to three years of experience with implementing the PA in their classrooms. Although teachers varied considerably in how accurately they implemented the PA, with scores ranging from 71%-94% on the fidelity checklist, it is important to note that the two teachers who implemented with the highest fidelity (94%) specifically mentioned using the *Young Investigators* (Helm & Katz, 2011) PA book to guide their planning. This is important when considering the overall feasibility of implementing the PA because teachers can use this inexpensive and widely available resource to immediately begin using this pedagogical approach in their classrooms.

The overall effectiveness of using the PA to promote science learning opportunities also varied across classrooms. The quality of the science environment in classrooms in this study was mostly “adequate” and ranged from 2.8 to 3.8 out 4 on the STERS (Chalufour et al., 2009). Likewise, the quality of instructional support varied considerably across classrooms, with scores ranging from 3.2 to 5.6 on a 7-point scale across all observed large and small group activities. Notably, when compared to the national average of 2017 Head Start grantee classrooms across the three CLASS domains, the classrooms in the current study scored similarly in the Emotional Support domain (current study: $M=6.32, SD=0.3$; Head Start: $M=6.07, SD=0.3$) and higher in both the Classroom Organization (current study: $M=6.20, SD=0.3$; Head Start: $M=5.83, SD=0.4$) and Instructional Support (current study: $M=3.88, SD=0.7$; Head Start: $M=3.0, SD=0.5$) domains (ACF, 2017). The classrooms with the highest quality instructional support in
this study were a full two points higher on the seven-point scale. These higher scores are likely due to the fact that when implemented with high fidelity, the PA naturally includes many of the elements assessed in the Instructional Support domain. For instance, the Concept Development dimension of Instructional Support includes indicators for analysis and reasoning (e.g., problem solving, prediction, experimentation), creating, integration, and connections to the real world.

When the PA is implemented with high fidelity, teachers provide children with many opportunities to problem solve as they investigate to find answers to their questions. They also provide children with opportunities to create when they ask children to complete observational drawings and represent their learning through culminating events. Because project topics are developed from student interests, they naturally relate to students’ lives and are connected to the real world. Although implementing the PA appears to be an effective way to promote science learning opportunities for preschool children, the overall quality of the science environment and instructional support could be improved if teachers are supported to intentionally and more frequently engage in a few specific teaching strategies that were observed in this study.

**Recommendations for Practice**

Teachers in this study used numerous strategies to promote children’s science learning opportunities in their classrooms. The four recommendations described in this section are a combination of those strategies that resulted in the highest quality science learning opportunities across all of the classrooms, as well as the most scientific utterances by children. The identified strategies were then compared to indicators on the PA implementation fidelity checklist, STERS, and CLASS to bring to light missed opportunities to promote high-quality science learning opportunities. These recommendations include specific strategies that are small changes teachers can make in their planning, in the environment, and in their interactions with students that will
ultimately improve the quality and quantity of science learning opportunities afforded to their students.

**Help Children Make Connections**

Research on the science of learning has demonstrated the importance of integrated experiences to deepen understanding of concepts and transfer of new knowledge (NRC, 2000; Lipson, Valencia, Wixson, & Peters, 1993). For this reason, integration and real-world connections are important indicators of Concept Development in the Instructional Support domain of the CLASS (Pianta et al., 2008). Teachers can help children make connections in their learning by integrating projects across the curriculum, within centers, and with family involvement.

Although all of the teachers mentioned integrating the project with the curriculum, few successfully did so during observations. Most often large and small group activities were either focused on the project topic or focused on discrete learning objectives. A few teachers attempted to integrate the project topic with math by using manipulatives related to the project, however, the teachers focused narrowly on the math objectives and did not provide opportunities for discussion related to the project. When teachers authentically integrate the project topic with learning objectives in specific curricular areas, they provide children with opportunities to connect and apply their knowledge from different domains. For example, one teacher successfully integrated the project with literacy by using a project-related book to teach reading skills during a small group activity. By using a book related to the project topic, the teacher was able to facilitate a conversation about the project while simultaneously working on the literacy objectives. In this example, children were able to make connections between what they had been learning about pets and apply that knowledge to their reading skills. As was the case with this
example, teachers must intentionally plan these cross-curricular connections to be successful. One strategy suggested by the PA developer and utilized by this teacher is to “find authentic opportunities to integrate standards” with project concepts (Helm, 2015, p. 66) and write them on the anticipatory planning web. This step in the planning process is particularly important because an integrated curriculum is not only important for helping children make connections, but it is also a key strategy for teachers to support multiple learning goals across domains in a very busy day.

Teachers can also help children make connections by integrating the project into centers. The value of play in children’s development and learning is well established as an important mechanism for children to connect their learning in a way that is meaningful to them (e.g., Bodrova, 2008; Fromberg, 2002; Hirsh-Pasek, 2009; Isenberg & Quisenberry, 2002; Rushton, Juola-Rushton, & Larkin, 2010). When teachers provide materials in centers that are integrated with the project topic, they provide children with opportunities to make connections related to their understanding of the project topic and “incorporate what they have learned about a topic in using symbolic tools and higher order mental functions” (Helm, 2015, p. 27). For example, by creating a burrow with children for the dramatic play area, one teacher was able to support children’s understanding of chipmunk habitats, which would then be reinforced each time they played in the burrow. By structuring the dramatic play center as a garden center, another teacher was able to help children make connections between their learning about flowers and gardens as they pretended to plant seeds and grow flowers in their garden.

Perhaps one of the most important areas where teachers can help children make connections is at home. The need for teachers to link classroom learning to students’ home lives is supported by core learning principles regarding the importance of family involvement
The PA offers many opportunities for family involvement, such as utilizing family members as expert visitors, requesting material donations related to the project topic, or simply inviting families to the culminating event. All of these strategies require ongoing communication between the teacher and the family about the project, which will inevitably lead to discussions and connections with the project between children and their families at home. One teacher in this study effectively involved families by utilizing families as expert visitors for a project on pets. In addition to the discussions that occurred during the visit in the classroom, these families likely had conversations about the pet project at home.

**Help Children See Their Learning**

Teachers who intentionally made science learning visible for the students in their classrooms had the highest quality science environments overall. One strategy teachers used to make science learning visible was to provide opportunities for children to represent their learning. When teachers provide children with the time, space, and materials to represent their knowledge, they support children’s concept development by engaging them in creative processes, such as brainstorming, planning, and producing. Children display these higher-order thinking skills as they plan and then produce their representations. Teachers also support children’s problem-solving skills when they provide children with a wide variety of open-ended materials to represent their learning (Daly & Beloglovsky, 2014). For example, when children in one classroom were given a variety of materials to represent their knowledge of trees, the teacher promoted problem solving by saying, “Alright, you have quite a bit of supplies. Let’s think about our process. You need your roots, trunk, branches, leaves. How are you going to put all of that together?” Children in this classroom had to problem solve how they could use the provided materials to represent what they had learned about trees.
Observational drawings are another effective strategy teachers can use to provide opportunities for children to represent their learning. Teachers can specifically use observational drawings as a strategy to help children notice and describe details in observable phenomena, which is the first science learning goal in the Head Start ELOF (ACF, 2015). It is important to note that observational drawings should be conducted while children observe authentic materials and that the representations should be children’s own ideas. Out of the observational drawings that were observed during large or small group activities in this study, very few were conducted while the children were observing authentic materials. Children were observed drawing from a representation in the form of a model or picture, rather than drawing their observations of a real object. A related issue occurred in the fact that some of the representations by children were not true renderings of their own concepts or ideas. For example, while completing an observational drawing, several teachers told children where and how to label specific parts, rather than letting the children describe their drawings and explain their own thinking. In order to help children see their learning, teachers need to provide children with opportunities to authentically represent their own ideas based on observations of real objects.

Documentation is another important strategy teachers can use to make science learning visible for their students. Documentation occurs when a teacher “collects, analyzes, interprets, and displays evidence of learning” (Helm & Katz, 2011, p. 66) and can take many forms, such as anecdotal notes, collection of children’s work, photographs, and audio or video recordings. Documentation is an essential component of effective teaching because it provides evidence of children’s learning and should be used to guide planning (McAfee, Leong, & Bodrova, 2004). Indeed, all of the teachers in this study mentioned using results from assessment and documentation of children’s learning to inform their planning. Most of the teachers were
observed using developmental checklists, taking anecdotal notes or videos, and collecting work for children’s individual portfolios. These teachers all engaged in the process of collecting, analyzing, and interpreting evidence of children’s learning, but they missed opportunities to display evidence of learning. According to Helm and Katz (2011) good documentation is ongoing and captures children’s active exploration and interactions with adults, other children, and materials. They note that teachers who are new to project work tend to gather documentation throughout a project, but they wait until the project is over to share documentation of children’s learning. This is problematic because when a project narrative is displayed throughout a project, children and adults are able to see the progress the class has made in investigating the topic and engage in metacognition and reflection on their learning. For example, one classroom had ongoing documentation of the project progression in the form of photos posted on the wall. By posting photos of children actively engaged in project investigations, the teacher provides opportunities for children to spontaneously engage in metacognition and reflect on their learning.

**Help Children Communicate Their Learning**

The second guiding principle in the Early STEM Matters Policy Report states, “Representation and communication are central to STEM learning” (Early Childhood STEM Working Group, 2017, p.14). Providing children with opportunities to represent their learning not only helps to make learning visible as previously mentioned, but it also serves as a mechanism for children to communicate their understandings. Teachers can further promote children’s communication about their learning by asking them to describe their representations (e.g., “Tell me about your picture.”) In addition to these hands-on representational activities, children also need opportunities to verbally reflect and share their learning with one another (Eshach & Fried, 2005). In fact, the most successful strategy teachers in this study used to elicit
children’s scientific talk and utterances related to the goal of communicating results was to simply provide children with opportunities and ample time to discuss and reflect on their learning related to the project topic. Teachers facilitated these discussions by prompting children with invitations to share (e.g., “Tell us about…”) and by asking open-ended questions (e.g., “What do you think?”). Some teachers also used documentation in the form of photos and videos to refresh children’s memories for these discussions. Through these opportunities for sharing with one another, children are able to extend their thinking and clarify their ideas (Campbell, Jobling, & Howitt, 2015). Children also begin to learn that others might have different ideas than they do and that there is not always one right answer.

An important aspect in helping children communicate their learning is to provide opportunities for children to reason about their experiences and explain their thinking (Lee, Quinn, & Valdés, 2013). When teachers query children’s responses or prompt them to explain their thinking, they engage children in metacognition and communication about their learning. For example, one teacher queried children’s thinking by asking them to explain how they sorted seeds. Children first had to engage in metacognition as they reflected on their sorting, and then they had to verbally communicate their thinking. This type of intentional communication about learning not only supports children’s higher-order thinking skills, but it also meaningfully contributes to children’s language development.

Teachers can further support children’s science and language development simultaneously by modeling the use of advanced language and introducing children to a variety of new words (Brenneman, Stevenson-Boyd, & Fred, 2009). These new words should be connected to familiar words and ideas, so children are able to arrive at their own understanding of word meanings (Harris, Golinkoff, & Hirsh-Pasek, 2011). Although a few teachers in the
current study introduced new words related to their project topic, many teachers used very simplistic language when engaging with children. The highest quality instructional interactions related to language modeling occurred when teachers introduced children to challenging words and helped build children’s understanding by connecting these new words to words or ideas familiar to children. By providing children with the vocabulary to describe and explain scientific processes and content, teachers support children in their ability to communicate their learning. Moreover, research suggests that exposure to uncommon vocabulary words predicts vocabulary development (Dickinson, Golinkoff, & Hirsh-Pasek, 2010), which in turn predicts later reading achievement (Dickinson & Porche, 2011). As emphasized in the landmark word gap study by Hart and Risley (1995), these language learning experiences are especially important for children from low-literacy environments.

Help Children Engage in a Cycle of Scientific Inquiry

Although the PA includes all of the elements of the scientific inquiry cycle (i.e., formulate and investigate questions, collect and analyze data, and reflect), teachers need to be intentional in authentically involving children in each stage. All of the teachers in the current study provided opportunities for children to formulate questions, but teachers did not involve children in planning investigations of their questions or engage them in predicting outcomes. Teachers can intentionally ask questions to help children develop these process skills. For example, rather than planning investigations to answer children’s questions, teachers can ask, “What do you think we could do to find out?” By providing children with opportunities to plan and predict, teachers simultaneously engage children in the scientific inquiry cycle and promote concept development.
Similarly, children were seldom observed using tools to observe, gather, and record meaningful data. Although all of the classrooms had a science center, most of the science centers were disorganized or included disparate materials unrelated to the project (e.g., magnetic toys, shells, and plastic animals). Only one science center had “materials and tools organized into conceptual groupings related to the current science study that [were] appealing and suggest[ed] particular purposes to children” (Chalufour et al., 2009). Relatedly, many of the science centers did not include science tools, or if they did include tools they were often limited to a balance and a few magnifying glasses. Teachers can encourage close observation of science phenomena and data collection by intentionally providing children with science tools that specifically aid observation (e.g., magnifying glasses) and support data collection (e.g., paper, clipboards, and pencils).

Teachers can also engage children in documentation and data analysis by making charts to help children see patterns and relationships as an investigation progresses. For example, one of the teachers in this study created a chart that compared four animals that children had been investigating across several characteristics (e.g., movement, diet, and habitat). As the teachers and children learned about each animal, the teacher would add the new information to the chart. By using this type of documentation, the teacher encouraged children to analyze data and look for patterns, which are important science process skills. Using documentation in this manner for data collection and analysis also helps make children’s learning visible to them.

To fully connect the stages of the scientific inquiry cycle, teachers need to intentionally review children’s initial questions and prompt them to communicate their learning about each question. Children in the current study were given ample opportunities to ask questions and to reflect on their experiences, but they were seldom asked to reflect specifically on their original
questions. Teachers can intentionally help children link the beginning and end of the inquiry cycle by asking, “What did you find out?” Documentation in the form of a K-W-L (Ogle, 1986) chart can be a useful tool to help children see the results of their investigations and relate them back to their original knowledge and questions about the project topic.

**Limitations**

Several limitations must be considered when interpreting the results of this study. Although all of the classrooms were in the Investigation Phase at the time of observations, some classrooms were just beginning investigations while others were transitioning to the Culminating Phase. The differences in the timing of project observations may have influenced implementation fidelity scores because some teachers had not yet planned for a field site visit or culminating event. A related limitation may have occurred due to the use of semi-structured interview questions regarding implementation. Teachers were asked open-ended questions, such as “How did you prepare for this topic?” to prompt a discussion about their planning process. Fidelity scores may have been higher if teachers had been directly asked about each item on the implementation checklist.

Another limitation of this study was the small number of observations that were completed in each classroom. Due to the nature of a multi-case study analysis, the present study does not provide an in-depth analysis of each teacher and classroom, but it does offer breadth of information that was used to compare across cases and increase the transferability of the study results to similar contexts.

There were also limitations with regards to measurement in this study. Due to time constraints and issues with gaining consent, the lead teacher in each classroom wore the LENA recording device instead of selected children as originally intended. This limited the amount of
data that could be collected regarding the classroom language environment, particularly concerning the quantity of teacher-child conversational turns. There are also limitations regarding reliability of the observational data because one researcher conducted all of the observations, so reliability checks were not conducted on the CLASS and the STERS data. Despite this lack of reliability checks, the researcher was a certified Pre-K CLASS observer and had completed formal training twice prior to beginning this study. Moreover, the researcher completed a re-certification process as data was collected.

**Future Research Directions**

In the Early STEM Matters Policy Report, experts called for more applied early STEM research “conducted in authentic early childhood settings that focuses on the effectiveness of early STEM programs, and that attends to specific early STEM teaching and learning challenges” (Early STEM Working Group, 2017, p. 34). The current study was an initial attempt to answer that call by providing an in-depth look into the strategies six preschool teachers used to promote science learning opportunities while implementing the PA in their classrooms. While the results of this study are promising regarding the feasibility and efficacy of implementing the PA to promote science learning opportunities, there is still much to learn about how the PA supports early science education.

Future research should compare the overall quality of the science environment and instructional support between PA and non-PA classrooms. A quasi-experimental design could provide empirical evidence of the impact of PA implementation on the quality of science learning opportunities afforded to preschool children. Relatedly, future research should directly measure children’s science outcomes to empirically test the relationship between PA implementation and children’s science learning. The *Lens on Science* assessment (Greenfield,
Dominguez, Greenberg, Maier, & Fuccillo, 2011) is a promising computer-adaptive direct assessment of science that was developed specifically for preschoolers in Head Start. The assessment includes questions about science practice skills, cross-cutting concepts, and science content from the four core domains of science (Physical Science, Life Science, Earth and Space Science, and Engineering design) as defined by the K-12 Framework for Science Education (NRC, 2012).

Additional research is needed to examine the feasibility and efficacy of using the PA to promote science learning opportunities with diverse populations of children. Researchers are beginning to explore the impact of implementation of the PA specifically for children with disabilities and children identified as at-risk (Alfonso, 2017; Beneke & Ostrosky, 2015; Harris & Gleim, 2008). Findings from these studies indicate that the PA engages and motivates diverse learners and has a positive impact on preschoolers’ play behaviors. The finding that children’s participation in project work resulted in positive gains in children’s language development (Beneke & Ostrosky, 2015) has important implications for children who are dual language learners. Future studies could extend this research by employing case study methodology to provide an in-depth understanding of the impact implementation of the PA has on diverse learners’ science and language outcomes.

Conclusion

There is currently a wealth of research available regarding how young children learn, but much of this research has not been adequately translated to practice. In 2004, experts at a workshop for mathematical and scientific development in early childhood cautioned against rushing the translation of research to practice too early and suggested that the gap could not be closed until “existing lines of research are evaluated systematically and integrated into a coherent
picture of development” (NRC, 2005, p. 34). Since that workshop, researchers have mapped out developmental trajectories for math (Clements & Sarama, 2014), but the process of mapping developmental trajectories for science is just beginning. Considering the most recent 8th grade science proficiency scores (NCES, 2012) and the research demonstrating the importance of early science education (e.g., Bustamante, White, & Greenfield, 2016; Early Childhood STEM Working Group, 2017; Kuhn & Pearsall, 2000; Nayfeld, Fuccillo, & Greenfield, 2013; NSTA, 2014), we cannot wait for research on developmental science trajectories to come to fruition before bridging the gap between research and practice. We specifically need applied research that identifies findings that are meaningful at a practical level. The results of this study demonstrate that the PA is a feasible and effective method preschool teachers can use to promote high-quality science learning opportunities for children in their classrooms.
References


APPENDIX A. INSTITUTIONAL REVIEW BOARD (IRB) APPROVAL

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
315-294-4156
FAX 315-294-4167

Date: 5/10/2016
To: Melissa Clucas

From: Office for Responsible Research
Title: Science Experiences in Preschool Classrooms
IRB ID: 16-198

Approval Date: 5/10/2016
Date for Continuing Review: 5/2/2018
Submission Type: New
Review Type: Full Committee

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- Use only the approved study materials in your research, including the recruitment materials and informed consent documents that have the IRB approval stamp.
- Retain signed informed consent documents for 3 years after the close of the study, when documented consent is required.
- Obtain IRB approval prior to implementing any changes to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- Immediately inform the IRB of (1) all serious and/or unexpected adverse experiences involving risks to subjects or others; and (2) any other unanticipated problems involving risks to subjects or others.
- Stop all research activity if IRB approval lapses, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- Complete a new continuing review form at least three to four weeks prior to the date for continuing review as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. Approval from other entities may also be needed. For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. IRB approval in no way implies or guarantees that permission from these other entities will be granted.

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 1138 Pearson Hall, to officially close the project.

Please don’t hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.
APPENDIX B. INTERVIEW PROTOCOL

1. Was this week’s science activity typical for your class regarding the:
   a. Amount of time usually spent on science per day?
   b. Kinds of learning experiences children have?
   c. Amount of time children are engaged in direct, hands-on experiences?
   d. Amount of time teachers spend talking with children about science experiences and ideas?

2. Why did you choose this topic? What are your goals for the children’s learning?

3. How did you prepare for this topic? How did you introduce the children to this topic?

4. What experiences (materials and activities) related to this topic preceded those I observed today?

5. What have you learned about children’s understanding of this topic up to this point?
   a. How have you learned this?
   b. Do you document learning in any way?
   c. How do you keep and use your information about children’s science learning?
   d. Do you use this information in planning? If so, how?

6. What additional experiences do you plan to provide related to this topic?

7. Can you explain why you sequence the experiences this way?

8. What are the most important strategies you use to support science learning?
### APPENDIX C. PROJECT APPROACH FIDELITY EVIDENCE TABLE EXAMPLE

<table>
<thead>
<tr>
<th>Elements Typical of Project Work</th>
<th>Score: 0 (absent)</th>
<th>1 (some)</th>
<th>2 (clear)</th>
<th>Evidence: I (interview)</th>
<th>O (observation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic was developmentally appropriate, curriculum connected, and worthwhile.</td>
<td>2</td>
<td></td>
<td></td>
<td>“Whenever I decide which one to do, I ask is it something they can hold or manipulate? With bugs it was broad enough that we could each go off in different directions, but focused enough that it was still relatable to them.” (I)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Topic connected to GOLD objectives, specifically in the areas of literacy/writing and math. (I)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Topic was integrated across curricular areas: sang songs about bugs-art, read books about bugs-literacy, labeled parts of bugs-literacy, sorted and classified toy bugs-math. (O)</td>
<td></td>
</tr>
<tr>
<td>Curiosity and engagement in topic was high.</td>
<td>2</td>
<td></td>
<td></td>
<td>Children were consistently engaged in all activities relating to the topic of bugs (O)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Children frequented science area to observe the caterpillars and ladybug, drew representations, and made up songs and dramatic play about butterflies (O)</td>
<td></td>
</tr>
<tr>
<td>Focusing events occurred.</td>
<td>2</td>
<td></td>
<td></td>
<td>Created common experience by using books during large group. (I)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Also caught a spider, put it in a jar, and set it on a table during free choice to see if children were interested. Then started putting bug materials in centers and invited children to bring their own bug catchers from home. (I)</td>
<td></td>
</tr>
<tr>
<td>Time for individual reflection on experiences with topic and opportunities to build background knowledge were included.</td>
<td>2</td>
<td></td>
<td></td>
<td>As a group, they listed out all the bugs they knew, and then the students got to choose from those bugs which ones they wanted to learn more about. (I)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Investigation groups (spiders, ladybugs, and butterflies) were formed based on children’s choice of which bug they wanted to explore. (I)</td>
<td></td>
</tr>
<tr>
<td>Teacher assessed and recorded prior knowledge.</td>
<td>2</td>
<td></td>
<td></td>
<td>Investigation groups got together and created a chart of what they already knew about their bug. Teacher recorded responses and chart is hanging on board at front of the classroom. (I &amp; O)</td>
<td></td>
</tr>
<tr>
<td>Activity</td>
<td>Frequency</td>
<td>Description</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-----------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anticipatory planning of concept and curriculum integration was recorded in web or list.</td>
<td>2</td>
<td>Looked at GOLD objectives when making the anticipatory web and also looking up a bunch of books to figure out what she could use, as well as considering who to contact for experts (I &amp; O)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children’s questions drove investigation (including higher-level questions by children).</td>
<td>1</td>
<td>Investigation groups worked together to create a chart about what they want to know about their bug. (O) Children drew representations of their questions to remember them when the insect zoo came to visit. (O) Few higher-level questions were asked by children. (O)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authentic artifacts were made available for investigation.</td>
<td>2</td>
<td>Teacher caught spider and ladybug to keep in classroom. Teacher ordered caterpillars, which are currently metamorphosing in the science center. (O) ISU bug zoo will bring bugs for hands-on investigation. (I)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Children had access to adult experts other than teachers.</td>
<td>2</td>
<td>ISU bug zoo is coming to talk about bugs and to bring bugs for children to investigate. (I)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ongoing documentation (photos of processes, not just products) was undertaken.</td>
<td>1</td>
<td>Did not see documentation in form of photos, but did see teacher keep children’s observational drawings for documentation purposes. (O)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field site visits happened.</td>
<td>2</td>
<td>ISU bug zoo coming to the preschool center. (I)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observational drawings and subsequent drawings were completed.</td>
<td>2</td>
<td>Children drew representations of bugs in a book and labeled body parts. (O) Children drew representations of their questions and will use when ISU bug zoo visits to remember their questions. (O) Children will draw what they learned from ISU bug zoo visit. (I)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provocations* were used by the teacher.</td>
<td>1</td>
<td>Although many activities were centered around the topic of bugs, often the focus of the activities was on discrete content-knowledge skills, with few opportunities for children to make wonderings visible. (O) Spider, caterpillars, and ladybug were intentional provocations. (O)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Representations by children were true renderings of their concepts/ideas.</td>
<td>1</td>
<td>While children did draw many representations, often the teacher was telling the children where or how to label specific parts, rather than letting the children dictate their own thinking. (O)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Children and teacher had opportunities for metacognition. | 1 | Teacher frequently demonstrated her own metacognition with self-talk saying things such as, “I wonder” and “I notice”. Children were occasionally queried to explain their thinking but not often. (O) 

There was a summarization or presentation activity of what was learned. | 2 | Thinking about doing a play using Eric Carle books: Very Hungry Caterpillar-butterfly investigation group, Grouchy Ladybug-ladybug investigation group, Very Busy Spider-spider investigation group. (I) 

Families had opportunities to be involved. | 2 | Children were encouraged to bring or create their own bug catchers from home. Families will be invited to the culminating event. (I) 

* Experience organized by an adult that will invite children’s curiosity and will make children’s interests and wonderings visible. There is always a clear intent behind a provocation.
## APPENDIX D. SCIENCE TEACHING AND ENVIRONMENT RATING SCALE (STERS) EVIDENCE TABLE EXAMPLE

<table>
<thead>
<tr>
<th>Elements of Science Teaching</th>
<th>Source of Evidence 1</th>
<th>Source of Evidence 2</th>
<th>Source of Evidence 3</th>
<th>Overall Score: 1-Deficient 2-Inadequate 3-Adequate 4-Exemplary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Create a physical environment for inquiry and learning (O)</td>
<td>Organization of classroom: (2) Science center on one side of a shelf next to the library area. The area is relatively small and may restrict number of children who can be engaged.</td>
<td>Placement and characteristics of materials and tools: (3) Some materials are related to current science study (e.g. live ladybugs and caterpillars, tub of plastic bus), but others are disparate items, such as magnetic toys. Tools are included, such as magnifying glasses and a balance. There are many science books related to the current topic available in the library center.</td>
<td>Content of displays: (3) Web of children’s questions are posted by investigation group, however these posters are hung on the wall above children’s eye-level.</td>
<td>3</td>
</tr>
<tr>
<td>2. Facilitate direct experiences to promote conceptual learning (O)</td>
<td>Structure of experiences (3): Science experiences varied in terms of level of engagement and direct experiences. Some activities involved reading from books and drawing, while others involved actually going outside and hunting for bugs or observing caterpillars in the science center.</td>
<td>Teacher-child interactions (3): Teacher facilitation focuses on children learning to observe, make observational drawings, and ask questions. Teacher often tells children to hold their thoughts and seldom follows up with them later.</td>
<td>On-going adjustment of environment and instruction (3): Teacher intentionally observes children’s science learning via quick checks, partner share, and having children complete observational drawings</td>
<td>3</td>
</tr>
<tr>
<td>3. Promote use of scientific inquiry (O &amp; I)</td>
<td>Teacher-child interactions: (3) Teacher encourages children to observe science topic and use of tools, such as magnifying glasses. Again, much of the teacher-child interaction is instructional or providing directions, rather than allowing opportunities for children to share and ask questions.</td>
<td>Collection and use of data (3): Teacher frequently uses observational drawings to encourage children to represent observations and ideas, however, teacher does not encourage children to analyze data and look for patterns. “I’ve been trying to incorporate more of their drawing and writing to give them more ownership.”</td>
<td>Use of science inquiry processes: (3) Teacher provides children with opportunities to ask questions but does not get input on how to investigate their questions. Rather teacher plans investigations and instructs children in how to investigate.</td>
<td>3</td>
</tr>
<tr>
<td>4. Create a collaborative climate that promotes exploration and understanding (O)</td>
<td>Efforts to engage children (3): Teacher encourages participation of all children, but at times is unresponsive to children or focuses on promoting her own ideas or instruction. Teacher seldom draws attention to similarities and differences in children’s observations and ideas.</td>
<td>Collaboration (2): At times children are encouraged to work together, such as during the bug hunt, but at other times they work independently, such as when drawing their questions. There are many missed opportunities for sharing of ideas among children.</td>
<td>N/A</td>
<td>2</td>
</tr>
<tr>
<td>5. Engage in extended conversations (O)</td>
<td>Selection of topics (3): Occasionally teacher will engage children in conversations about science activities, but other times conversations are close-ended with teacher question and student responses.</td>
<td>Varied opportunities (4): Teacher engages children in conversations throughout the day, including small-group, large-group and individual conversations.</td>
<td>Promotion of science learning (3): While most conversations lead toward science learning, they are not often extended conversations. Typically teacher question and student answer.</td>
<td>3</td>
</tr>
</tbody>
</table>
New words are introduced and discussed across classroom activities (e.g. learning the word chrysalis during large group, then applying to observations in science center, and observational drawings during small group).

Teacher typically offers children opportunities to define words before providing definition. (e.g. chrysalis, compliment)

Teacher shows excitement for big words calling them “Wow” words! Teacher frequently uses new words and acknowledges children’s use of “wow words”

### 7. Plan in-depth investigations (O & I)

**Goals for learning (3):**

Goals for learning are based on Teaching Strategies GOLD objectives and integrated across subjects.

**Extended time for learning (4):**

Project investigation is extended over time and investigations are intentionally sequenced (e.g. bug hunt to explore on own before expert visitors). Teacher provides plenty of free choice and exploration time each day.

**Teacher knowledge (3):**

Teacher has some knowledge of content being taught, but invites experts to come in and teach more.

### 8. Assess children’s learning (O & I)

**Goals for assessment (2):**

Stated learning goals are based on Teaching Strategies GOLD and are more general or focused on math and literacy; not very focused on specific science goals.

**On-going collection & documentation (3):**

Teacher assesses children in varied ways including quick checks, informal partner sharing, and collection of observational drawings. Teacher has limited physical evidence of science learning beyond children’s drawings.

**Teacher reflection (4):**

Teacher takes children’s ideas and questions into account and differentiates into project investigation groups.

### Total; Average

24; 3
## APPENDIX E. CONCEPTUALLY CLUSTERED CROSS-CASE ANALYSIS MATRIX

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Case A</th>
<th>Case B</th>
<th>Case C</th>
<th>Case D</th>
<th>Case E</th>
<th>Case F</th>
</tr>
</thead>
</table>
| **Planning for authentic and meaningful experiences** | - “hold or manipulate”  
- plan with others  
- hands on things to see  
- provide ownership  
- recurring experiences | - based on children’s interests  
- planning partner  
- anticipatory planning web  
- incorporate GOLD objectives  
- integrate with art  
- “opportunities to see the real stuff”  
- “use children’s questions to guide planning” | - based on children’s interest  
- use PA book to guide planning  
- inquiry focused learning goals  
- children’s ?s guide planning  
- local resources  
- include families | - planning partner  
- anticipatory planning web  
- science process goals  
- consider resources  
- integrate w/ TSG  
- children’s ?s guide planning | - based on children’s interest  
- anticipatory planning  
- integrate TSG  
- local resources  
- inquiry goals | - based on children’s interests  
- use PA book to guide  
- anticipatory planning web  
- local resources  
- inquiry/process goals  
- children’s ?s guide planning |
| **Structuring the environment**   | - prior knowledge chart  
- questions for investigation  
- authentic materials  
- outdoor learning env.  
- science tools  
- books | - prior knowledge chart  
- children’s questions  
- authentic materials  
- outdoor learning env  
- plastic bugs in small group  
- books | - integrate w/ dramatic play  
- field site visit to pet store  
- books  
- technology (iPads) | - integrate w/ dramatic play  
- integrate project materials in activities  
- field site visits  
- books | - prior knowledge chart  
- children’s questions  
- comparison chart  
- authentic materials  
- integrate w/ dramatic play  
- outdoor learning env.  
- books | - science center materials specific to project  
- science tools  
- wall dedicated to project investigation  
- integrated w/ centers  
- books |
| **Interacting with children**     |                                                                         |                                     |                                                                        |                                                                        |                                                                        |                                                                        |
| **Quality** | -link to prior knowledge  
-connect to children’s lives  
-extend responses  
-use advanced language | -repeat children’s why questions  
-link to prior knowledge  
-connect to children’s lives  
-ask follow-up ?s | -link to prior knowledge  
-connect to children’s lives  
-expand responses  
-encourage peer conversation/sharing  
-introduce new words  
-“Why do you think?” | -scaffolding  
-feedback loops  
-self-talk  
-repeat & expand student responses | -provide opp. to brainstorm  
-link to prior knowledge  
-connect to children’s lives  
-expand student responses | -link to prior knowledge  
-connect to children’s lives  
-feedback loops  
-scaffold responses  
-clarification/expansion of student responses  
-frequent conversation  
-use advanced language |
| **Quantity** | -observational drawings  
-closed and open ?s  
-“What do you notice?” | -use books to teach science words  
-activate prior knowledge  
-“I wonder…” | -small group rotations  
-model observations w/ self-talk  
-provide opportunities to share (“Tell us about…”)  
-ask follow-up ?s (“What else…?”)  
-“What do you notice?” | -small group rotations  
-structure of activity  
-explain thinking (“Why did you…?”)  
-authentic materials | -self-talk  
-repeat & extend student responses  
-follow up ?s  
-write down children’s ?s  
-wait time  
-provide opp to plan/create | -children represent learning  
-prompt to describe work  
-songs related to topic  
-provide time, space, materials  
-provide opp to reflect on learning |