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Science at the center: Meaningful science learning in a preschool classroom

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Abstract

Even though children are natural scientists, many preschools isolate and limit science, which can cause children to miss out on valuable learning experiences and school readiness skills. Additionally, minimizing science at the preschool level fails to set a solid foundation for K-12 science education. In this single case study, we focused on the experiences and daily work of one constructivist-oriented preschool teacher who utilized science-based guided play and emergent curriculum as vehicles for important aspects of preschool learning. Findings demonstrate that with careful planning and intention, science can be utilized as a context for nonscience preschool learning objectives outlined by the National Association for the Education of Young Children, such as socioemotional development and early literacy. Further, being purposeful about taking up children's ideas about science can lead to rigorous engagement in the three dimensions of science found in the *A Framework for K-12 Education* as well as the Nature of Science. What is notable in this case study is that the teacher did not fundamentally alter her instruction, nor did she take up a prescribed science curriculum; rather, she utilized children's science noticings and wonderings about the world to build meaningful learning experiences. In this way, we see the efforts and outcomes of this teacher being attainable by other

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preschool teachers. From these findings, we put forward the Integrated Preschool Science Framework that can be used by researchers and teacher educators to think more deeply about how placing science at the center of preschoolers' learning can provide rich opportunities for supporting preschools in multiple learning domains.

KEYWORDS

early childhood, emergent curriculum, guided play, preschool, science

"…as soon as children realize that they can discover things for themselves, their first encounter with science has occurred." (Tu, 2006, p. 245)

1 | INTRODUCTION

Children are natural scientists. They question, observe, investigate, experiment, and question again (Saçkes et al., 2011). Often, children readily participate in culturally and socially relevant science and sensemaking with their families in ways that build foundations for future science inquiry through playfulness and joy (Goldman et al., 2021; Junge et al., 2021). Children can gain skills and dispositions about science from their families that they then bring to more formal learning spaces (Keifert, 2021; National Academies of Science, Engineering, and Medicine, 2022). Engaging in science with young children has been shown to be beneficial in a multitude of ways (Borgerding & Raven, 2018). Science is a subject that provides children with opportunities to explore the world around them and to interact with content in a manner that is significantly different from reading, mathematics, or social studies (Bowman et al., 2001; Gelman & Brenneman, 2004). Additionally, early childhood science experiences have the potential to support children's intellectual and linguistic development (French, 2004), creativity (Mirzaie et al., 2009), strengthen executive functioning skills (Nayfeld et al., 2013), lessen gender and socioeconomic gaps in science learning (Leibham et al., 2013), lead to enhanced science learning in later grades (Eshach & Fried, 2005; Waldfogel & Zhai, 2008), and overall contribute to school readiness (Bustamante et al., 2018; Larimore, 2020).

National teaching and learning standards highlight the importance and need for science for young learners. Standards from the National Association for the Education of Young Children (National Association for the Education of Young Children, 2018) recommend activities that encourage observation, data collection and representation, and the communication of results, while the Head Start Early Learning Outcomes framework (U.S. Department of Health and Human Services, 2015) has a scientific reasoning learning domain that advocates for children to ask questions, plan and carry out investigations, and analyze data. *A Framework for K-12 Science Education* (National Research Council, 2012) articulates rigorous expectations for science learning in terms of practices, content, and connections across content, beginning with kindergarteners. Yet despite the known benefits of science for early learners, and in opposition to (early childhood) guiding policy documents, research shows that young children are not receiving adequate science instruction—particularly at the preschool level (National Academies of

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Science, Engineering, and Medicine, 2022). Instead, preschool classrooms often isolate, limit, or completely remove science from instruction altogether. For instance, preschool classrooms often have a "science center," just as they have a dramatic play area, art center, and writing center (Trundle & Smith, 2017). However, the science center usually consists of natural materials or objects for children to investigate in a hands-on manner (i.e., sand, leaves, rocks, wood slices, magnifying glasses) and no other connections or activities.

Research demonstrates the often-problematic nature of preschool science. A study of Head Start children showed lower scores in science readiness than in every other subject area (Greenfield et al., 2009; Lee, 2005) and it has been noted that preschoolers spend significantly less time on science learning than learning in other disciplines (Early et al., 2010). The lack of science opportunities for young learners can create gaps in knowledge and skills that can rarely be closed (Morgan et al., 2016). As such, it is essential that researchers and practitioners consider how science can be meaningfully integrated into the daily activities of preschool. In consideration of this goal, and the noted dearth of research on integrating play with early childhood science (Andrée & Lager-Nyqvist, 2013; Charara et al., 2021), this study focuses on the work of one preschool teacher who used science not merely as a stand-alone subject or center, but as a play-based context for multiple aspects of children's learning. In other words, this teacher was able to support not only rigorous science learning, but also learning in other National Association for the Education of Young Children (2018) curricular components (e.g., social and emotional development, physical development, early literacy) through scientific explorations and discussions. Using daily summaries of the class's activities and individual interviews with the teacher, we provide an exploration of this teacher and her classroom and build an Integrated Preschool Science Framework. The questions guiding this study were:

1. How does one preschool teacher use science as a context for multiple aspects of children's learning?
2. In what ways do the children in one preschool classroom engage in science in ways that reflect nascent versions of the disciplinary core ideas, science and engineering practices, crosscutting concepts, and nature of science, as discussed in the *Framework for K-12 Science Education*?

To be clear, the *Framework* guides science learning for students K-12—not preschool learners. As such, one would not expect a preschool teacher to follow the *Framework*. Nevertheless, as Larimore (2020) notes, "K-12 reforms eventually make their way to PreK" (p. 703), and the *Framework* presents important shifts in science education away from learning about static facts and skills and toward making sense of phenomena and engaging in the practices of science. In this spirit of this, and in alignment with Greenfield et al. (2017), who adapted the *Framework* to create their own Early Science Framework, we make connections between one preschool teacher's work with science in her classroom and the *Framework* in this study. We see the findings of this study as valuable to preschool teacher educators and researchers, as well as those who are interested in creating a solid science foundation for children in their early years.

1.1 | Literature review

While there is a significant body of literature related to elementary (grades K-5) science for both students and preservice or inservice teachers, we have chosen to focus solely on preschool-related

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literature for several important reasons. First, the landscape of preschool education versus elementary schooling is radically different (e.g., National Academies of Science, Engineering, and Medicine, 2022). Beginning in kindergarten (in public schools), there are statewide standards that must be met each year. This means that there is a deeply reduced ability for teachers to follow children's interests (often termed an "emergent curriculum," which is discussed below). There are, indeed, organizational standards for preschool (e.g., NAEYC and Head Start), but they vary widely and are often more flexible (Greenfield et al., 2009; Larimore, 2020). Second, elementary teachers are held to strict preparation standards. Unlike preschool teachers—many of whom do not need a degree in education (or sometimes even a bachelor's degree)—elementary teachers take required pedagogy and content classes, must satisfy all requirements in a student teaching context, and pass state licensure tests. Preschool teachers who do hold bachelor's degrees often leave to work in elementary schools, as they are paid so little compared to K-5 teachers (McLean et al., 2021). Finally, beginning in kindergarten, children receive grades that become part of their educational record, unlike in preschool. Thus, there are often more efforts on assessment and evaluation for grades rather than allowing learning to happen for learning's sake. Consequently, there are significant differences between elementary and preschool educational contexts, some of which allow for more flexibility and autonomy when it comes to science learning in the preschool classroom. In short, the structures that make preschool different from elementary settings set the stage for rigorous and highly relevant science learning at the preschool level. As such, the following literature review focuses solely on scholarship with preschool children and teachers.

1.2 | Preschool science goals

The majority of science education research focuses on upper elementary and beyond (e.g., Chen et al., 2013; Kawalkar & Vijapurkar, 2013; Osborne et al., 2013). However, in recent years, researchers have begun to advocate for children's preschool experiences with science, as they set a foundation for future learning (e.g., Early Childhood STEM Working Group, 2017; National Academies of Science, Engineering, and Medicine, 2022). This research asserts that preschool science is essential for supporting science content understandings (Akerson et al., 2015; Saçkes, 2015), leads to improved readiness across many domains (Larimore, 2020; Lee & Kinzie, 2012), and can support children's science interests that "persist over time and have implications for long-term learning trajectories" (Pattison & Dierking, 2019, p. 364).

For early childhood centers to be accredited, they must be approved by NAEYC. This association's standards cover a wide array of aspects related to early childhood centers, including but not limited to students' relationships, curriculum, families, and leadership and administration (National Association for the Education of Young Children, 2018). Standards related to science can be found under the umbrella of "curriculum." NAEYC's guidelines suggest that science is an integral aspect of children's learning and that infants and toddlers have the capacity to begin to learn about physics, chemistry, and biology:

> Curriculum should include activities that encourage children to use their five senses to observe, explore, and experiment with scientific phenomena. Include simple tools in your science learning center so that preschoolers and kindergartners can observe objects and scientific phenomena. Provide experiences and materials that allow children to collect data and to represent and document their findings (e.g., through drawing or graphing). Teachers should plan activities and provide

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experiences that encourage children to think, question, and reason about observed and inferred phenomena. (2018, p. 27)

Five of the eleven NAEYC science standards center on hands-on engagement and playing with toys and materials; for example, children should have access to and be able to play with toys to "make things happen," "solve simple problems," and "provide interesting sensory experiences." The remaining six science standards focus on more rigorous, specifically named science-based activities and content: data collection and representation (two standards), asking questions and making predictions (two standards), physical science content (one standard; physical properties of matter), and science vocabulary (one standard). Beyond NAEYC standards, many (but not all) states also have PreK standards that address science, but these vary in quality and depth (Friedman-Krauss et al., 2021) and may not figure into accreditation.

In addition to standards that exist for preschool science, there are others who provide guidance to preschool teachers. Greenfield et al. (2017) assert that "science education is both foundational, and developmentally appropriate for infants, toddlers, and preschoolers" (p. 15) and thus crafted their Early Science Framework, which includes the Disciplinary Core Ideas (DCIs), Crosscutting Concepts (CCCs), and Science and Engineering Practices (SEPs) just as the *Framework* does. They note that their Early Science Framework allows the adults in preschoolers' (and younger children's) lives to "make science visible" for children. And although generally considered a K-12 organization, the National Science Teachers Association (2014) has released a position statement that is endorsed by NAEYC regarding early childhood science education, stating that "learning science and engineering practices in the early years can foster children's curiosity and enjoyment in exploring the world around them and lay the foundation for a progression of science learning in K-12 settings and throughout their entire lives" (para. 1). To achieve this goal, NSTA writes that children need multiple opportunities during learning to engage in science exploration and that these opportunities should be present in both formal and informal settings. Building on this and other key research, National Academies of Science, Engineering, and Medicine (2022) makes these recommendations (among others) to support preschool science learning:

- To draw on and further develop children's science and engineering proficiencies and identities, teachers should arrange their instruction around interesting and relevant phenomena and design problems that leverage children's natural curiosity and give children opportunities for decision-making, sensemaking, and problem-solving.
- Teachers should enact science and engineering learning experiences that establish norms for a caring, collective culture and position children as active thinkers and doers while also providing opportunities to support collaboration and collective thinking. (pp. 7–8)

It should be noted that these standards and recommendations often include components related to family and cultural assets related to science. Research demonstrates time and again that families are children's first teachers (e.g., Junge et al., 2021; National Academies of Science, Engineering, and Medicine, 2022) and that families are significant influences on children's interest, engagement, and aspirations in science (e.g., Archer et al., 2012; Goldman et al., 2021). Children's cultures (familial and broader) color what they deem "inquiry-worthy" and how they approach science (Keifert, 2021). Honoring familial and cultural (science) knowledge in schools can serve to expand "what counts" as science and increases the relevancy of science in children's lives (National Academies of Science, Engineering, and Medicine, 2022). As such, it is highly recommended—and in the case of National Association for the Education of Young Children

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(2018) accreditation, required (Standard 7)—that preschool learning centers partner with families to support learning (National Academies of Science, Engineering, and Medicine, 2022).

Collectively, research on and guidelines for preschool science set the expectation that children are actively engaged in SEPs to make sense of the questions they have about the world around them. Given the freedom that preschool teachers often have in terms of what and how they teach, preschool classrooms can be contexts for rich science learning. To these ends, preschool teachers must purposefully create opportunities that capitalize on children's interests and support these interests via strategic use of materials, collaboration, and questioning.

1.3 | Preschool science enactment

Enacting high-quality science in preschool classrooms requires that teachers not only formally implement science lessons, but also name and notice science that is already taking place. There are several different categories of science learning that involve young children in the classroom (Eliason & Jenkins, 2003; Tu, 2006). Neuman (1972) divided "sciencing" (his term to describe science-related activities) into three categories: formal, informal, and incidental. Formal activities are directed and organized: the teacher plans a lesson, prepares specific materials, and guides children through an exploration. Informal activities involve indoor or outdoor science centers: children use provided materials to guide their own explorations. Incidental activities are also child-directed, but take place through natural exploration, conversation, or context. These are unplanned activities that are guided by children's interests. For instance, children notice the changing weather and the teacher helps to expand on the topic. Tu (2006) advocates for teachers who craft opportunities for each type of these sciencing activities to occur on a regular basis; Fleer et al. (2014) describe this purposeful approach to science as the "sciencing attitude" of the teacher.

Studies show, however, that children and teachers seldom see activities within preschool classrooms as being related to science, and often misidentify science activities taking place, even though science is "ubiquitous in the preschool classroom as children explore and engage in their environment" (Bustamante et al., 2018, p. 36). Inan et al. (2010) defined science-related activities as making and manipulating things, building, caring for pets and plants, and playing. Using this definition, they found that children were engaging with science at multiple locations in the classroom, including the sensory table, art studio, kitchen, dramatic play area, circle area, science table, and the playground. However, while science was abundant in the classroom, there was an observed lack of activities focused on "what science is." Akerson et al. (2010) found that preschool teachers often struggle with how to teach science in part because they fail to recognize when science learning was or should be occurring. For instance, in Akerson et al.'s study, teachers associated science with anything active and although there were aspects of science in these activities, they were not named "science" among students or teachers.

Along these lines, preschool teachers have reported low self-efficacy regarding teaching science and have expressed concern about having enough time to prepare children in all learning domains (Greenfield et al., 2009). There is considerable emphasis placed on early numeracy and literacy in preschool, leading to lack of time and resources devoted to science (French & Woodring, 2012; Guo et al., 2016). However, while this may account for some of why science is generally avoided, many preschool teachers also lack science-specific pedagogical knowledge; they often have difficulty answering science-related questions and developing inquiry-focused activities (Kallery & Psillos, 2001); may express discomfort with science; and do not feel

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adequately prepared to utilize science-specific pedagogical approaches (Allen & Kambouri-Danos, 2017; Pendergast et al., 2017). As such, teachers may attempt to bypass science in a variety of ways, including "teaching as little of the subject as possible, teaching more biology versus physical science, relying on commercially developed lessons, using non-fiction children trade books, and avoiding all but simple hands-on activities" (Saçkes et al., 2011, p. 230).

Clearly, science can easily fade into the background within preschool classrooms if teachers are not prepared to be thoughtful about bringing science to the forefront. As it stands, there are significantly fewer opportunities in preschool for science than other content areas (Russell & McGuigan, 2017; Saçkes et al., 2011); Tu (2006) found that although half of preschool classrooms had science areas, 87% of the time spent in the classroom was spent on nonscience activities, and that teachers interacted least often with children when they were in the science area. Similarly, Nayfeld et al. (2011) studied six different preschool classrooms and found that the science area was empty approximately 78% of the time. Other studies have shown that preschool teachers may also miss "teachable moments" (Tu, 2006), fail to address science misconceptions, and enhance science misconceptions unintentionally (Andersson & Gullberg, 2014). However, similar findings are true for elementary science, and yet, Zembal-Saul et al. (2020) discuss a "possibility-centric" vision of science for elementary teachers; this vision focuses on "what *can be*" (p. 118, emphasis original). Likewise, this research presents a possibility-centric vision of what preschool science can be, depicting how one teacher capitalized on students' interests, focused on sensemaking, and used science as a context for aspects of children's learning.

1.4 | Theoretical framework

We examined one teacher's support of preschool science through the lens of constructivism. However, before we share how this theoretical framework informs the study at hand, it is necessary to delineate *what kind* of constructivism and *at what level* we are using this theory. Taber (2019) created a complex conceptual map of the ways in which constructivism has been used throughout educational literature—as a philosophy, a research program, a research tradition, a principle in cognitive development, and a theory of teaching and learning—to illustrate the need to be clear when utilizing constructivism as a driving theory in a study. Similarly, Matthews (2002) noted the need to separate the dimensions of constructivism (e.g., as a theory of learning; as a theory of scientific knowledge; as a worldview, etc.) such that one could be transparent in their assumptions. Nevertheless, as Jenkins (2000) states, "If there is common ground among constructivists of different persuasion it presumably lies in a commitment to the idea that *the development of understanding requires active engagement on the part of the learner*." (p. 601, emphasis added). Additionally, constructivism acknowledges the fact that learners come to the learning environment with experiences that color how they go about making sense of the world (Jenkins, 2000; Matthews, 2002). For the purposes of this study, we adopt constructivism as a theory of teaching and learning. More specifically, we consider what a preschool teacher with this philosophy would do in her classroom to support (science) learning.

Although Bächtold (2013) has stated that "constructivism does not tell us how to teach" (p. 2478), the teacher nonetheless plays an important role. In the past, some have held an oversimplified view of constructivism in that learners construct meaning *on their own*, without support from teachers (Cobb, 1994; Taber, 2019). However, Taber (2019) points out that teachers with a constructivist view may make deliberate choices concerning any number of things, such as learning activities, student grouping, and resources to support children's sensemaking.

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Suggestions for pedagogical strategies aligned with constructivism include focusing on the process rather than the end-point of a task (Adams, 2006), acknowledging students' existing ideas (Jenkins, 2000), using questioning strategies to reveal student thinking (Colburn, 2000), engaging in and supporting meaningful discourse (Cobern, 1995; Windschitl, 1999), crafting an environment conducive to wonder and exploration (Seimears et al., 2012), and framing learning in terms of worthwhile problems to be solved (Gil-Pérez et al., 2002; Windschitl, 1999). As Taber (2019) states, in a classroom with a constructivist view of learning, "the lesson activities are structured and coordinated by the teacher, who aims to provide the optimal level of guidance to encourage learning" (p. 331).

1.5 | Constructivism, emergent curriculum, and guided play

Relating to early childhood education specifically, it has been noted that a key part of supporting early learners from a constructivist viewpoint is to ensure that learners have enough time, space, and resources to explore, interact with others, and revise their ideas (Branscombe et al., 2013). This notion is consistent with an emergent curriculum philosophy. Emergent curriculum focuses on children's curiosities and interests, and tends to be open-ended and driven by children (Jones et al., 2001; Jones & Nimmo, 1994); this can be an important part of developmentally appropriate practice in preschool (National Association for the Education of Young Children, 2020). Even though emergent curriculum is child-led, it also depends on "teacher initiative and intrinsic motivation...Emergent curriculum emerges from the children, but *not only from the children*" (Jones, 2012, p. 67, emphasis added). Perry and Dockett (1998) noted that aligned with a constructivist philosophy of learning, preschool teachers should see their role as, "not [simply] setting up the environment and then passively waiting to see what children make of it, but rather as one based on action and interaction that serves to model, guide and scaffold children's learning" (p. 12).

Emergent curriculum comes from incidental experiences and play, but to have meaningful learning experiences, teachers must notice and extend students' ideas (Jones, 2012), which is consistent with the notion of guided play. Weisberg et al. (2016) note that the strength of a guided play approach is that it

> ...combines the best elements of free play and direct instruction: child autonomy and adult expertise. It provides an optimal medium for delivering educational content in ways that are enjoyable and that allow for genuine child agency, while constraining children's activities to facilitate learning. (p. 180)

At times, play and learning have been framed in a false dichotomy (Weisberg et al., 2016), but guided play is rooted in a constructivist philosophy of learning and has been shown to promote intellectual development in language, literacy, logic, and mathematics (Van Hoorn et al., 2014). Relating to science specifically, Trundle and Smith (2017) write that "with careful planning, the design of preschool classrooms provides places and spaces for incorporating and supporting play in science learning" (p. 81). The key phrase from Trundle and Smith is "careful planning" in terms of making this type of play meaningful. This perspective echoes Jones' (2012) work, as noticing and developing children's science questions and interests is an essential constructivist teacher skill, and integral to emergent curriculum. Further, Windschitl et al. (2012), in their *Ambitious Science Teaching* framework, focus on teachers' ability to notice and

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adapt to students' needs and ideas, stating that "students' everyday language, experiences, and knowledge had to be used as legitimate resources for learning" (p. 885).

Therefore, preschool teachers with a constructivist philosophy of (science) learning should be purposeful in creating environments so that "science becomes more like the science that scientists do; it is an active, social process of making sense of experiences…" (Seimears et al., 2012, p. 269). In this study, we explore how science is used as a context for learning in a preschool classroom by a teacher who holds a constructivist philosophy of learning, and thus, is intentional about her pedagogical choices.

2 | MATERIALS AND METHODS

We utilized a qualitative single case design for this study, as Yin (2018) notes that single case studies are appropriate for critical, unusual, common, revelatory, or longitudinal cases (p. 49). We see the preschool teacher in this study as simultaneously unusual and common. On the one hand, it can be seen as unusual for a preschool teacher to intentionally focus on inquiry as the context in which all learning will occur (and, as she noted, while she did not intentionally set out to focus on science, it became clear to her that much inquiry and building on children's natural interests can be done within the context of science). On the other hand, many preschool teachers *do* use science extensively in their classroom even though they may not acknowledge or notice this. In this way, we saw this single case study as illuminating what a sciencing attitude (Fleer et al., 2014) toward preschool could look like to provide a possibility-centric vision (Zembal-Saul et al., 2020) of preschool teachers supporting science in their classroom.

2.1 | Setting

This study took place at a midwestern university's laboratory school which offers programming for children 18 months old through kindergarten. The school gives priority enrollment to families connected to the university (faculty, staff, students), but also enrolls children from the larger community. Based on a Reggio Emilia philosophy of education, the mission statement of the school states that, "We believe knowledge is constructed through an active process of inquiry that prioritizes exploration, communication, meaningful relationships and play"—clearly aligned with a constructivist philosophy. Within the school, this study focused on the science enactment of one preschool teacher who taught in a classroom with 20 children, aged 3–5. Occasionally, there were university-based student teachers in the classroom as well. However, the teacher had the final say concerning what would be taught in the classroom as well as the pedagogies employed.

The school had several outdoor learning areas, including a playground, a mud kitchen, a water-play area with pipes and other recycled materials, and a nearby meadow. The layout of the classroom as well as the various materials and centers available to the children are relatively typical of preschool classrooms. There was an area with four tables seating six children each, as well as the following centers around the classroom: Dramatic play area, art area (paint, clay, etc.), library area, sensory table area (sand, rice, water, etc.), light table, bins of building toys (blocks, magnetic tiles, etc.), and pretend-play toys (small dinosaurs, little animals, etc.).

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2.2 | Participant

The sole participant in this study is the preschool teacher, whom we will call Tasha. Tasha, who identifies as a middle-socioeconomic-status (SES) white woman, received an undergraduate degree in early childhood education and a master's degree in the social and cultural foundations of education. She worked in the education departments of two large children's museums over the span of 8 years, developing and delivering educational content for audiences of children, families, and educators. Tasha was invited to participate in the study by the first author, who had a working relationship with the school. At the time of the study, Tasha had been teaching in the school's preschool class for 3 years; this study documents her fourth year. She was not compensated for her participation in the study beyond the opportunity to reflect on her pedagogy.

Tasha's museum experiences played a significant role in shaping who she is as an educator. Her first experiences included facilitating learning within family contexts and interacting with families, which allowed her to see the power of families as learning partners. In terms of planning learning activities, at one museum, she was expected to design curriculum with other educators that would support learning a variety of content (including science) through music. This may have laid some of the groundwork for Tasha seeing how to teach in an interdisciplinary manner and/or utilize one content area as a vehicle for teaching others. Throughout her time at museums, she had relative freedom in terms of what content to focus on, and how to construct learning experiences; this demonstrated to Tasha the possibilities of following both her and her patrons' interests to engage in learning. Toward the end of her time working in museums, her focus shifted to adult education and the role of play in learning; Tasha led several workshops and discussions with educators to discuss how play and learning connect as well as the barriers to play and learning within play. Certainly, this period of her work was quite impactful, as Tasha strongly believes in the power of learning through (guided) play in her classroom and allowing children to construct ideas about their world through their play activities. Finally, throughout her time working in museums, Tasha often found herself needing to learn more about a topic so that she could present it to others (e.g., she was not an expert in music, but wanted to present music meaningfully to others). Now in the classroom, because Tasha does not have a degree in the sciences, she often conducts research on scientific topics so she can support children's learning. She noted that learning about new things has ceased to be "scary" and is now "exciting"; learning new things is part and parcel to being a teacher for Tasha (Int. 1).

Although Tasha does not have a degree or extensive coursework in the sciences, she stated that she had been quite lucky during her schooling to have teachers and professors who had emphasized hands-on, active learning and made connections between science and the world, which led her to enjoy science learning. Tasha also noted that through her time working in museums, she saw science as "a great way to connect with kids," which is one of the reasons why she prioritized science in her own classroom. Additionally, Tasha enjoyed teaching science because she wanted to push back against the myth of "cold, sterile" science and present science as a place to "make mistakes and where we get to struggle and be in conversation and think about things together" (Int. 1).

The demographics of the 20 preschool students in Tasha's class during this study are as follows: 15% were students of color, 85% were white; ~75% of the students came from homes that could be described as middle-SES, ~15% of the students came from homes that could be described as lower-SES, ~10% of the students came from homes that could be described as

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higher-SES; approximately half of the students in the class had at least one parent/guardian affiliated with the university.

2.3 | Data collection

Multiple sources of data were collected for this study throughout the 2015–2016 academic year, including three 60-minute interviews, daily summaries (three per week for the whole year—85 total), and a short book co-written by Tasha and her preschool students entitled *We Are Scientists*. Each semistructured interview (Roulston, 2010) was conducted by the first author; semistructured in the sense that there were particular questions the author planned on asking in each interview, but there were also extensive follow-up questions or additional questions as information relevant to the study arose in the conversation. In the first interview, Tasha provided information about her educational background, teaching experience, and learning philosophy. In the second interview, Tasha shared her thoughts concerning emergent curricula and focusing on science. In both the second and third interviews, each major curricular unit was discussed (fossils, caterpillars, plant growth, crystals, and the *We Are Scientists* book) and how she conceptualized these units. For each unit, Tasha was asked to explain how she came up with the lessons, her comfort level with teaching the lessons and the research she needed to do for each of them, her learning goals for her students, and changes she would make if she were to repeat the unit based on the experience. Overall, the purpose of the interviews was to gain insight into Tasha's intentionality surrounding the emergent curriculum and to learn more concerning how she enacts her constructivist philosophy through guided play.

While Tasha taught 5 days per week, this study focuses on the preschool class she taught 3 days per week. For each day they met, Tasha was asked to write a daily summary, which included descriptions of the day's content and activities, as well as quotes from and pictures of her students. Besides the inclusion of these components, there were no additional parameters for the summaries. Each summary was approximately 600–800 words in length.

As the end of the school year approached, Tasha worked with her students to create an end-product that reflected some of their science learning from the year. As a group, Tasha and her students co-wrote the *We Are Scientists* book, described by Tasha as a "product of long-term inquiry work conducted by the children...in Room 8" (WAS Book). Each page of the book began with "Scientists" and the children were asked to provide an idea of something scientists do as well as some details about this action. For example, on the "Scientists Study" page, a quote from one of her students reads, "I'm going to make some zebras with a scientist in the desert. He'll study the zebra—all about his stripes and bones and that!" A copy of this book was distributed to each child at the end of the school year. We requested to use this book as a data source as it provided insight into what children were taking away from their science education.

2.4 | Data analysis

The data were coded by both researchers in two phases. First, the data were coded inductively in a grounded theory (Corbin & Strauss, 2015) manner to answer the first research question, *How does a preschool teacher use science as a context for multiple aspects of children's learning?* Given National Association for the Education of Young Children's (2018) curricular components, we wanted to see how Tasha was meeting these goals via science. Additionally, as a

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teacher who espouses a constructivist view of teaching and learning, we wished to gain insight into how Tasha took up children's ideas and interests in deliberate, guided ways. Based on the three interviews with Tasha, a set of codes concerning how science was being "used" in the classroom was developed. We then applied this set of codes to analyze the daily summaries and *We Are Scientists*. For example, Tasha introduced children to how dinosaur fossils are found, preserved, and transported to research facilities. Children were encouraged to wear sun hats to keep the hot, desert sun at bay and use tools such as small shovels and brushes to pretend they were paleontologists. This activity was coded "Science as dramatic play," which is part of NAEYC's larger "Creative Expression and Appreciation for the Arts" curricular component.

Each author coded 10 daily summaries independently and then met to discuss any discrepancies in coding and solidify understandings of how to apply the codes. From there, minor edits were made to the codes and the remaining daily summaries and *We Are Scientists* were divided among the researchers and coded. There were 148 coded excerpts in this round of coding, with some excerpts having multiple codes applied simultaneously. The instances of each applied code were tallied to provide more information as to how often each of these codes arose in the data. Table 1 shows these codes as well as the frequencies of each code in the data. Coding data according to this emergent framework allowed us to have a clearer picture of the different ways in which science was used as a context for learning in a preschool classroom. And although each component of the emergent framework did appear in the data, the results here report on the components most seen in the data: Science as Sensory Play; Science as Curiosity; Science as Connected to Literature, and Science as Socioemotional Learning Opportunities.

Setting aside the coding from the first phase of data analysis, we then recoded the data to answer the second research question, *In what ways do the children in one preschool classroom engage in science in ways that reflect nascent versions of disciplinary core ideas*, *science and engineering practices*, *crosscutting concepts*, *and nature of science*, *as discussed in the* Framework for K-12 Science Education?, using the *Framework* as a guide. We felt it was important to view the data through this more formal science lens as there is often the misconception that young children are unable to do or understand "real" science. However, National Academies of Science, Engineering, and Medicine (2022) notes that preschool curriculum should include attention to content, practices, and CCCs (DCIs, SEPs, and CCCs). Additionally, research has demonstrated that texts (such as read-alouds or creating science notebooks) can support children's understanding of the nature of science (NOS; National Academies of Science, Engineering, and Medicine, 2022). Using Greenfield et al.'s (2017) Early Science Framework to assist us with coding, we posed questions to think about each of the three dimensions as they apply to preschool children:

- DCIs—What are children interested in?
- SEPs—What can children do to answer their questions?
- CCCs—What are children trying to understand? (p. 14)

We used these questions as a jumping-off point for coding the three dimensions and then tried to further classify the SEPs and CCCs as they are described in the *Framework* (e.g., cause and effect, planning and carrying out investigations, etc.). NOS was only coded for when science and/or scientists were explicitly being discussed by the teacher.

Each data source (interviews, summaries, book) was coded in this second phase using *Framework*-inspired codes. Once again, the authors each independently coded 10 summaries and met to discuss discrepancies and solidify codes. From there, the remaining data were

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TABLE 1 Grounded theory coding

Code (*NAEYC curricular component*)	Definition	Example	Frequency of code in data (raw count)
Science as community (*Social Studies*)	Building community in the classroom and/or the idea that the practice of science is done in a community	After reading *What is a Scientist?* by Barbara Lehn (1998), children discussed how the practices in the book were similar to and/or different from what they and their friends do in the classroom.	11
Science as curiosity (*Social and Emotional Development*)	Asking questions about the world around us and how it works	In the early spring, children saw "fuzzies" at the ends of some magnolia tree branches and wondered what they were (leaves, flowers, stems) and why they looked that way.	35
Science as dramatic play (*Creative Expression and Appreciation for the Arts*)	Engaging in role play around science content/ practices	Children engaged in an activity around dinosaur fossils and were encouraged to use brushes and other tools to pretend they were paleontologists.	13
Science as socioemotional learning opportunities (*Social and Emotional Development*)	Learning or reinforcing self-awareness, self-management, responsible decision-making, relationship skills, and/or social awareness through science	After finding worms outdoors, children considered how to care for the worms and how children could behave to show kindness to the worms.	51
Science as connected to literature (*Early Literacy*)	Using books to connect to science or using science to tell stories	After reading *Bye, Bye, Butterflies!* (Larsen, 2012) the children were able to make connections between the boy in the book (a self-proclaimed "butterfly scientist") and themselves and discuss why it's important to let butterflies fly free.	35
Science as sensory play (*Physical Development*)	Using science as a motivation for engaging in sand, snow, mud, water, etc. play	To learn more about the properties of clay, children added water, manipulated it with their hands, sliced it, etc.	50
Science through family/ community connections (*Social Studies*)	Making connections with expertise and experiences with those outside the classroom	Children were able to visit a paleontologist and learn more about the work he does.	2

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TABLE 2 Framework inspired coding

Code	Definition	Example	Frequency of code in data (raw count)
Nascent DCIs	Children learning about science content	Children learning about the life cycle of a butterfly	94
Nascent SEPs	Children engaging in simple versions or precursors of SEPs	Analyzing and Interpreting Data: A child states, "Scientists look closely to sort by color." Another replies, "We're sorting to see how much there is and how much colors there is [sic]."	398
Nascent CCCs	Children noticing simple versions of or making connections by CCCs	Cause and Effect: In the mud kitchen, a child is making "cake batter": "It was sand but now it's like juice…When you put in more water it becomes liquidier. [sic] [But] when you scoop it out, it doesn't look like liquid. It looks like dirt."	184
Nascent NOS	The teacher explicitly engaging children in discussions related to science and/or scientists	"[Tasha] read aloud Barbara Kerley's book *The World is Waiting For You*…The book features images of real scientists and explorers in the field…Learning more about scientists at work creates space for grounding classroom conversations and thinking about scientists in real world contexts."	47

divided among the researchers to code independently. There were 303 coded excerpts in this round of coding, with some excerpts having multiple codes applied simultaneously. The instances of each applied code were once again tallied to provide more information as to how often each of these codes arose in the data. Table 2 shows the *Framework*-related codes as well as the frequencies of each code in the data. Through this second phase of coding, we were able to make visible the "real" science that can be conducted in a preschool classroom with early learners; the results report on nuances within each of these components.

2.5 | Quality

To ensure that the findings represented here are credible, a final draft of this manuscript was presented to Tasha with the request that she read it carefully to ensure that we accurately represented her intentions, actions, and the activities of her preschoolers. While many researchers are familiar with this process as a "member check" (Lincoln & Guba, 1985), we prefer Tracy's (2010) term "member reflections," as she notes that "member reflections are less a test of research findings as they are an opportunity for collaboration and reflexive elaboration… Through the reflection process, participants can react, agree, or find problems with the research" (p. 844). Tasha was kind enough to do a close read of the manuscript, provide edits, and ask questions that we feel have allowed us to further clarify key points and findings; Tasha did not note any misrepresentations or errors in our final presentation of the findings or the discussion.

3 | RESULTS

The findings from our analysis will be organized by research question.

3.1 | Science as a context for aspects of children's learning

Science served as a context to fulfill the school's mission for children to explore, communicate, play, and create meaningful relationships. And while all codes in Table 1 were seen repeatedly in the data, most often, science was used as a backdrop to participate in sensory play, be curious about the world, make connections with literature, and to engage in socioemotional learning.

Science as sensory play. In Tasha's classroom, children interacted with a variety of materials and science was often the context for sensory play. As Newman and Kranowitz (2012) note, "Between birth and about age 6, children learn about their world by feeling and moving their bodies through it" (p. 7), making *feeling* and *experiencing* objects key for learning. Further, National Association for the Education of Young Children (2018) suggests that best practices for physical development is to include opportunities for both gross motor and fine motor experiences. Two particularly sensory play-rich episodes were when children played with snow/ice and learned more about clay.

In the children's inquiry into snow and ice, they were often the ones to move the snow, pack it, shovel it, rake it, and bring it into the classroom—at times even building snowpeople. Children explored the snow and ice with their hands, as well as with different tools and materials Tasha had provided, such as containers, pipettes, water, salt, ice-skating blades, shovels, and sleds (Int. 3). To learn more about the snow and ice, children tried blowing on it to see what would happen, wondering why some snow felt granular while ice felt smooth, and trying different ways to make it melt and refreeze. These investigations took place outside as they played in the meadow or went sledding down a hill, as well as inside at their water table or the local ice arena. As children engaged with the snow and ice, Tasha would press the children to verbalize their experiences and share their thinking with others (DS. 0210-0219; Int. 3).

Similarly, as children played with clay in the classroom, this became a rich sensory experience. Children used a variety of tools as well as their hands to shape the clay, mix it with water, and create different shapes. They noted as they played, "It's hard to take apart," or "It's smooth now!" or "It turned into squishy clay!" Experimentations with the clay included how to best rip off large chunks, seeing how to make pieces stick together, and how to make it more malleable (DS. 0201-0208). Tasha recognized the power of clay as a sensory learning experience and commented, "As the children continue to work with clay, they are learning more about its physical properties, how they can manipulate the material, and how to craft the material into the outcomes they intend. Plus, working with clay is a great opportunity to exercise fine motor (and sometimes gross motor) strength and power" (DS 0219). Tasha relished these sensory play experiences, as children were not only learning more about the physical properties of different materials, phases of matter, and other scientific content while having fun, but also developing the foundational skills and strength for writing and drawing (Int. 2).

Science as curiosity. Hand in hand with children's sensory play, science often served as a backdrop for children's curiosity about the world and how things worked. As Tasha noted, children are "big about asking questions and explaining and observing things and that is honestly such a big part of science" (Int. 1). To those ends, Tasha wanted to encourage children's curiosity because their observations and questions made science "real" to them: "[Science] is so

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connected to children because if they get to touch it, they can see if they can do it...[then] it is not all that abstract. There is something for them to hold onto and that is what they really really want" (Int. 1).

When bringing snow indoors, children asked, "Will it melt?" and then wondered how the salt the street crews used melted the snow (DS. 0210). While making Epsom salt crystal paintings, children asked what would happen when they mixed colors, or where the water would go when the painting dried (DS. 0222-0224). During a particularly exciting walk through the woods nearby, children found worms and asked, "Are they sticky?" and "Why did we find so many worms today?" which led to a discussion about possible weather-related reasons. On the way back from the walk, they found a family of garter snakes and wondered if they would feel cold or warm to the touch. After these two discoveries, children then wondered where they might find more snakes and worms and tried looking under logs outdoors (DS. 0314).

Tasha facilitated this curiosity by asking the children to respond to each other about their ideas and to consider how they might answer their questions. She asserted,

> I want my children to be thoughtful. I want them to ask questions. And I want them to be inquirers. I want them to be asked to engage in topics that do not necessarily have a finite [answer]. We do not always know exactly where we're going... [or] what we're going to learn but the learning process comes with the journey...I want my kids to question and I want my kids to wonder and I want my kids to be able to learn skills to know how to do that themselves, because that is something that concerns me about the world. I sometimes get worried that people do not know how to think, that they do not know how to engage challenges or problems (and they're not always problems but just big question marks) and have any idea about how to move forward and to be okay with the ambiguity of not finding an answer immediately. (Int. 2)

Tasha also noted that this curiosity led to collaborations with others, required children to actively figure things out, and taught them that persistence while investigating a question is valuable. Consequently, Tasha asserted that, "in addition to whatever science content and whatever relationships that [the children] may build," children were also able to "learn to look for the little things and to realize that there is massive complexity in tiny stuff" (Int. 2). For Tasha, supporting curiosity provides new opportunities to learn.

Science as connected to literature. Tasha stated, "Including literature...in classroom life gives one more avenue through which children can make connections to and build understandings regarding experiences they are having in the classroom" (DS. 0224). Related to science, children made connections both as readers/audience members and as authors. Throughout the data set, Tasha explicitly mentioned 32 different books that connected to science and what the children were learning. Discussions around these books supported the children in learning content knowledge about topics such as birds, dinosaurs, crystals/rocks, the human body, leaves, the Earth, and trees. For example, when children were thinking about what plants needed to grow and planting their own seeds, they read and discussed together *Zinnia's Flower Garden* (Wellington, 2005); *The Tiny Seed* (Carle, 1987); and *Garbage Helps Our Garden Grow: A Compost Story* (Glaser, 2010), among other books.

Books were also used to learn about scientists' lives and explicitly compare the children's scientific work to the characters in the book ("Making connections to their own experiences, the children discussed the seeds they planted at school, the care they have been providing, and the

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growth they have [or have not yet] seen." [DS. 0425]). And children used books to guide their actions in investigations ("The weeds get the food and water from the plants, so then the [nutrients] will all go back into the dirt when you pull the weeds." [DS. 0408]; "We were right! It does need sun and water!" [DS. 0314]). Additionally, children participated in literacy by creating their *own* information to communicate via observational drawings. Using a variety of media, children made drawings of birds, leaves, gourds, bugs, bones, and plants to share with others (e.g., DS. 1012, 1202, 0504).

Children also had the opportunity to contribute to a book that they created for their classroom community called *We Are Scientists*. Tasha noted that this initiative grew out of several observations in the classroom. First, the children had become interested in bookmaking, stapling pages of paper together and having the ability to take their book home. Second, she had noticed that the children were not "owning" their identities as scientists:

> …I remember reading some read-aloud and I asked the question, "Are you scientists?" and the overwhelming answer from the children was "No." …That was not an identity that they felt even remotely connected to and as a teacher, I was really surprised by that because I felt like the kids were doing all sorts of science work all the time. I had not expected that they would not see themselves as scientists. So, my teaching team [student teachers] and I were thinking about how that was an identity that we really wanted the children to be able to claim for themselves. (Int. 3)

Finally, Tasha wanted to document the children's explorations in "a more permanent way" (Int. 3). Consequently, the book idea was born.

Contributions to the book included photographs of the children and their explorations throughout the year, children's comments on or narratives of what was happening in those photos, children's drawings, and words written by the children (see Figures 1–4): "It was a really great literacy connection for them that they were working to write words that were really meaningful to them about things that they were doing within the classroom" (Int. 3). As time went on, the book allowed the children to recognize the science that they were engaging in on a regular basis while also making connections to how books can tell people's stories. Fittingly, the last page of the book is an interview with a child, asking the child what he would want people to know about scientists and he replied, "I am a scientist."

Science as socioemotional learning opportunities. Tasha saw science as a site where "we can work on all of that social emotional learning while at the same time having access to work on a lot of academic content" (Int. 1). The Collaborative for Academic, Social, and Emotional Learning (2022) describes five general areas of socioemotional learning: self-awareness, self-management, responsible decision-making, relationship skills, and social awareness. Each of these areas were seen in activities and conversations around science in Tasha's classroom, but three areas—self-awareness, responsible decision-making, and social awareness—stand out. Related to self-awareness, the children identified and worked through their feelings when discussing the impending release of their class butterfly, with one child voicing, "I really don't want the butterfly to go," while another noted that they needed to release the butterfly for its well-being, and yet another child wanting to wait to release it so it would have friends: "He'll be sad. What if he doesn't find butterflies in the world? He'll have no friends. Please can we keep it until the other butterflies come?" (DS. 0504). To support these feelings, Tasha read a book about caring for butterflies to emphasize the importance of releasing their butterfly.

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FIGURE 1 *We Are Scientists* excerpt

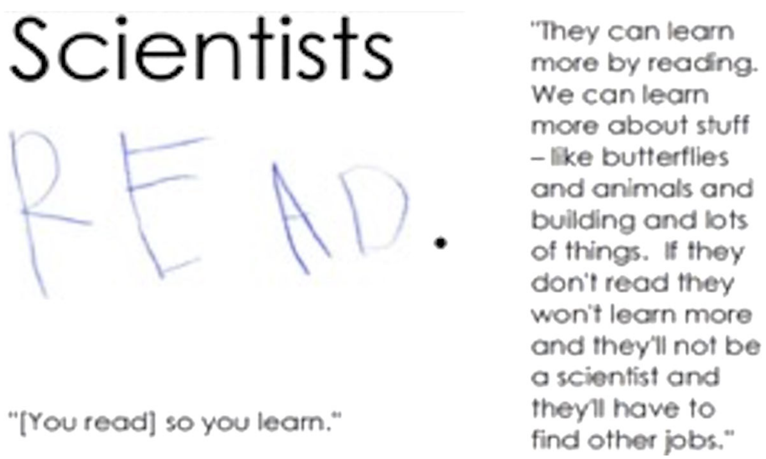

FIGURE 2 *We Are Scientists* excerpt

FIGURE 3 *We Are Scientists* excerpt

Thinking about their beautiful meadow space, children were concerned with keeping it clean and taking care of it (Responsible Decision-Making). As part of a schoolwide project, Tasha's students and families helped clean up litter along the roadside as well as in the

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FIGURE 4 *We Are Scientists* excerpt

meadow. Tasha engaged children in reflecting on these activities, with one child sharing, "I don't know why people would do that [litter]" and the class brainstormed ways to take care of the earth. Tasha commented on these activities, saying,

> Experiences like the children had today provide powerful motivation for framing and solidifying children's relationship with and sense of responsibility for the natural world. In addition, it helps them know that they don't need to wait until they are older to have a positive impact on the world; they have both the power and the ability to make a difference now. (DS. 0420)

Finally, Tasha strongly felt that children "have the opportunity to take responsibility to support the care and well-being of other living things" (Social Awareness; Int. 3). To those ends, Tasha meshed conversations at the beginning of the school year about building a classroom community with talking about how to care for the caterpillars in their classroom. Comparisons were made between how the children need food, space, for others to keep their hands to themselves, and to observe others' body language to how caterpillars need food, space, and how they might "scrunch" up or move quickly if they do not want to be handled. As she shared, this comparison "gives them a place to do a little empathy building, to really begin to think about how do other creatures…feel and what is my role in that" (Int. 2). As seen here, Tasha thought deeply about how to build on science experiences to include socioemotional learning.

3.2 | Preschool engagement in nascent *Framework*-aligned science

The NSTA Position Statement on Early Childhood Science Education (National Science Teachers Association, 2014) makes the declaration that early childhood settings should, "Understand that science experiences are already a part of what young children encounter every day through play and interactions with others…" and "Emphasize the learning of science and engineering practices…" (Para. 11). Echoing these declarations, Tasha's classrooms engaged children in nascent versions of DCIs, SEPs, CCCs, and NOS.

Nascent DCIs. To begin, science content *was* a large part of the children's work, but rather than this content being dictated by a set curriculum or Tasha's ideas, the content emerged on an "as-needed" basis, when children became interested in a topic. Further, the content was richly integrated with children *doing* science as well as engaging in other curricular areas.

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A key example of this is when the children became interested in dinosaurs, Tasha used her background working in children's museums to allow children to experience a mock paleontological dig and learn more about dinosaurs. They read books together to learn about the work of paleontologists as well as about different dinosaurs, they engaged in sensory play and actually dug for "fossils" using the proper tools, learned how to wrap "fossils" in jackets for transport, and considered how paleontologists reconstruct skeletons as they began to reconstruct their "fossil" skeletons. To continue learning about paleontology, children visited a local paleontologist's lab and saw graduate students at work with various tools while the professor talked to the children about various fossils that caught their eyes (DS. 1116-1202).

What is particularly interesting about the dinosaur example of rich integration and scientific content is that the unit was not originally envisioned to be as rigorous. Tasha recalled,

> My student teachers came to me and said, "You know, the kids are really interested in dinosaurs. We want to do something with dinosaurs," and I said, "OK. What is it that you want to do?" I didn't really like their answers. They were saying things like, "Well maybe the kids can be the dinosaurs," and I said, "What do you think the children will do?" They said, "I think they will yell a lot." I said… "Maybe that is not the best plan."…How could you engage the idea of dinosaurs in a way that the work that the children will do would be a bit more meaningful? It does not mean that there would not be space for imaginative play or storytelling or acting things out…but how do you give children some context so that instead of every dinosaur roaring and yelling and clawing at people…there is some depth…So I asked them…"Have you thought about what paleontologists do [and] how can that be translated into our classroom?"…So it was way better than the children running around the room pretending to be dinosaurs, to give them a way to think about the content in a more authentic, enriched, active way…A way that could give them knowledge about the outside world where it wasn't just about the dinosaurs but it is about people's relationships to dinosaurs. (Int. 2)

Tasha went on to say that she did quite a bit of research for this unit, because she wanted to present children with accurate information about how paleontologists do their work, and she feels that this type of research is necessary for any teacher wanting to support children's interest. She also stated that while she *did* have learning goals for the children in terms of being able to tell her what a paleontologist does and other related scientific content (e.g., nascent components of the DCIs ESS1.C The History of Planet Earth and ETS2.A Interdependence of Science, Engineering, and Technology [National Research Council, 2012]), she also wanted students to grow as learners and thinkers as well as recognize that they are capable of doing work that is difficult (Int. 2). So, although scientific content was infused throughout children's experiences, Tasha's primary goals were to challenge children and show them that they are capable of pursuing knowledge. Taking into account Greenfield et al.'s (2017) guiding question of *What are children interested in?*, we see this content learning as important precursors to DCIs that will be learned in kindergarten and beyond.

Nascent SEPs: Children in Tasha's classroom often engaged in science through various SEPs. Many of these overlapped, or one led to another, depending on the types of materials available. Most often, children were engaged in observation of some kind (a component of Planning and Carrying out Investigations) as they used their senses to notice or wonder. For example, children looked at and touched bugs in a terrarium ("This caterpillar is black and green. The other is black, green, and yellow." [DS. 0916]), different types of feathers they had collected ("One's brown and one's black." [DS. 0127]), and different balls before they rolled them ("The rubber ball is hard and round." [DS. 1118]). In the meadow, children noticed the noises from animals (DS. 0923, 0422) and how the ground felt and sounded underfoot (DS. 0330). The school's outdoor mud kitchen also provided opportunities for children to make observations about textures and colors of mud and clay when mixed with water or other natural materials.

Like scientists' work, children's observations often led to other SEPs. For example, children wondered how they could make a marble roll from one end of the hallway to the other (Asking Questions). They crafted plans, gathered various materials, and kept trying different designs through trial and error to make it work (Planning and Carrying Out Investigations; Analyzing and Interpreting Data): "We need to make it steeper." "Make it higher so we have enough speed." [DS. 1104]. This then led children to select different balls from the classroom and observing their properties, children made predictions concerning how far they would roll and considered why particular properties were more conducive to rolling (Analyzing and Interpreting Data; DS. 1113). This continuous SEP path was also seen when observing black swallowtail caterpillars and chrysalides in their classroom, children wondered why the butterflies were not emerging (Asking Questions), so with assistance, they researched what these butterflies need to emerge and what the typical life cycle timeline is (Obtaining, Evaluating, and Communicating Information). Some children then drew pictures of the chrysalides in their classroom to note what they looked like at the time (a component of Developing and Using Models; DS. 0502). Finally, children often had opportunities to share with their families what they were doing in the classroom (Obtaining, Evaluating, and Communicating Information) during drop-off and pick-up times, which Tasha saw as key:

> [I]t is a really nice way for families to be involved in the work that is going on in the classroom…I can hear questions that families might have, I can hear conversations that adults and children are having together, [and] I can hear the way that children are talking about their experience to people that are important in their lives. (Int. 3)

While children's engagement in SEPs emerged from their curiosity and interests, Tasha was also keen to facilitate this engagement in a meaningful way. For example, from the moment the children became interested in caterpillars, Tasha physically set up the space so that children could help monitor, feed, draw, and interact with the caterpillars. To support their research and identification, she amassed books, field guides, songs, and other materials that would help children understand butterflies and their life cycles. Tasha also reported that she did a great deal of "Googling" on her own when particular questions came up (specifically around why the butterflies were not emerging) so she could then ask probing questions and set the children off on their next investigation, which led them to relocate the chrysalides to the cold, dark storage shed behind the school (Int. 2).

Tasha noted that when children have the opportunity to engage in science as practices, "The feedback that I get from the children is demonstrating to me a recognition that they had the ability to engage in the world and pursue knowledge and I think that they were very proud of the work that they could do." She went on to say that, "My job is to help children learn how to learn…to help them develop the skills so that they become independent thinkers who have the ability to access knowledge" (Int. 2). Through having children engage in SEPs (or as Greenfield et al. (2017) put it, what children can do to answer their questions), Tasha felt she was supporting the children in becoming lifelong learners.

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Nascent CCCs: Although all CCCs were seen in Tasha's classroom, far and away the most common CCC observed was cause and effect. Children were constantly exploring "What would happen if…?" during their sensory play, as they engaged in play with their peers, and as they interacted with information shared with them via literature. For example, while playing in the outdoor mud kitchen, children noticed that if they added more water to sand, it became darker and the water "disappeared" (DS. 0516; Int. 2); when children increased the angle of a ramp for a marble run, the marbles were able to go further (DS. 1204); and when they added milk to frozen fruit in a blender, it turned into a smoothie, which the children then put into muffin tins and into the freezer to see if they would indeed freeze (DS. 1114). For those who work with young children, it is no surprise that cause and effect was embedded in this preschool classroom on a regular basis, as children often seek to learn more about their world by seeing "What will happen if…?"

Also commonly seen in the classroom was the CCC of patterns. Children noted patterns in life cycles between butterflies, moths, people, and other species (DS. 0502; DS 0921; Int. 2) and by sorting different items. For example, they sorted several stones and marbles into different containers based on color and transparency (DS. 0113) and sorted coins by size and color (DS. 0316). In another activity, there was a project that supported the CCC of patterns when the children were making a leaf "people" by using natural materials found in the meadow and sorting the collected materials by shape, size, color, and what type of body part (arm, leg, head, etc.) the material could be used for (DS. 1023).

A third CCC that was often seen in Tasha's classroom was that of stability and change, particularly in relation to children's observations of the meadow during different parts of the year. Throughout the changing seasons, children were very observant of changes in trees, noting when leaves were missing, when they were budding, and when flowers bloomed on the branches (DS. 1021, 0205, 0401). The children also considered what living things or natural features were in certain places the last time they were in the meadow versus what they saw in the present, from remembering there was snow in the stream the last time they were there to comparing the quantity of wildlife sightings (DS. 0330). Additionally, the weather on their meadow walks was an opportunity to observe stability and change as they compared sunny days to storms they had previously experienced (DS. 1102).

Finally, children observed the nascent versions of the CCC of structure and function when observing the features of living things. While often more focused on the structure alone—like the sizes and features of different bugs (DS. 0127) and the colors of male and female butterflies' wings (DS. 0504)—there were times when children considered how the structure and function of something were interconnected. For example, one student found an animal skull in the meadow and shared it with the class. Tasha noted, "Looking at its sharp, pointy teeth, the class decided that it must have eaten meat and based on its size and shape, they wondered if it might be a raccoon skull (which it is)" (DS. 0420). Similarly, related to the birds' feathers, children hypothesized that feathers help birds fly, "keep them safe" and "keep them warm" and are very good for tickling friends. Tasha then read *Feathers: Not Just For Flying* (Stewart, 2014) so the children could see that birds use feathers "to help them sled (for emperor penguins), to attract attention like fancy jewelry (for peacocks), for cushioning their nests (for wood ducks), and so on" (DS. 0127).

Nascent NOS. NSTA (2020) makes the following statement concerning the NOS:

> NOS is best understood by students if it is explicitly addressed within the context of students' learning of science and engineering practices, disciplinary core ideas, and CCCs. "Explicit" does not mean that the teacher should lecture about NOS. Rather, it refers to reflective discussions among students about the science concepts they are learning (Clough, 2011). (para. 5)

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As this statement makes the point that NOS must be explicitly discussed—it is not simply "absorbed" via doing science—the findings reported upon here only reflect instances in which "science" or "scientists" were explicitly discussed in Tasha's classroom.

The most common component of NOS that was seen in Tasha's classroom was the focus on the diversity of people who are (and can be) scientists. As she asserted, one of her goals was for the children to see that "not all scientists look like this or function in this way," referring to the trope of the Einstein-like mad scientist (Int. 3). Rather, she wanted the children to recognize that there are scientists in their community, and that *they are*, in fact, scientists themselves. To these ends, the children met two different local scientists (DS. 1207, 0309) and Tasha worked to emphasize connections between actions that scientists do and actions that the children did within their classroom. She said that she wanted "to give [the children] a bridge to begin to expand their understanding…that scientists are not just those people way over there that I've never met, that I don't know anything about, that I do not have any connection to…I think that began to help them put some sort of material face on what it means to be a scientist" (Int. 3). Tasha also included read-aloud books in their daily activities about a variety of scientists, such as marine biologist Sylvia Earle, paleontologist Paul Sereno, and primatologist and anthropologist Jane Goodall, and facilitated discussions about what different scientists might have in common (DS. 0401; Int. 3).

A second ongoing conversation explicitly about science in the classroom was that scientists use an array of different methods and tools in order to do their work. As evidenced in the *We Are Scientists* book, the children came to the realization that scientists do a variety of things, such as read, work together, count, and ask questions to study the world. Many times, the vocabulary was greatly simplified in these discussions, such as, "Scientists like to touch stuff" (WAS Book). But other times, the children were able to use more sophisticated language: "That's one of the things scientists do! They watch! 'Observed' is the scientist word for that" (DS. 0316). The children also made note of the variety of tools a scientist might use, such as a magnifying glass or gloves (DS. 0307).

3.3 | Summary of findings

These findings present strong evidence that science inquiry can easily be utilized as a context for rich and rigorous preschool learning. Following children's ideas and curiosity about the world around them often naturally leads to children engaging in sensory play, making connections with literature, and even nascent versions of science as described in the *Framework*. The purposeful, pedagogical moves and discussions that Tasha implemented in her classroom allowed children to engage more deeply with their wonderings and observations while recognizing that their behaviors mirror those of scientists. It is important to reiterate that Tasha did not fundamentally alter what she was already doing as preschool teacher. Rather, as children engaged in their "typical" activities or shared items or ideas from home, she took the time to name and notice what the children were doing and make connections to the real world of science. As Tasha pointed out,

> We [student teachers and Tasha] did not change the work that we were doing in the classroom. We just changed the way that we talked about it and the way that we were framing it with the children so that they had a better idea of what is science, what does it mean to be a scientist, what does that look like, and how do I

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FIGURE 5 Integrated preschool science framework

> embody those things. My hope would be...that they can say, "I am a scientist too," so that regardless of how they may choose to move on in their lives, that is something that feels accessible and open as a possibility for them because they are capable of doing science. (Int. 3)

Tasha also noted that the teacher's role is to observe, listen to what children are trying to do, offer words of encouragement, and perhaps even make explicit to the children the learning they are doing (Int. 3).

In light of these findings, in Figure 5, we have created the Integrated Preschool Science Framework that extends Greenfield et al.'s (2017) Early Science Framework, grounded in the possibilities for science instruction demonstrated in our findings. In particular, we have added Early Childhood Curricular Components as well as the Nature of Science components to Greenfield et al.'s original framework and underscored the importance of acknowledging the assets that children and their families bring to science learning. We see these additions as crucial to making science more approachable and realistic in a preschool classroom. That is, rather than thinking of science as something that must be added on top of everything else preschool teachers are expected to do, it is an integrated part of preschool education with the academic, social, emotional, and physical developmental goals for early learners.

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4 | DISCUSSION AND IMPLICATIONS

The purpose of this study was to explore how one teacher was able to use science as a context for rich learning in a preschool classroom over the course of one school year, and how this aligned with nascent components of rigorous science as described in the *Framework*. Additionally, it sought to contribute to research on integrating play with early childhood science (Andrée & Lager-Nyqvist, 2013; Charara et al., 2021). Although Tasha did have some experiences early in her career that led her to be more aware of the potential science holds for engaging children in learning, she did not hold a degree in science, nor did she study science extensively. Moreover, she did not adopt a formal science curriculum for her classroom or change the typical activities one might find in a preschool classroom. All to say, what Tasha achieved in her classroom is at once wholly remarkable and completely attainable by other preschool teachers.

This study demonstrates that science in the preschool classroom can be a vehicle to learning much more than science. National Association for the Education of Young Children (2018) emphasizes that preschools should support a wide variety of learning including, but not limited to, socioemotional skills, physical skills, early math and literacy, and creative expression. The findings in this study show that through science, children can move, express themselves, collaborate, interact with literature and research, and solve problems that are meaningful to them. Tasha did not deviate from what most preschool teachers might do: To meet National Association for the Education of Young Children (2018) learning expectations, she implemented an emergent curriculum (Jones et al., 2001; Jones & Nimmo, 1994). Where Tasha perhaps differs from other preschool teachers is that she seized on the (science) ideas that children were interested in and crafted rich, multifaceted experiences for children to engage in, as her constructivist philosophy reinforced that engagement and actively working with ideas and materials *is* learning. And although there were some activities that were more structured than others, such as read-alouds or crafting the *We Are Scientists* book, much of what Tasha facilitated was guided play, providing a variety of ways for children to build the skills and knowledge they need in all content areas.

This study also reinforces the notion that young children *are* capable of rigorous science (e.g., Borgerding & Raven, 2018; Eshach & Fried, 2005; Guo et al., 2015), or at least the foundations to rigorous science in a developmentally appropriate manner (Keifert & Stevens, 2019) when adequately supported. Children learned science content throughout their work in Tasha's classroom: content about butterflies, snow, crystals, rocks, birds, and more. Engaging in learning about science content at this early age sets the stage for wanting to learn more in the future (DCIs) and teaches children that they have the power to answer the questions they have about the world. Additionally, children engaged in all SEPs and CCCs from the *Framework* (National Research Council, 2012) over the course of the year, which again sets a foundation for future learning and engagement in science. Finally, the children were able to engage in ideas surrounding NOS which provides them with early understanding of what science is and is not, as well as who engages in science and how. The *Framework* notes that all components of the standards spiral K-12, building upon previous grade levels' work to expand students' knowledge and skills. We argue that this spiral can and must begin at the preschool level, setting children up for success at the very beginning of their K-12 career. Once again, however, it should be noted that it was Tasha's purposeful pedagogical moves, rooted in ideas of constructivism, that led to this deep engagement in science. National Academies of Science, Engineering, and Medicine (2022) asserts that,

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> Teachers and other adults need to be able to notice, name, and build on children's ideas and experiences to help them continue to make sense of the natural and designed world…By developing learning environments that support both development and the demonstration of children's proficiencies…educators help children see their ideas, interests and identities, and practices as meaningful for school science and engineering as well as seeing how science and engineering can be useful in their lives. (p. 4)

Aligned with this statement, we argue that rigorous engagement in science does not just "happen" by virtue of children tinkering in science spaces, but that it requires thought and intention on the part of the teacher.

The Integrated Preschool Science Framework in Figure 5 is based on data from one classroom with one teacher. However, we see this Framework as holding potential for generalizability and use in work that builds on Greenfield et al.'s (2017) Early Science Framework. First, researchers may investigate the use of the Integrated Preschool Science Framework during observations within preschool classrooms as coding schema, or in designing preschool science curricula or interventions. This may assist researchers in seeing beyond the surface of joy and play (which is certainly important) to also acknowledge the learning that is taking place via guided play. Second, given that preschool children are capable of much deeper engagement with science than previously thought, it is vital for stakeholders to consider the ways in which science can be better supported in the preschool classroom because, as many studies have pointed out, the key to unlocking this support heavily relies on teachers to follow students' interests in an intentional manner, naming and noticing the science that is inherent in their curiosities and actions (Trundle & Smith, 2017). To those ends, researchers may investigate the potential of the Integrated Preschool Science Framework to support early childhood teacher educators in focusing preservice and inservice teachers on students' actions and connections in terms of science learning as well as making science and NOS visible to children. Finally, teacher educators could explore the use of the Integrated Preschool Science Framework to support lesson/unit planning as well as larger conversations about student learning in the classroom; in this way, the Integrated Preschool Science Framework might be used as a guide or checklist to ensure both the science and the connections to other content areas are present.

We do believe that what Tasha accomplished is attainable by the average preschool teacher. But, we also acknowledge that not all preschool classrooms may have the resources and connections of a university laboratory school, there may be pressures (depending on their affiliations or funding) to focus more narrowly on literacy and numeracy, and/or teachers may feel unsupported by their colleagues to pursue science learning as described here. While specific recommendations for actions are beyond the scope of this study, we offer observations of how Tasha "made it work" that could support others preschool teachers in utilizing science as a context for rich learning:

- Tasha generally did not buy expensive or specialized equipment and materials. Rather, she capitalized on nature (snow, leaves, butterflies, walks in the meadow), local resources (the ice rink, the paleontologist), and household materials (salt, clay, cardboard, marbles) as sources of inquiry.
- Tasha was willing to do her own research, bring in books and other research materials, and learn along with the children when she felt she needed more content knowledge.

- Tasha did not allow other areas of learning to fall by the wayside, but rather used science to practice skills and create a "need" for learning in different areas. For example, children practiced writing, collaborated and problem-solved with others, and sought out information in books and online as a part of science-based activities.
- Tasha had her annual "stand-by" units; for example, butterflies and their life cycles is a unit that happens each year. In this way, she could keep some foundational pieces the same from year to year (books she reads, discussions they have about life cycles) while still having time to adapt to children's interests and needs (working through emotions about the release of the butterfly) and taking up children's ideas for other units (snow).

Each preschool setting will have its own particular affordances and constraints for using science as a context for early childhood learning, but small actions preschool teachers take can make a big difference in foregrounding the joy and wonder of science.

5 | LIMITATIONS

We do recognize that there are limitations to this study. We did not focus extensively on student work or behaviors themselves, but rather on Tasha's descriptions and interpretations of how her decisions played out in the classroom. Therefore, while the findings of this study lead us to believe meaningful learning rooted in science was happening, a more thorough investigation of the children's products and actions are needed to draw any definitive conclusions. Further, given that we did not record children's behaviors in the moment, we also could not ask about Tasha's pedagogical decision-making in those moments or after the fact. Documenting this would be a fruitful area for future research, to learn more about how these science-supporting decisions are made. Additionally, while Tasha's teaching actions were not directed by a science curriculum director (the school did not have one) nor by science-specific required curricula (the only required standards for the school were NAEYC standards, as described in the literature review), she did report that being interviewed about science had potentially influenced her classroom choices. As such, while it is clear that Tasha had significant freedom in the classroom in regard to curriculum, there was potential bias toward science due to the investigative nature of the study. Finally, Tasha did discuss families as partners in learning, but it was beyond the scope of this study to further investigate these partnerships in science. Given the importance of families in science learning, this would be an additional fruitful area for future research.

6 | CONCLUSION

This study presents the case of Tasha, a teacher who is simultaneously typical and unique when it comes to her instruction. She is typical in that she wants her students to become learners and thinkers, to feel empowered in relating to the world, to see the joy and beauty of learning, and to cultivate skills and knowledge that will create a foundation for K-12 learning. She is unique in that she has made the choice—due to her constructivist philosophy, her belief in the power of guided play, and her past experiences—to position science at the center of her teaching so that it is the facilitator of these goals for her students. Importantly, Tasha's teaching presents to us a possibility-centric vision of preschool science that is achievable for other preschool teachers.

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However, it is important to acknowledge that there is still much to be done to support preschool teachers in teaching science in this way. While the freedom of preschool learning environments is quite conducive to the types of teaching and learning seen in Tasha's classroom, as noted earlier, there must be intentionality on the part of the teacher to make the science visible and meaningful. Generative areas for future research must include deeper analyses of preschools students' learning while in a science-based classroom such as Tasha's; existing barriers and supports for preschool teachers wanting to place science at the center of their teaching as well as interventions that allow teachers to "transition" into this mode of teaching; activities and experiences implemented by teacher educators that support preschool teachers in naming and noticing the science that students are already engaging in and following their (scientific) interests. Further, Tasha *did* have past experiences in museums that served as resources for her to implement science; future research must investigate and create resources that can aid preschool teachers in following children's emergent science interests. Collectively, these types of research will serve to strengthen preschool science and all that young children can learn when science is at the center of their learning.

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REFERENCES

Adams, P. (2006). Exploring social constructivism: Theories and practicalities. *Education*, *34*(3), 243–257.

Akerson, V. L., Buzzelli, C. A., & Donnelly, L. A. (2010). On the nature of teaching nature of science: Preservice early childhood teachers' instruction in preschool and elementary settings. *Journal of Research in Science Teaching*, *47*(2), 213–233.

Akerson, V. L., Weiland, I., & Fouad, K. E. (2015). Children's ideas about life science concepts. In K. C. Trundle & M. Saçkes (Eds.), *Research in Early Childhood Science Education* (pp. 99–123). Springer.

Allen, M., & Kambouri-Danos, M. (2017). Substantive conceptual development in preschool science: Contemporary issues and future directions. *Early Child Development and Care*, *187*(2), 181–191.

Andersson, K., & Gullberg, A. (2014). What is science in preschool and what do teachers have to know to empower children? *Cultural Studies of Science Education*, *9*(2), 275–296.

Andrée, M., & Lager-Nyqvist, L. (2013). Spontaneous play and imagination in everyday science classroom practice. *Research in Science Education*, *43*(5), 1735–1750.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal*, *49*(5), 881–908.

Bächtold, M. (2013). What do students "construct" according to constructivism in science education? *Research in Science Education*, *43*(6), 2477–2496.

Borgerding, L. A., & Raven, S. (2018). Children's ideas about fossils and foundational concepts related to fossils. *Science Education*, *102*(2), 414–439.

Bowman, B. T., Donovan, M. S., & Bums, M. S. (Eds.). (2001). *Eager to Learn: Educating Our Preschoolers*. National Academy Press.

Branscombe, N. A., Burcham, J. G., Castle, K., & Surbeck, E. (2013). *Early Childhood Curriculum: A Constructivist Perspective*. Routledge.

Bustamante, A. S., White, L. J., & Greenfield, D. B. (2018). Approaches to learning and science education in head start: Examining bidirectionality. *Early Childhood Research Quarterly*, *44*, 34–42.

Carle, E. (1987). *The Tiny Seed*. Little Simon.

Charara, J., Miller, E. A., & Krajcik, J. (2021). Knowledge in use: Designing for play in kindergarten science contexts. *Journal of Leadership, Equity, and Research*, *7*(1), 1–28.

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Chen, Y., Hand, B., & McDowell, L. (2013). The effects of writing-to-learn activities on elementary students' conceptual understanding: Learning about force and motion through writing to older peers. *Science Education*, *97*(5), 745–771.

Clough, M. P. (2011). Teaching and assessing the nature of science: How to effectively incorporate the nature of science in your classroom. *The Science Teacher 78*(6), 56–60.

Cobb, P. (1994). An exchange: Constructivism in mathematics and science education. *Educational Researcher*, *23*(7), 4.

Cobern, W. W. (1995). Constructivism for science teachers. *Science Education International*, *6*(3), 8–12.

Colburn, A. (2000). Constructivism: Science education's "grand unifying theory". *The Clearing House*, *74*(1), 9–12.

Collaborative for Academic, Social, and Emotional Learning. (2022). What is the CASEL framework? Retrieved from https://casel.org/fundamentals-of-sel/what-is-the-casel-framework/

Corbin, J., & Strauss, A. (2015). *Basics of Qualitative Research* (4th ed.). Sage.

Early Childhood STEM Working Group. (2017). *Early STEM Matters: Providing High-Quality STEM Experiences for all Young Learners*. University of Chicago and the Erikson Institute.

Early, D. M., Iruka, I. U., Ritchie, S., Barbarin, O. A., Winn, D. M. C., Crawford, G. M., Frome, P. M., Clifford, R. M., Bruchinal, M., Howes, C., Bryant, D. M., & Pianta, R. C. (2010). How do pre-kindergarteners spend their time? Gender, ethnicity, and income as predictors of experiences in pre-kindergarten classrooms. *Early Childhood Research Quarterly*, *25*(2), 177–193.

Eliason, C., & Jenkins, L. (2003). *A Practical Guide to Early Childhood Curriculum* (7th ed.). Prentice Hall.

Eshach, H., & Fried, M. N. (2005). Should science be taught in early childhood? *Journal of Science Education and Technology*, *14*(3), 315–336.

Fleer, M., Gomes, J., & March, S. (2014). Science learning affordances in preschool environments. *Australasian Journal of Early Childhood*, *39*(1), 38–48.

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

French, L. A., & Woodring, S. D. (2012). Science education in the early years. In O. N. Saracho & B. Spodek (Eds.), *Handbook of Research on the Education of Young Children* (3rd ed., pp. 179–196). Routledge.

Friedman-Krauss, A. H., Barnett, W. S., Garver, K. A., Hodges, K. S., Weisenfeld, G. G., & Gardiner, B. A. (2021). *The State of Preschool 2020: State Preschool Yearbook*. National Institute for Early Education Research.

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

Gil-Pérez, D., Guisasola, J., Moreno, A., Cachapuz, A., Pessoa de Carvalho, A. M., Torregrosa, J. M., Salinas, J., Valdés, P., González, E., Duch, A. G., Dumas-Carré, A., Tricárico, H., & Gallego, R. (2002). Defending constructivism in science education. *Science & Education*, *11*(6), 557–571.

Glaser, L. (2010). *Garbage Helps our Garden Grow: A Compost Story*. Millbrook Press.

Goldman, S., Luce, M. R., & Vea, T. (2021). Opportunities and tensions in family science: Challenging dominant paradigms of science education. *Cultural Studies of Science Education*, *16*(2), 621–641.

Greenfield, D. B., Alexander, A., & Frechette, E. (2017). Unleashing the power of science in early childhood: A foundation for high-quality interactions and learning. *ZERO TO THREE*, *37*(5), 13–21.

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

Guo, Y., Piasta, S. B., & Bowles, R. P. (2015). Exploring preschool children's science content knowledge. *Early Education and Development*, *26*(1), 125–146.

Guo, Y., Wang, S., Hall, A. H., Breit-Smith, A., & Busch, J. (2016). The effects of science instruction on young children's vocabulary learning: A research synthesis. *Early Childhood Education Journal*, *44*(4), 359–367.

Inan, H. Z., Trundle, K. C., & Kantor, R. (2010). Understanding natural sciences education in a Regio Emilia-inspired school. *Journal of Research in Science Teaching*, *47*(10), 1186–1208.

Jenkins, E. W. (2000). Constructivism in school science education: Powerful model or the most dangerous intellectual tendency? *Science & Education*, *9*(6), 599–610.

Jones, E. (2012). The emergence of emergent curriculum. *Young Children*, *67*(2), 66.

10982736, 2023, 3, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.21807 by Clemson University, Wiley Online Library on [26/09/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Jones, E., Evans, K., & Rencken, K. (2001). *The Lively Kindergarten: Emergent Curriculum in Action*. National Association for the Education of Young Children.

Jones, E., & Nimmo, J. (1994). *Emergent Curriculum*. National Association for the Education of Young Children.

Junge, K., Schmerse, D., Lankes, E. M., Carstensen, C. H., & Steffensky, M. (2021). How the home learning environment contributes to children's early science knowledge—Associations with parental characteristics and science-related activities. *Early Childhood Research Quarterly*, *56*, 294–305.

Kallery, M., & Psillos, D. (2001). Pre-school teachers' content knowledge in science: Their understandings of elementary science concepts and of issues raised by children's questions. *International Journal of Early Years Education*, *9*(3), 165–177.

Kawalkar, A., & Vijapurkar, J. (2013). Scaffolding science talk: The role of teachers' questions in the inquiry classroom. *International Journal of Science Education*, *35*(12), 2004–2027.

Keifert, D., & Stevens, R. (2019). Inquiry as a members' phenomenon: Young children as competent inquirers. *Journal of the Learning Sciences*, *28*(2), 240–278.

Keifert, D. T. (2021). Family culture as context for learning through inquiry. *Cognition and Instruction*, *39*(3), 242–274.

Larimore, R. A. (2020). Preschool science education: A vision for the future. *Early Childhood Education Journal*, *48*(6), 703–714.

Lee, O. (2005). Science education and student diversity: Synthesis and research agenda. *Journal of Education for Students Placed at Risk*, *10*(4), 431–440.

Lee, Y., & Kinzie, M. (2012). Teacher question and student response with regard to cognition and language use. *Instructional Science*, *40*(6), 857–874.

Lehn, B. (1998). *What is a scientist?* Millbrook Press.

Leibham, M. B., Alexander, J. M., & Johnson, K. E. (2013). Science interests in preschool boys and girls: Relations to later self-concept and science achievement. *Science Education*, *97*(4), 574–593.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic Inquiry*. Sage.

Matthews, M. R. (2002). Constructivism and science education: A further appraisal. *Journal of Science Education and Technology*, *11*(2), 121–134.

McLean, C., Austin, L. J. E., Whitebook, M., & Olson, K. L. (2021). *Early Childhood Workforce Index—2020*. Center for the Study of Child Care Employment, University of California Retrieved from https://cscce.berkeley.edu/workforce-index-2020/report-pdf

Mirzaie, R. A., Hamidi, F., & Anaraki, A. (2009). A study on the effect of science activities on fostering creativity in preschool children. *Journal of Turkish Science Education*, *6*(3), 81–90.

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

National Academies of Sciences Engineering and Medicine. (2022). *Science and Engineering in Preschool Through Elementary Grades: The Brilliance of Children and the Strengths of Educators*. The National Academies Press.

National Association for the Education of Young Children. (2018). NAEYC early learning program accreditation standards and assessment items.

National Association for the Education of Young Children. (2020). Developmentally appropriate practice [Position statement]. Retrieved from https://www.naeyc.org/resources/position-statements/dap/contents

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. The National Academies Press.

National Science Teachers Association. (2014). NSTA position statement: Early childhood science education. Retrieved from http://www.nsta.org/about/positions/earlychildhood.aspx

Nayfeld, I., Brenneman, K., & Gelman, R. (2011). Science in the classroom: Finding a balance between autonomous exploration and teacher-led instruction in preschool settings. *Early Education and Development*, *22*(6), 970–988. https://doi.org/10.1080/10409289.2010.507496

Nayfeld, I., Fuccillo, J., & Greenfield, D. B. (2013). Executive functions in early learning: Extending the relationship between executive functions and school readiness to science. *Learning and Individual Differences*, *26*, 81–88.

Neuman, D. (1972). Sciencing for young children. In K. R. Baker (Ed.), *Ideas that Work with Young Children* (pp. 27–52). National Association for the Education of Young Children.

Newman, J., & Kranowitz, C. (2012). Growing in sync children. *Teaching Young Children*, 6(1), 7–10.

NSTA. (2020). *NSTA position statement: Nature of science*. Retrieved from https://www.nsta.org/nstas-official-positions/nature-science

10982736, 2023, 3, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/tea.21807 by Clemson University, Wiley Online Library on [26/09/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Osborne, J., Simon, S., Christodoulou, A., Howell-Richardson, C., & Richardson, K. (2013). Learning to argue: A study of four schools and their attempt to develop the use of argumentation as a common instructional practice and its impact on students. *Journal of Research in Science Teaching*, *50*(3), 315–347.

Pattison, S. A., & Dierking, L. D. (2019). Early childhood science interest development: Variation in interest patterns and parent–child interactions among low-income families. *Science Education*, *103*(2), 362–388.

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

Perry, B., & Dockett, S. (1998). Play, argumentation and social constructivism. *Early Child Development and Care*, *140*(1), 5–15.

Roulston, K. (2010). *Reflective Interviewing: A Guide to Theory and Practice*. Sage.

Russell, T., & McGuigan, L. (2017). An updated perspective on emergent science. *Early Child Development and Care*, *187*(2), 284–297.

Saçkes, M. (2015). Young children's ideas about earth and space science concepts. In K. C. Trundle & M. Saçkes (Eds.), *Research in Early Childhood Science Education* (pp. 35–65). Springer.

Saçkes, M., Trundle, K. C., Bell, R. L., & O'Connell, A. A. (2011). The influence of early science experience in kindergarten on children's immediate and later science achievement: Evidence from the early childhood longitudinal study. *Journal of Research in Science Teaching*, *48*(2), 217–235.

Seimears, C. M., Graves, E., Schroyer, M. G., & Staver, J. (2012). How constructivist-based teaching influences students learning science. *The Educational Forum*, *76*(1), 265–271.

Stewart, M. (2014). *Feathers: Not Just for Flying*. Charlesbridge.

Taber, K. S. (2019). Constructivism in education: Interpretations and criticisms from science education. In *Early childhood Development: Concepts, Methodologies, Tools, and Applications* (pp. 312–342). IGI Global.

Tracy, S. J. (2010). Qualitative quality: Eight "big-tent" criteria for excellent qualitative research. *Qualitative Inquiry*, *16*(10), 837–851.

Trundle, K. C., & Smith, M. M. (2017). A hearts-on, hands-on, minds-on model for preschool science learning. *Young Children*, *72*(1), 80–86.

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

U.S. Department of Health and Human Services. (2015). Head start early learning outcomes framework. Retrieved from https://eclkc.ohs.acf.hhs.gov/school-readiness/article/head-start-early-learning-outcomes-framework

Van Hoorn, J., Nourot, P. M., Scales, B., & Alward, K. R. (2014). *Play at the Center of the Curriculum* (6th ed.). Pearson.

Waldfogel, J., & Zhai, F. (2008). Effects of public preschool expenditures on the test scores of fourth graders: Evidence from TIMSS. *Educational Research and Evaluation*, *14*(1), 9–28.

Weisberg, D. S., Hirsh-Pasek, K., Golinkoff, R. M., Kittredge, A. K., & Klahr, D. (2016). Guided play: Principles and practices. *Current Directions in Psychological Science*, *25*(3), 177–182.

Wellington, M. (2005). *Zinnia's Flower Garden*. Dutton Children's Books.

Windschitl, M. (1999). A vision educators can put into practice: Portraying the constructivist classroom as a cultural system. *School Science and Mathematics*, *99*(4), 189–196.

Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education*, *96*(5), 878–903.

Yin, R. K. (2018). *Case Study Research and Applications* (6th ed.). Sage.

Zembal-Saul, C., Carlone, H., & Brown, M. (2020). A possibility-centric vision of elementary teachers and ambitious science teaching. In D. Stroupe, K. Hammerness, & S. McDonald (Eds.), *Preparing Science Teachers Through Practice-Based Teacher Education* (pp. 117–132). Harvard University Press.

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