

**Preschool Teachers' Experiences of Teaching Science
to Low-Income, Language-Minority Children**

A thesis submitted by

Yoori Kim

in partial fulfillment of the requirements for the degree of

Master of Arts

in

Child Study and Human Development

Tufts University

May 2025

Thesis Committee:

Christine M. McWayne, Tufts University (Advisor)

Jayanthi Mistry, Tufts University

Andres S. Bustamante, University of California, Irvine

Abstract

Preschool teachers are identified as key stakeholders to the expansion of science learning opportunities in early childhood, especially for children from low-income and multi-language learning backgrounds. Many studies on early science education focus on factors externally observable such as teaching frequency or curriculum content, and there is a gap in literature on teachers' perspectives of their teaching practices. This study investigated 21 preschool educators across eight public schools as reflect on their science teaching and their experience undergoing a series of science-focused professional development (PD) sessions. Findings from this thematic analysis revealed three key domains of preschool science education that teachers identify as closely related to their science teaching, as well as elements of PD that contribute to the shifts in their perspectives of these domains. Implications for future design and implementation of PD to better support teachers in creating science learning experiences for low-income, MLL children are discussed.

Acknowledgements

I first and foremost thank God who gives me strength to do all things and open the doors that I decided to knock on. Not a single step of completing this thesis, including but not limited to meeting the wonderful people and having the opportunities, would have been possible without His love and grace.

I would like to express my most sincere gratitude to my primary advisor Dr. Christine McWayne, whose guidance has been instrumental to the completion of this thesis and to my academic and personal growth over the last two years. I extend my gratitude to my committee members, Dr. Jayanthi Mistry and Dr. Andres Bustamante, for the considerable expertise and insightful feedback they have shared. Christy, Jayanthi, and Andres, I am beyond grateful to have worked with you; your commitment for social justice and community-based research have been and will continue to be an inspiration for my work. I also thank the Heising-Simons Foundation for funding the larger RISE project and therefore this study. My appreciation extends to every former and current RISE team member for their diligent work and to the RISE phase III cohort 1 teachers and Santa Ana Unified School District staff for their participation.

During my times at Tufts, Eliot-Pearson Department of Child Study and Human Development has been more than just a site of academic learning. I hold dear the memories of passing by the children's school on my way to class and hearing the happy giggles, exchanging smiles and greetings through the wide-open office doors of our faculty members, packing generous leftovers that well-nourished this (and many other, I am sure) hungry thesis-writing soul during busy times, chatting with some of my favorite people as they come by my lab office, and building some invaluable relationships. Special thanks to my friends for believing in me, being there for me, and genuinely celebrating my accomplishments – even in times that I was a bit too self-disciplined to admit being proud of them myself. Love you!

마지막으로 엄마아빠, 지난 2년간 이 공부를 하면서 학문적인 배움과 동시에 당신들께서 저와 언니를 얼마나 사랑으로 키우셨는지, 얼마나 많은 어려움을 이겨내고 우리가 바라게 자라도록 애쓰셨는지 조금은 더 이해하게 된 것 같아요. 넘치게 받은 사랑 널리 베풀고, 지어주신 이름처럼 이로운 일 하는 자랑스러운 작은 딸이 될게요. 늘 감사하고 사랑합니다.

Table of Contents

Abstract.....	ii
Acknowledgements.....	iii
Table of Contents.....	iv
Tables.....	vi
Figures	viii
Preschool Teachers’ Experiences of Teaching Science to Low-Income, Language-Minority Children	1
Theoretical Framework	2
Young Children’s Capability for Science Learning.....	3
Early Science Education for Children from Marginalized Groups	5
Understanding Teachers’ Experiences	7
Efforts for Teacher Support.....	10
Professional Development as More Than Skill-Building.....	12
Context of the Larger Study	12
Current Study	14
Method.....	15
Participants	15
Procedures	17
Data Analysis	18
Positionality Statement.....	20
Results.....	20
Aspects of Preschool Science Teaching Identified by Participating Teachers	21
Teachers’ Experiences During Professional Development Sessions	25
Shifts in Teaching Practice Across the Year	29
Remaining Barriers.....	34
Member Checking Outcomes.....	34
Discussion.....	35
Under-Recognition of Preschool Science as a Potential Root Cause for Current Challenges.....	35
Expanding Conceptual Knowledge Attenuates the Effects of Existing Barriers	37
Hands-on Practices during PD Foster In-Class Implementation.....	39
Positive Relationships are Key to Successful Teacher Growth	40

Teachers' Internalization of Their Profession Beyond Teaching Practice.....	41
Implications	42
Limitations and Future directions.....	43
Appendices	45
Appendix A: Institutional Review Board Approval Form for Current Study.....	45
Appendix B: Teacher Interview Protocols	46
Appendix C: Science Framework Reference Sheet	51
Appendix D: Member Checking Procedure	53
References.....	56

Tables

Table 1
Teacher Demographics for 2023-2024 RISE Participants from Santa Ana Unified School District

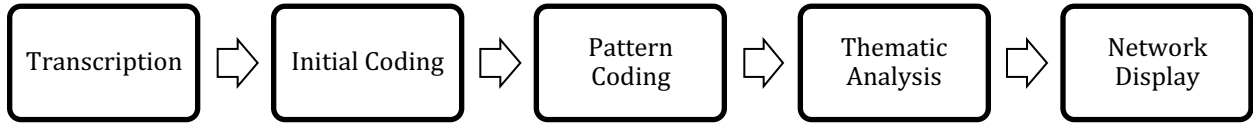
Teacher Number	Gender	Years in ECE* Profession	Years at Current District / Current Role	Role**	Education Level	Identifies as Hispanic	Ethnicity	Ethnicity if responded "other"	Born in the U.S.	Country of Origin	Primary language spoken at home	Other languages spoken at home	Primary language used in classroom	Origins of Families in Classroom
Teacher 1	Female	9	6 / 6	FD Teacher	Some graduate courses	Yes	American Indian/Native American/Alaska Native	Mexican American	Yes	USA	English	Spanish	Spanish	Mexico, other Central America
Teacher 2	Female	30	25 / 25	FD Teacher	Graduate degree	Yes	Multiracial	-	No	Mexico	Spanish	English	English	Mexico, other Central America
Teacher 3	Female	2	2 / 2	FD TA	High school diploma or GED	Yes	White	-	No	Mexico	Spanish	English	English	Mexico, other Central America
Teacher 4	Female	12	3 / 3	PD Teacher	Graduate degree	Yes	White	-	No	Mexico	Spanish	English	English	Mexico, other Central America
Teacher 5	Female	4	4 / 4	PD TA	4-Year College	Yes	White	-	No	Mexico	Spanish	Spanish	English	Mexico, other Central America
Teacher 6	Female	30	6 / 6	FD Teacher	4-Year College	No	White	-	Yes	USA	English	-	Spanish	Mexico
Teacher 7	Female	32	32 / 32	FD Teacher	4-Year College	Yes	Other	Puerto Rican	No	-	Spanish	English	English	Mexico
Teacher 8	Female	11	7 / 7	PD Teacher	Some graduate courses	Yes	White	-	Yes	USA	Spanish	English	English	Mexico, other Central America, Cambodia
Teacher 9	Female	28	25 / 25	PD Teacher	4-Year College	Yes	White	-	No	Panama	Spanish	English	English	Mexico, other Central America, Cambodia
Teacher 10	Female	11	16 / 8	FD Teacher	4-Year College	Yes	American Indian/Native American/Alaska Native	-	Yes	USA	English	Spanish	Spanish	Mexico), other Central America, South America (Colombia, Peru)
Teacher 11	Female	9	8 / 4	FD Teacher	2-Year College	Yes	White	-	No	Mexico	English	Spanish	Spanish	Mexico), other Central America, South America (Colombia, Peru)
Teacher 12	Female	2	2 / 2	FD TA	4-Year College	Yes	American Indian/Native American/Alaska Native	-	Yes	USA	Spanish	English	Spanish	Mexico, other Central America, South America (Colombia, Peru)
Teacher 13	Female	19	20 / 19	PD Teacher	4-Year College	Yes	White	-	No	Mexico	Spanish	Spanish	Spanish	Mexico
Teacher 14	Female	8	8 / 4	PD Teacher	4-Year College	Yes	White	-	Yes	USA	English	Spanish	Spanish	Mexico, Colombia
Teacher 15	Female	6	6 / 6	PD TA	Some College or Certificate	Yes	American Indian/Native American/Alaska Native, White	-	No	Mexico	Spanish	English	Spanish	Mexico
Teacher 16	Female	15	7.5 / 6	FD Teacher	4-Year College	Yes	White	-	No	Mexico	Spanish	-	English	Mexico, Vietnam
Teacher 17	Female	7	10 / 7	FD Teacher	4-Year College	Yes	Other	Hispanic/Latino	Yes	USA	English	-	English	Mexico, Vietnam
Teacher 18	Female	7	8 / 7	FD TA	Some College or Certificate	Yes	Other	Mexican/Latino	No	Mexico	Spanish	English	English / Spanish	Mexico
Teacher 19	Female	20	8 / 8	PD Teacher	4-Year College	Yes	Other	Hispanic	No	Mexico	English	Spanish	English	Mexico, El Salvador, Guatemala, South America (Peru)
Teacher 20	Female	26	8 / 8	PD Teacher	4-Year College	No	Asian	-	No	Vietnam	Vietnamese	-	Spanish	Mexico
Teacher 21	Female	3	3 / 3	PD TA	4-Year College	Yes	Other	Hispanic	Yes	USA	English	-	English	Mexico, El Salvador, Guatemala, South America (Peru)

Note. *ECE = early childhood education, **FD = Full day, PD = Part day, TA = teaching assistant

Figures

Figure 1

A Flowchart of the Data Analysis Process



Note. Adapted from Braun & Clarke's (2006) 'Phases of Thematic Analysis'

Figure 2
Three Key Domains Around Preschool Science Teaching

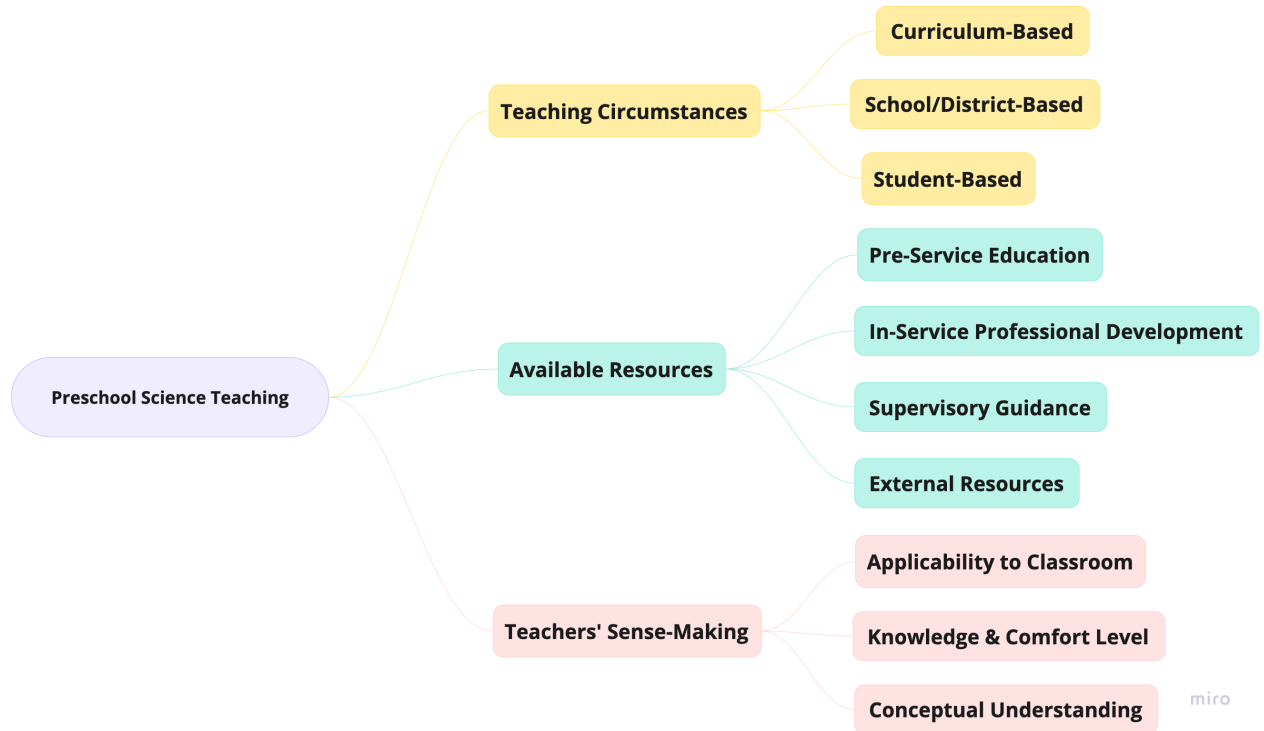


Figure 3
Teacher-identified Inputs and Outputs of Science-Focused Professional Development



**Preschool Teachers' Experiences of Teaching Science to
Low-Income, Language-Minority Children**

The teaching and learning of science have been a national priority in recent years, motivated by international competitiveness, workforce shifts, and the rapidly industrializing world (Hadani & Rood, 2018). It has received even more recognition globally after the outbreak of the COVID-19 pandemic, the development of vaccines for which saved numerous lives, earning the respect of and appreciation for science and medicine around the world (National Academies of Sciences, Engineering, and Medicine [NASEM], 2024). However, despite this increasing interest, researchers and practitioners alike often consider the science curriculum as only being applicable to children above a certain “capable” age, and not to younger children in preschool settings (Greenfield et al., 2009; Nayfeld et al., 2011; Roth et al., 2013).

More studies have been uncovering that, when done in age-appropriate and meaningful ways, science learning in preschool can yield greater school readiness, academic achievements, social-emotional skills, and more (Bustamante et al., 2017; Greenfield et al., 2009; McWayne et al., 2022; NASEM, 2024; Saçkes et al., 2009). These benefits may be greater for children from traditionally marginalized communities such as multi-language learners (MLLs), racial minorities, and low-income families, yet they have even less exposure to high quality education, and science education especially (NASEM, 2024).

To close this gap in educational opportunities and strengthen the science education system in preschools, early childhood teachers have been identified as key stakeholders. As teachers' beliefs and attitudes directly impact their teaching practice (Nespor, 1987), understanding teachers' experiences of teaching science to young children in preschools emerges as a significant step towards bringing systemic change in early science education.

Theoretical Framework

This study uses a constructivist framework to examine the importance of science education in the early years, as well as that of understanding preschool teachers' experiences to learn about their needs.

Constructivism focuses on learning by doing: an idea that a learner obtains information through their active involvement in the activity. Many educationalists with constructivist views, including Wang et al.

(1993), consider learners to be “architects building their own knowledge structures” (p. 277). Schwandt (1994) writes that the constructivist approach allows one to “[understand] the complex world of lived experience from the point of view of those who live it” (p. 221).

The constructivist view suggests that young children, who are “little scientists” according to Jean Piaget (1952), learn based on the prior knowledge they obtained from their lived experiences. Through the process of assimilation and accommodation children are able to understand their experiences by either categorizing them into similar events or developing a new group for the stimulus to be sorted as (Piaget, 1952). Preschool children who are naturally curious and exploratory (McWayne et al, 2022), then, learn best by interacting with their environments and relevant artifacts. Science education in early childhood aligns with this notion as science learning is often hands-on and inquiry-driven (Greenfield et al., 2009; Shtulman & Walker, 2020). With scientific concepts widely present in people’s everyday lives (Tu, 2006), science education in preschool classrooms enables young children to explore their surroundings and learn from their peers, families, and teachers.

In addition, the constructive approach also supports the importance of examining teachers’ own reflections on their experiences. As teachers are important social agents that help expand children’s knowledge into the zone of proximal development (Vygotsky, 1978) and play a vital role in the occurrence and quality of science learning in preschool classrooms (Desimone, 2009), understanding their beliefs can guide strategies for enhancing early science education. Because teachers become aware of what they find challenging or helpful in their practice while teaching and explicate the learned knowledges while they reflect on their experiences, it is critical for researchers to scrutinize teachers’ own interpretations of their teaching experiences for informing best practices in early childhood classrooms.

Young Children’s Capability for Science Learning

Amidst this widespread recognition and focus on science education, early childhood science learning has unfortunately been largely neglected as a target for action (Early et al., 2010; Greenfield et al., 2009; Saçkes, 2014; Saçkes et al., 2011; Tu, 2006). According to a recent NASEM (2021) report,

“science during the preschool years has been a neglected aspect in the science education literature.” The few existing studies, according to Saçkes (2014), have been conducted with small, non-random samples that limit any generalization. Furthermore, the absence of interest in preschool science extends to practice. Many US states that utilize the National Science Education Content Standards (National Research Council, 1996) to develop their state-level science standards focus heavily on kindergarten through twelfth grade, and only a few states consider science in preschool to kindergarten contexts (Saçkes et al., 2009; Saçkes, 2014). Even within the handful of states that include science curriculum, it is far below priority (Cabell et al., 2013; Greenfield et al., 2009; Hadani & Rood, 2018; Phillips et al., 2009). Phillips and colleagues (2009) found that science instruction in Oklahoma preschools, while occurring 30-50% above the national average, occur half as frequently as English language arts contents (Greenfield et al., 2009; Nayfeld et al., 2011; Roth et al., 2013). Some studies, including one by Roth et al. (2013), argue that this notion of children’s inability is deeply rooted in Piagetian theories where children are viewed in comparison to adult standards. If young children are held to the same standards as adult scientists, it may be true to say that young children under 6 will not be able to answer abstract scientific questions as an adult scientist responds. In this case it would seem that science requires more complex levels of thought that only emerge in the later stages of a child’s life and cannot be unlocked at this specific age.

However, an increasing number of studies have been documenting young children’s science learning according to their own developmentally appropriate ways. This research shows that children are capable of performing various cognitive skills such as asking questions and making predictions (Saçkes, 2014), carrying out explorations and inferring causal structures (Shtulman & Walker, 2020) and understanding the physical and social aspects of their worlds. In fact, young children’s natural curiosity (McWayne et al, 2022; National Science Teaching Association [NSTA], 2014) and tendency to experiment hands-on (Bustamante et al., 2018; Greenfield et al., 2009) align with the scientific method of asking questions, making observations, hypothesizing, experimenting, analyzing, and coming up with conclusions (Saçkes, 2014). Furthermore, science’s hands-on nature also aligns with the preexisting play-

based learning methods of preschool classrooms, notably through the involvement of agency, exploration, collaboration, and creativity (Shtulman & Walker, 2020).

Science learning at preschools, when done in developmentally appropriate and culturally relevant ways, is fundamental to young children's development in multiple ways. It is found to be integrated with learning across domains like math, language, and executive functioning (Bustamante et al., 2018; Greenfield et al., 2009) and helps young children build their identities, among which are self-concepts of capability in science and engineering (Rhodes et al., 2019). In addition, preschool science may provide opportunities for stronger student engagement, further contributing to their school readiness skills and academic achievement in the future (McWayne et al., 2022). Overall, science education in early childhood have been found to serve as a strong foundation to young children's science trajectory (NSTA, 2014) and to foster their cognitive and social development.

Early Science Education for Children from Marginalized Groups

Traditionally, children from marginalized communities have not been the focus of attention when studying the effects of early education (NASEM, 2024). Unfortunately, the already minimal research and practice of early science education have been focused on White, English-monolingual, middle-class children. Multiple longitudinal studies from the 1960s and 1970s have demonstrated that some high-quality early childhood educational experiences confer long-term benefits for children in areas such as school performance and future earnings, yet some scholars criticize these older studies for using a deficit-based approach and racially biased language, as well as their "lack of attention to the lived experiences of young children from diverse backgrounds and contexts" (NASEM, 2024, p. 1-20). Researchers have found that children from historically marginalized populations lack access to high-quality learning opportunities during the preschool period (NASEM, 2024). For example, only 1% of Latine and 4% of Black children were enrolled in public pre-K programs that met the National Institute for Early Education Research's (NIEER) Pre-K benchmarks (NIEER, 2019). In addition, early childhood classrooms serving children from low-income families show particular underrepresentation in science instruction

(Bustamante et al., 2018). Classrooms serving minoritized children have tended to focus on more direct pedagogy and basic skills instruction than complex, self-driven, exploratory activities. This practice is believed to stem from a deficit model focusing on their predicted weaknesses and not recognizing their potential as knowledgeable contributors to the classrooms' learning (Adair & Colegrove, 2021).

This deficit-based approach to the education of marginalized children, which limits their exposure to science education, is reflected in their academic outcomes. The U.S. Department of Education (2000, 2015) shows that significant differences in academic outcomes exist between many racially marginalized, low-income, non-English speaking children and their White, U.S.-born, English-speaking, middle- and upper-class peers. Curran & Kellogg (2016) found that science achievement differs by racial/ethnic groups in kindergarten, with Black and Hispanic students outperformed by their White peers by over three quarters of a standard deviation, and others have found that these gaps carry into the elementary and middle school years (Curran, 2019; Morgan et al., 2016). Further widening this gap is the decline in preschool enrollment of non-White children from low-income households over the COVID-19 pandemic (NASEM, 2024). Overall, their lower enrollment in preschools and missed opportunities for self-driven science learning, along with poor urban planning and temporal-financial barriers that limit informal learning opportunities (Roth et al., 2013) all contribute to the inequitable learning environment for these marginalized children.

Such discrepancy has traditionally been labeled the *achievement gap*, terminology that denounces minoritized families and children as incapable of yielding the same accomplishments as their peers when in fact the system is pre-structured in favor of the dominant cultural group. In recent years, this now-called *inequity in educational opportunities* or *education debt* has been slowly emerging as the center of attention. When done in culturally responsive and linguistically appropriate ways, preschool education can be “a potent means of moving the needle on instructional quality, classroom processes, and children’s early learning, particularly for children from marginalized groups” (NASEM, 2024, p. 2-9). Programs incorporating children’s heritage cultures and language/dialects encourage student engagement, social-

emotional and academic skills development, and shift in self-conceptualization as someone capable of doing science (Gort & Sembiente, 2015; Hancock, 2017). They can also foster positive teacher-family relationships and family engagement in their children's education, which are also important contributors to children's academic success later on (McWayne et al., 2019, 2023).

Understanding Teachers' Experiences

This discrepancy between the need for more early science education and the actual science learning taking place in preschool classrooms has been examined by a growing number of studies in recent years. A widely recognized key stakeholder is the preschool teachers, who help facilitate the connection between children's learning and engagement with specific curricular content (NASEM, 2024). This idea stems from Vygotsky's sociocultural theory (1978) which designates teachers as primary social agents that transmit information to children. Teachers, when seen through a sociocultural lens, guide children's acquisition of information just out of their existing knowledge, known as the process of *scaffolding*. This recognition of preschool teachers as critical players has encouraged further research on the development and execution of different teaching practices.

Educators' teaching practices are widely assumed to be driven by the teachers' thinking (Desimone, 2009; Nespor, 1987). Nespor (1987) states that teachers' "ways of thinking and understanding are vital components of their practice," which then is reflected on student outcomes (p. 1). Desimone (2009) also argues that "teachers use their new knowledge and skills, attitudes, and beliefs to improve the content of their instruction or their approach to pedagogy, or both." The report from NASEM (2024) further adds that "[t]he quality of young children's learning experiences and their interactions with curriculum depends on teachers' qualifications and professional development and the fidelity of implementation." Teachers' beliefs, shaped by their experience, determine the enactment of school curriculum (Burns, 1992). Therefore, it is critical to focus on the early educators' experiences as they can provide insider knowledge of how much science learning is taking place, in what forms, and why.

As it turns out, preschool teachers have been expressing various challenges that interfere with teaching science to young children (Appleton & Kindt, 1999; Saçkes et al., 2009). Previous studies, most of which directly involved working with the teachers to learn about their experiences, have identified limited knowledge of scientific content, shortage of resources (i.e., time, materials, staffing), and lack of confidence as key factors that hinder teachers' likelihood of teaching science in their preschool classrooms (Appleton, 1992; Early et al., 2010; Greenfield et al., 2009; Saçkes, 2014; Saçkes et al., 2011).

Limited Science Knowledge

According to the NASEM report (2024), the current early childhood education workforce is made of teachers with a wide range of training and qualifications; while some teachers complete preparatory programs such as a bachelor's degree (or higher) or formal certifications, others begin their training as an educator after being put on the job. Additionally, teacher preparation programs are found not to provide sufficient training for preschool teachers to teach science, technology, engineering, and math (STEM) contents to young children (Bustamante et al., 2018). In a previous study examining preschool teachers' attempts to teach science, it was found that while teachers' limited knowledge sometimes opened an opportunity for investigation, more often it caused teachers to panic and feel overwhelmed (Roth et al., 2013).

Previous studies show that early childhood teachers' science knowledge and their practice of teaching science are closely related (Kallery & Psillos, 2001; Saçkes, 2014). Teachers with greater training in science education are more likely to teach science to their students, as are the teachers with more early childhood teaching experience. Because scientific knowledge is not a requirement that determines teachers' ability to work with children (Roth et al., 2013), teachers often neglect science education in their classrooms.

Lack of Confidence

Closely related to the limited science knowledge is the lack of confidence teachers report in teaching science to young children. Teachers' low self-efficacy for teaching science has been identified as

another key barrier to facilitating science learning in their classrooms (Andersson et al., 2020; Bustamante et al., 2017; Roth et al., 2013; Saçkes, 2014; Saçkes et al., 2011). Bustamante et al. (2018) found that early childhood teachers often report feeling “intimidated and underprepared” to teach science, and many of them “self-select into early childhood specifically to avoid” teaching science to their students. Roth et al. (2013) wrote that elementary and early childhood teachers are afraid of teaching science and “drop it from the curriculum as soon as there is an opportunity to do so.” Many recent studies have found that preschool teachers experience pressure and feel overwhelmed when they need to address children’s science-related questions (Saçkes, 2014) and introduce complex, non-life-science topics such as physics and chemistry (Andersson et al., 2020), or use science equipment in classrooms (Saçkes, 2011). In addition to the aforementioned variety in overall teacher preparation, teachers without sufficient training in science content or pedagogy feel more uncertain about teaching science to their students (Roth et al., 2013). Because teachers’ beliefs directly influence their teaching practice (Nespor, 1987), this notion of inefficacy leads to limited science education in their classrooms.

Shortage of Resources

Yet another identified barrier was the shortage of resources needed for science learning, mainly materials and time (Greenfield et al., 2009; Saçkes, 2014; Saçkes et al., 2011;). While the availability of instructional materials can encourage teachers’ likelihood of conducting science activities (La Paro & Pianta, 2000; Saçkes, 2014), preschool teachers consistently report a lack of such resources (Saçkes, 2014; Saçkes et al., 2011). Moreover, early childhood educators express difficulty in finding time during the school day to teach science, particularly because science education is not a priority in preschool classrooms (Greenfield et al., 2009; Hadani & Rood, 2020; Saçkes, 2014; Saçkes et al., 2011). Because assessments in literacy and mathematics start at least a year prior to science-based standardized testing, teachers tend to focus on these topics rather than science (Hadani & Rood., 2020; Roth et al., 2013; Saçkes, 2014). For example, a study by Weiss and colleagues (2002) showed that instruction time for language arts was five times more than for science in 5,765 early childhood classrooms.

Other Concerns

Other identified challenges to preschool science education include lesson planning and shifting instructional methods. Teachers often found it difficult to construct developmentally appropriate science lessons for children (Andersson et al., 2020; Greenfield et al., 2009; Roth et al., 2013), as well as to resist the inclination toward excessive instructions (rather than child-driven exploration; Appleton & Kindt, 1999; Roth et al., 2013). In addition, some teachers' beliefs that young children are incapable to process scientific concepts (Greenfield et al., 2009; Nayfeld, 2008; Roth et al., 2013; Saçkes, 2014) and that science is incompatible with early childhood education (Andersson et al., 2020) also hinder science education taking place in many preschool classrooms. In classrooms that serve ELL and immigrant students, language barriers were another challenging factor mentioned (NASEM, 2024).

Efforts for Teacher Support

Amidst this extensive list of challenges, efforts to identify ways to support preschool teachers' science pedagogy have been consistent. Several studies found that instructional materials, improved teacher preparatory programs, and effective in-service professional development (PD) and coaching can help teachers increase science teaching in preschool classrooms (El-Moslimany et al., 2017; Ferguson et al., 2022; McWayne et al., 2021; Saçkes et al., 2011; Tu, 2006).

Instructional Materials

As the shortage of materials has been one of the identified challenges, providing teachers with appropriate instructional materials (e.g., ramps and blocks, books, or plants) has been found to be a helpful way to encourage science teaching (Appleton & Kindt, 1999; Ferguson et al., 2022; Saçkes, 2014; Saçkes et al., 2011). In addition, Tu (2006) suggested that teachers "utilize the science materials that are available in their environment" because "science is everywhere." For example, in a study with a classroom serving Chinese-heritage children, the structure of a bamboo plant (a common gift in some Chinese communities) in the classroom was used as an inspiration for an engineering project. In another classroom, the concept of structure and function was discussed in reference to the water pipes children see

in their kitchens or bathrooms (see McWayne et al., 2018). The use of everyday artifacts that children are exposed to daily can expand their science learning opportunities.

Improved Preservice Teacher Education

In order to bring sustainable improvement to early science education, it is important to prepare future teachers to be comfortable and knowledgeable in science content. While preschool teachers' initial teacher education is assumed to be positively associated with their science teaching competencies, only a few studies examine this relationship (Barenthien et al., 2020). Specific science methods courses that focus on young children's capabilities and how to appropriate them, as well as highlighting the importance of early science education have been noted as key foci in this improvement effort (Andersson et al., 2020; NASEM, 2024; Saçkes, 2014; Saçkes et al., 2011). In addition, a science course covering the fundamental scientific concepts taught by an instructor of science background (as opposed to an educational personnel with science teaching experience) was proved to strengthen the preservice teachers' scientific understandings and comfort level with teaching science (Miller et al., 2019).

In-Service Professional Development and Coaching

The Next Generation Science Standards, and therefore the states that adopt them, identify PD as a key component to the improvement of preschool teachers' science teaching practice (NASEM, 2016). Desimone (2009) defines effective PD as having subject-specificity, active learning opportunities, coherence with the existing school system, sufficient duration, and collective participation. In addition, a recent review of 25 National Science Foundation-funded prekindergarten (pre-K) and elementary science teaching programs by Ferguson et al. (2022) shows that providing professional development to experienced teachers, who then mentor preservice and newly appointed teachers, as well as a series of professional development experiences throughout a teaching year improved both the teachers' science teaching and student outcomes.

In addition to professional training workshops, coaching has become a common practice to support preschool teachers in their classrooms. The National Association for the Education of Young

Children (NAEYC) defines coaching as “a relationship-based process led by an expert with specialization and adult learning knowledge and skills... designed to build capacity for specific professional dispositions, skills, and behaviors and is focused on goal setting and achievement for an individual or group” (Child Care Aware of America & NAEYC, 2023, p. 11). According to Rush & Shelden (2020), early childhood coaching must be adult-appropriate, nondirective, reflective, collaborative, and hands-on in order to provoke sustained improvement in the teachers' practice. In addition, integration of discipline-specific coaches into the existing coaching system through co-coaching was found to increase district-funded general coaches and the teachers' comfort levels in science teaching (El-Moslimany et al., 2017).

Professional Development as More Than Skill-Building

Studies also claim that some PD and coaching can provide more than pedagogical knowledge- and skill-building opportunities; effective PD can also change teachers' attitudes and beliefs that then translates to teaching practice and, moreover, student learning outcomes (Desimone, 2009; Guskey, 2010). Impactful PDs allow for teachers to explore their identity as teachers and encounter “a change in professional identity based on trying to make sense of oneself, of what one is experiencing, and of one's past, present, and future” (Mistry et al., 2022, p. 1). Giejsel & Meijers (2005) labels this process *creative learning* (as opposed to *reproductive learning*), during which teachers reflect on and internalize their learning experiences rather than regurgitating instructed content. Thus, strong learning environments that can “allow for experiential learning and... providing a communicative structure that invites the learners to reflect on their experiences” is crucial for designing professional development programs (p. 420).

Context of the Larger Study

The present study is part of a larger project named RISE (*Readiness through Integrative Science and Engineering*), a curriculum and professional development (PD) research study aiming to implement culturally inclusive preschool classroom curricula (see McWayne et al., 2021). The project's main goal revolves around three key constructs: home-to-school connections (HSC), science, engineering, and technology (STE) content appropriate for preschool-aged children, and co-construction of curriculum

between teachers, families, and researchers. The home-to-school connection component is based on Vygotsky's (1978) sociocultural theory, specifically that "concepts of human functioning are culturally and contextually situated and, therefore, need to be understood from an emic (i.e., culture-specific or "inside-out") perspective" (McWayne et al., 2019, p. 5). In this approach, complemented by González et al.'s (1992) idea of *funds of knowledge*, families are believed to hold expert knowledge in their own cultures that are reflected in their everyday practices; this expertise is invited into classrooms to serve as a foundation to children's science learning. The STE focus connects to this because many caregivers engage in rich science activities in their daily lives, perhaps without recognizing it (McWayne & Melzi, 2023). Given the increase in anticipated importance of science education, the connection between a home-to-school approach and science, technology, and engineering provides an accessible and impactful science learning opportunity for young children. Lastly, the co-construction aspect of RISE stems from a community-based participatory research framework, in which research involving a specific population (e.g., teachers of low-income, language minority children) is done in partnership *with* them instead of *to* them (Wallerstein et al., 2017). While teachers receive information and ideas from research professionals, the same teachers simultaneously provide practical input and iteratively, with the support of the research team, integrate the ideas into their own practice.

These three aspects of RISE are assembled into a series of professional development workshops, one-on-one reflective coaching sessions, and peer professional learning community meetings. In the professional development sessions, teachers share and reflect on their practice, engage in hands-on activities with one another and the RISE researchers, and discuss what HSC and STE opportunities arise from their classrooms. They are also introduced to both the HSC and STE frameworks which enable teachers to identify the two aspects more easily in daily teaching practice and their interactions with families. For example, the STE framework, based on the U.S. Conceptual Framework for K-12 Science Education from the National Research Council (NRC) and its adaptation for children from birth to age five (Greenfield et al., 2017), provides lists of core ideas (e.g., force and motion, living and nonliving

things), cross cutting concepts (e.g., patterns, cause and effect, stability and change), and scientific practices (e.g., making observations, using tools, comparing and contrasting; NRC, 2012; also see Appendix C). This framework helps teachers identify and plan for what types of science learning will take place in their classrooms. The coaching sessions allow for each teacher or teaching team (from one classroom) to meet with the coach for individualized feedback, reflection, and goal-setting/lesson planning, while the peer professional learning community meetings allow for smaller groups of teachers to share their examples in detail while co-constructing future lessons with the support of their peers.

In the current phase of RISE, preschool teaching teams from a Southern Californian public school district have been receiving six professional development workshops over the course of a year, as well as individualized one-on-one or classroom-based coaching. The data used in the current study were drawn from the first-year cohort of teacher interviews that occurred toward the beginning and after their first year as a part of RISE.

Current Study

Science education in early childhood is not just possible, but essential in ensuring children's school readiness as well as their development of interdisciplinary skills (Bustamante et al., 2018; Greenfield et al., 2009; McWayne et al., 2021). This is especially true for children in immigrant and non-English speaking communities, as science learning "presents low expressive language demands... but great opportunity to show learning progress and understandings through nonverbal means" (McWayne et al., 2020, p. 4). While an increasing number of studies have identified factors affecting the frequency and style of science education in preschool classrooms, many have examined them in connection to science teaching frequency or specific student outcomes. Minimal efforts have been made to understand what the teachers view as critical obstacles or crucial supports. It is essential to understand the beliefs and experiences of these primary stakeholders to children's learning in classroom settings in order to implement impactful and sustainable preschool science curriculum. Through the narrated interpretations of their science teaching and professional development experiences, how teachers make meaning of their

teaching and how they integrate new events (i.e., PD and coaching) into those practices can be made explicit (Mistry et al., 2022).

The current study examined preschool teachers' perspectives on teaching science to young children as part of a larger curriculum and professional development research project. More specifically, answers to the following research questions were sought:

1. What are the aspects of preschool teachers' science teaching experiences that may hinder or facilitate science education in their classrooms?
2. How do their perspectives change throughout their participation in a series of science-focused professional development and coaching sessions over the course of one academic year?

Semi-structured interviews of 21 preschool teachers from 8 preschool classrooms in a public school district in Santa Ana, California, who participated in the RISE Project, were examined qualitatively through a thematic analysis to understand their experiences teaching science to young children.

Method

Participants

Context of the School District and its Preschool System

Santa Ana is the 13th most populous city in the state of California, with over 300,000 residents according to the U.S Census Bureau report from 2020. Santa Ana Unified School District (SAUSD) is the second largest school district in the county with 40,328 students in 38 elementary, 16 middle, and 11 high schools (2023-2024; SAUSD, 2024). Preschool programs are operated as a part of certain elementary school campuses instead of standing as separate entities. The California Department of Education (CDE) report for 2022-2023 enrollment shows that 95.8% of enrolled students identify as Hispanic or Latino, followed by Asian (1.84%), White (0.93%), multiracial (0.33%), American Indian or Alaska Native (0.27%), Black or African American (0.26%), and Others/Not Reported (0.54%; CDE, 2023).

Approximately 45% of the students enrolled in the district are MLLs from mostly Spanish, Vietnamese,

and Khmer-speaking backgrounds. About 87% of the student population comes from low-income families, with 77.5% of students receiving free or reduced-price meals (CDE, 2023).

SAUSD's early childhood education programs serve children between the ages of 3 through 5 years old. Enrollment priority is given to the lowest income families, with every family required to meet at least one criterion: homelessness, involvement with child protective services, disability, low-income, receiving benefits from governmental programs, FRPM (Free/Reduced Priced Meals), or other personal need (SAUSD, 2023a). Part-day programs are free, and full-day program fees are on an income-based sliding scale. (SAUSD, 2023b)

Teacher Demographics

The present study sample included 21 preschool teachers, teacher's aides, and instructional providers from 8 classrooms (4 full-day and 4 part-day) at 4 preschool sites in SAUSD. Out of these teachers, 14 were instruction-providing teachers, while seven were teaching assistants. Participants volunteered to participate in the larger project (RISE) to promote family engagement in preschool science education through a home-to-school approach (see McWayne et al., 2020). Teacher demographics are listed in more detail in Table 1.

All teachers in the sample were female with teaching experience at the district ranging from 2 to 32 years ($M = 14$; $SD = 8.4$). A majority of the teachers graduated from a 4-year college ($n = 13$; 61.9%) followed by two teachers each with a graduate degree, some college education and/or certificate, or some graduate courses (9.5% each), and one each with a 2-year college degree or high school diploma/GED ($n = 1$, 4.8% each). Most teachers identified as Hispanic ($n = 19$, 90.5%) from the United States, Mexico, and Panama, while two non-Hispanic teachers (9.5%) answered that the U.S. and Vietnam are their countries of origin. Slightly more than half of teachers spoke Spanish as their first language ($n = 12$, 57.1%) with other teachers speaking English ($n = 8$, 38.1%) and Vietnamese ($n = 1$, 4.8%) as their first language. Teacher identified the families in their classrooms as mostly from Mexico, although different regions were represented, as well as from El Salvador, Guatemala, Colombia, Peru, Cambodia, and

Vietnam. Nine (42.9%) classrooms spoke Spanish as a primary language in their classrooms, while 11 (52.5%) spoke English, and one (4.8%) classroom used an even amount of English and Spanish in the classroom based on teacher report. Two classrooms (one full day and one part day, led by Teachers 10 through 15) were part of the districts' dual language learning programs.

Procedures

Towards the beginning and at the end of the first year of RISE implementation, these 21 teachers were invited to participate in a pre- and post- interview with one of two doctoral-level researchers (“interviewers”) from the research team. The interviews were mostly conducted in English, but both interviewers were fluent Spanish speakers and able to conduct interviews in Spanish upon request. The interview questions were created by the RISE research team members and designed into a semi-structured format, in which the general interview guide with questions aimed at the research objective exists but is not strictly enforced (see Appendix B). Instead, it provides structure and focus to the “natural flow” of conversation for each interview in which interviewees are invited to elaborate or expand on their thoughts as they respond to the guided questions (Adeoye-Olatunde & Olenik, 2021, p. 1362). Interview questions ranged from those about the teachers' and classroom demographics (e.g., “What is your name and how many years have you been teaching?”, “How would you describe the characteristics of your students and families?”) to reflective questions about their teaching practices (e.g., “What are some barriers to teaching science in your classroom?”, “How have RISE professional development sessions been different from other professional development sessions you have attended in the past?”). Interviews ranged in length from seven to 71 minutes ($M = 31.4$; $SD = 11.3$). The interviews were audio-recorded and transcribed primarily using transcription software (HappyScribe) as well as a research assistant, followed by verification by another research assistant. Research assistants doing transcription and verification were different from those who conducted the interviews. Interviews conducted in Spanish were transcribed and verified by Spanish bilingual research assistants. These interviews were also translated into English by one of the bilingual research assistants prior to data analysis in English.

Data Analysis

Analytic Strategy

For this study, I used a thematic analysis methodology as laid out by Braun and Clarke (2006) to examine the teachers' interviews. Thematic analysis, according to the authors, is "a method for identifying, analyzing and reporting patterns (themes) within data" that "minimally organizes and describes a [researcher's] data set in (rich) detail" (Braun & Clark, 2006, p. 79). It is a foundational qualitative research method that offers flexibility and adaptability to, or the lack thereof, any framework. It emphasizes the active role of a researcher as the decision maker of what themes get extracted from the data, thus rejecting the passive view of data analysis as following the emergence of various themes. Furthermore, this methodology allows for the capture of themes whose "keyness" is not assigned through quantifiable measures; any important idea that relates to the research question can be added to the list of findings, not just those that are recurring or widely shared (p. 82).

The analysis followed five steps (see Figure 1): transcription, descriptive coding through an inductive approach, second cycle of pattern coding, defining and naming themes, and network and diagram displays (Miles et al., 2014). Firstly, audio-recorded interviews were transcribed using an online transcription software HappyScribe and by a research assistant, followed by another round of verification (see Procedures above). Then, seemingly meaningful texts from interview transcripts were tagged in the form of highlighted text within the original full-length transcription documents to be coded. The initial coding cycle involved descriptive and in vivo coding techniques (Miles et al., 2014), summarizing the identified key parts of teachers' experiences into a few simple words (i.e., "Barriers? I don't know, like having a big size of whole classroom because it requires more supervision" was coded as BIG CLASS SIZE) or quotes (i.e., "Science is everywhere... I guess in every project, I'm going to think, how does this reincorporate science?" was coded as "SCIENCE IS EVERYWHERE"). The following cycle involved *pattern coding*, which groups the above summaries into a smaller number of themes or constructs ("*meta-codes*") to yield more fundamental and parsimonious units of analysis (Miles et al., 2014). Afterwards,

the identified themes were refined through iterative cross-check between the original interview transcripts and emerging thematic patterns, generating clear definitions and names for the synthesized network among the codes. Finally, the codes were examined for any patterns across the sampled participants and displayed in two network diagrams, using an online software program, MIRO, for an overview of the superordinate (pattern) codes as first-cycle descriptive codes, as well as examples of original excerpts.

Credibility Checks

To minimize researcher bias in the data process, the study implemented various validation strategies. In order to enhance the credibility of my qualitative data analysis, my thesis primary advisor and the second committee member – both professors at research-focused universities with multiple years of community-based educational research experience – served as external auditors. Their role involved a thorough review of the data analysis process and the resulting findings, thus contributing to the intersubjectivity of the study and ensuring that the research was conducted with rigor and transparency (Creswell & Miller, 2000).

The intersubjectivity of this research is further strengthened through member-checking (Creswell & Miller, 2000; Saldaña, 2009), which involved taking the initial findings back to a subsample of teachers from the original cohort ($n = 5$) in a focus group meeting format to confirm the accuracy in how participants' narrative responses were represented (Creswell & Miller, 2000; Goldblatt et al., 2011; Smith et al., 2009). This process took place in person eight months after their post-interviews and involved the author, five teachers who were randomly selected by the district administrator based on availability, and a Spanish bilingual research assistant with no prior relationship to the teachers. The meeting was conducted in English, but teachers were encouraged to converse in Spanish if preferred. In an hour-long meeting, teachers were firstly presented with slides summarizing the purpose of the study and the member checking process, findings from data analysis, and potential implications drawn from such findings. Teachers were then invited to openly discuss their reaction to these findings with three guiding questions (see Appendix D for full protocol).

Positionality Statement

Before I present the findings, and in the spirit of self-reflexivity, I acknowledge my standpoint as an immigrant, a former teacher and an active member of the RISE research team. With my personal background as a Korean immigrant, I have prior knowledge of growing up as a multilingual learner and the educational conditions surrounding this experience. As many participants themselves are immigrants, my background may have allowed for me to identify more closely with the teachers as well as the students in their classrooms. In addition, while I do not have a professional history of teaching in a preschool setting, my past experience as a high school teacher may still have prompted a more empathetic view of the participating teachers' experiences, which might influence my interpretation of the findings. However, the use of credibility checks (auditors and member-checking) helped guard against this bias. Finally, my participation in and familiarity with the RISE project may have prevented an unbiased interpretation of the effects of RISE training on teachers' practices. This risk was also minimized by verifying the findings with the original participants through the process of member checking.

Results

The analysis of teacher interviews identified several factors pertaining to facilitators and barriers to teaching science education in preschool classrooms including curriculum, student capabilities, teachers' previous trainings, and teacher efficacy among others. These were further reduced and grouped into three key domains: teaching circumstances, available resources, and teachers' sense-making of science education (see Figure 2). In addition, aspects of the RISE program that teachers found helpful and the changes these sessions stimulated were identified. The three domains pertaining to preschool science teaching and their elements, as well as how teachers described their progression during the year-long RISE PD, are described in more detail below.

Aspects of Preschool Science Teaching Identified by Participating Teachers

Teaching Circumstances

When asked what science learning looks like in their classrooms, teachers mentioned various factors impacting their daily teaching that could be categorized into three subdomains: teaching curriculum (i.e., amount of scientific content, repetitiveness), school district system (i.e., class size, time, and material resources), and student capabilities (i.e., age- or language-restricted challenges). Concerning curricula used in their classrooms, teachers admitted that their schools “really don’t have a big science curriculum” (Teacher 6) and that science education “has not been [their] main priority” (Teacher 8). Teacher 8 also pointed out the repetitiveness of their curriculum, from which her excitement for the provided training stemmed. She shared:

[I am excited about] just incorporating something new into the classroom. Because sometimes as teachers, you get burned out using the same curriculum, using the same stuff. So you need to find other ways... to bring different ideas into the classroom and not repeat the same pattern over and over.

In addition to the curriculum, teachers also acknowledged that sometimes their working conditions within the school or the district can hinder their science teaching. Teacher 5 brought up her challenge incorporating science activities into her classroom due to a big class size, as it requires more supervision than can be provided due to her school being short-staffed. Other teachers reflected on the time constraints when preparing the materials needed for science activities, sometimes because the teachers themselves are too busy (“we are here in the classroom eight to four; we don't have time even for us to do the paperwork”) and other times due to a long turnaround of supplies (“if we're going to do something I had to order now, so within three months we receive it”). Furthermore, even when teachers find time to order the materials for a science activity, teachers expressed that financial burden (“there's a lot of cool science projects that we can do, but then you have to pay for it out of your income”) or

insufficient space at the school facility to store the materials (e.g., not having a freezer to store ice for a snow exploration activity) sometimes posed challenges.

Another recurring theme relevant to the teachers' teaching circumstances was the students in their classrooms. While teachers assured that their students love certain science activities that are eye-catching or exploratory (e.g., making a volcano with vinegar and baking soda, digging out a pumpkin), many teachers also expressed concerns about the children's capabilities. In addition to preschool children's young age, Teacher 4 also mentioned that some MLL children may face a language barrier:

I feel like children who are only Spanish speakers, maybe that could be like a barrier about how they understand the idea of science. So it could be a little difficult for them to understand, unless if we teach it in both languages... Some children, they don't understand when we're trying to give instructions about a specific activity. And so we have children who are like... they don't even know what to do.

Another student-based challenge, linked to the aforementioned lack of designated science curriculum in the classrooms, was children's activity preferences. Teacher 14 shared that children's participation in science activities "depends on what is [there]" and, without anything special, "science, unfortunately, is... not as visited as other areas." Without a science-focused curriculum, most science activities in class were solely voluntary, one choice among many other choice activities, with not every student exposed to the same learning opportunities.

Available Resources

This study's analysis further revealed that preschool teachers rely not only on material availability but also on direct guidance from more experienced staff to incorporate science into their classrooms. Pre-service trainings (such as credentialing programs), in-service professional development, guidance from supervisory figures, and other resources from teachers' personal lives (e.g., social media, personal connections) all seemed to contribute to the science teaching in preschool classrooms. In their interviews most teachers acknowledged that they have not had proper training in teaching science to

young children during college. For some teachers, such minimal exposure to science content and pedagogy continued through their current profession; for others, many PD sessions or coaching they have had have focused on behavior management or accommodation for special needs. A few teachers recalled some sort of preparatory instructions for preschool science teaching, but they were from many years ago (Teacher 7) or during another research-practice partnered intervention (Teacher 13).

Teachers also described many of these PDs as repetitive (as expressed by Teacher 1, “I don't want to have the same PD over and over and over when there's other things that we can learn about”), unidirectional (e.g., “cut and dry,” “you can feel it... they're there to *teach* us”), uninteresting (e.g., “like pulling teeth”), or not reflective of the reality of the teachers' classrooms. Teacher 20 summarized these concerns as below:

Sometimes PD training is... more lecturing and talking... but we're not seeing the actual results, like how they're implementing it on their end. I think that makes a big difference... or we get a video, and they have like three children in the video. And, of course, the three children are sitting there. They're following every direction. But that's really not reality in our classrooms.

Another teacher also commented on the time of the year some trainings are offered, sharing that learnings during trainings at the end of the year do not last when teachers come back from a vacation.

A few teachers have shared that they have received science-focused professional development, but these opportunities were not provided by the district directly; instead, individual teachers had to “know where to find them and how to sign up” in order to attend one. Other teachers have shared that they utilize external resources available to them when brainstorming for science activities, demonstrating their resourcefulness. Two teachers have mentioned using Pinterest for inspirations, while another teacher keeps in contact with her high school teacher for ideas. Some also mentioned brainstorming or practicing science activities with their own children.

Teachers' experiences with coaching were similar, where the majority of teachers did not have previous coaching experiences, while some teachers that did stated that the coaching was for non-science

aspects of their classrooms. For one teacher who had been coached on science teaching in the past, she had shared that the guidance was “not as deep” or “expanding” as the coaching provided by RISE.

Teachers' Sense-Making of Science Education

Though not explicitly stated during the interviews, it could be inferred from the teacher interviews that teachers' perceptions of and relationship to science as a subject was also related to their science teaching in classrooms. One repeated challenge brought up by teachers was to see the compatibility between preschool children and science education. While a few teachers seemed excited to incorporate more science into their teaching, many others were concerned about making science preschool-friendly. Teacher 20 further elaborated:

But here as our three-year-olds... even younger now... before they even hit three. So that's a challenge to like, how do we implement that so that it's meaningful for the three-year-old or the almost three-year-old's? ... Maybe the barrier would probably just be us, maybe not knowing how to implement those things for that age group, that would probably be a barrier.

In addition to building age-appropriate science lessons, several teachers also found their lack of scientific knowledge challenging. They often identified themselves as “not a fan of science” or admitted the need to “educate [themselves] first” before teaching science in their classrooms. These reflections were followed by expressing their low comfort level teaching science, which further restricted their science pedagogy.

Furthermore, their lack of scientific knowledge was also visible in how they conceptualized what science is. When asked about their comfort level with STE concepts, many teachers understood their *familiarity with the concept of technology* as equivalent to their *technology literacy* within classrooms, and commented on their abilities to “[pull] things up online, [show] children videos,” or use tablets in class. These responses demonstrated that teachers have a fixed concept of what science, engineering, and technology looks like and have not yet realized the everyday opportunities to interact with these concepts. Their narrow conceptualization of these topics is further examined in the upcoming subsection around the

teachers' experiences post-PD as they reflect on the shifts in their perspectives regarding science teaching and learning.

Teachers' Experiences During Professional Development Sessions

During their participation in the RISE project, the teachers underwent six professional development (PD) sessions as well as one-on-one or classroom-based coaching and bimonthly professional learning community meetings. Throughout the PD sessions teachers were able to connect everyday practices to scientific concepts through a science framework, engage in collaborative hands-on activities that were easily replicable in their classrooms, and exchange ideas and examples with teachers from other classrooms. The coaching sessions added more focused guidance specific to a teacher or a teaching team from a classroom, while small-group professional learning community meetings allowed for teachers to share their ideas in more detail and co-construct upcoming lessons with other teachers and their science coach. In addition to the content of these sessions, teachers found the relationships they built both with the research team members (including the science coach) and among themselves greatly contributing to their positive PD experiences. Figure 3 displays the specific elements teachers have found helpful from these professional development sessions (top left), as well as the outcomes these elements effected within the participants' teaching practices (bottom right), which are to be discussed in the next subsection on teachers' shifts in teaching practice.

Conceptual Framework

As a part of their training, teachers were introduced to a conceptual framework of preschool science through the Science Framework Reference Sheet (as adapted from California Pre-K Learning Foundations for Three-to-Five-and-a-Half-Year-Old Children in Center-Based, Home-Based, and TK Settings; see Appendix C). This framework, based on the Next Generation Science Standards (Greenfield et al., 2024), listed various science practices (e.g., making predictions, using tools), crosscutting concepts (e.g., stability and change, cause and effect), and core domains (e.g., life science, physical science) for preschool-level teaching. Through experience with this framework in PD sessions, teachers were able to

understand what everyday experiences and encounters can lead to science learning opportunities.

Teachers found this helpful as it allowed for them to visualize how their science activities should look.

Teacher 8 elaborated:

...just having the framework was better because we were looking at what we wanted to teach the children as opposed to before... These are the guidelines to what we want to see in the classroom:

Are the children using their cause and effect to find out whether this experiment works or not?

Are the children *making predictions* before we start? Are they *making observations*?

Hands-On Activities

In addition to learning about how daily activities and scientific concepts connect, teachers were able to enact this knowledge through various shared learning activities in PD that were hands-on. They shared that they were able to “really see it and experience [the science] rather than just reading it on the web or reading it on a brochure.” Because these activities were designed based on the upcoming units of their classrooms, teachers also mentioned learning how to extend science learning opportunities by “just going a little deeper” rather than having to adapt to entirely new teaching practices. Furthermore, teachers found that these activities allowed them to “see... the perspective of the kids” because they closely aligned with how preschool children learn:

I think the kids learn more on hands on than just listening to my voice. And I think that was RISE PD. That was what we did, only hands-on... it works better with me. And I know for our kids too... They learn better with hands on and things that they can do in the classroom or at home.

(Teacher 2)

This alignment with children’s learning style also made the activities done in PD easily replicable in the preschool classrooms. Teachers repeatedly shared about bringing the exact activities executed in PD back into their classrooms.

Further facilitating this translation from PD to classroom were the practice opportunities that the PD activities provided; teachers mentioned that “it would be easy for [them] to show it to the children, to

teach the children in the classroom” because the teachers have already done the same activities prior to implementing them in class.

Individualized Guidance

Similar to how teachers felt about the offered activities already aligning with their curriculum, teachers in unison acknowledged that the coach’s guidance was individualized to the teachers’ existing ideas. According to the teachers, the coach would “take... what [they] think” and expand on it, so that the teachers “didn't have to recreate anything... It was what [they] were already doing and then enhancing it.” In addition, they found that coach was able to keep them accountable by frequently checking in and actively communicating with them. The coach’s accessibility (“only an email away,” “very willing to help”) and accountability (“[she] makes sure you been actually following through” “follow-ups we had with her... motivated us”) were also recognized as helpful for the teachers. In addition, Teachers 8 and 16 also stated that having a point person to reach out when they were confused helped them to understand the concepts newly introduced during the PDs more easily.

Relationship-Centered Interactions

This individualized guidance was made possible as the teachers formed genuine personal relationships with the coach and the research team members. Teachers pointed out that these PDs “[gave] everyone the opportunity to speak” with the researchers who were “actually listening to [them].” Several teachers expressed that they felt comfortable (“they did make you feel like we've known them for years”) and appreciated that the research team members ensured the teachers feel confident to execute the discussed lessons (“making us feel comfortable and reassuring us like, okay, ‘we got this’”). Teacher 13 further reflected:

Normally in the training, I’m the type of person that doesn’t really talk. And I don’t know, this time I felt really confident being able to express my ideas to other people, and to the RISE staff about what we do here in the classroom. I don’t know, I mean, you all give... such confidence, you all are, I don’t know, I feel, I feel good.

Another interaction that some teachers found exciting was meeting the research team leaders (i.e., principal investigators) who are directly behind the design of the project materials. When discussing the science framework, Teacher 6 recalled:

I liked when we got that handout... and actually meeting somebody who is behind it. Because often we just see names, but we don't know who these people are. But now we can put a name to face of who wrote these standards.

As the teachers construct positive working relationships with the research team, they also built a strong peer network among themselves during these trainings. During PD and professional learning community meetings, teachers had ample opportunities to interact and collaborate with other teachers from different schools or classrooms. Teachers were able to present their own ideas and learn from others' examples, co-constructing a network of ideas that can be easily adapted into another classroom.

Examples and Materials

In addition to the above, teachers also showed appreciation for the ample number of practical resources provided such as examples from other RISE classrooms and activity materials. Teacher 20, who had criticized her past job for making suggestions without showing results, commented on previous RISE classrooms' examples presented during PD sessions:

I think what I'm liking with the PDs is that they're showing, they're giving us examples. Like they're showing us the videos of them working with students back in Boston, and we're seeing their results. We're getting those examples. They're not just up there talking about it... I really enjoy watching those videos and seeing how they're doing it as opposed to like, reading it in a book or somebody just lecturing about it.

Providing opportunities for teachers to share the activities that they executed in their classrooms also allowed for teachers to learn from each other's ideas. According to Teacher 11, seeing what other schools have done and being able to ask questions to those teachers enabled her to understand different approaches to explore a curricular unit.

Another helpful resource provided to the teachers were the physical materials needed for science activities. During PDs, teachers were able to take the same materials they used during their hands-on activities back to their classrooms (for example, after an activity in which teachers used their five senses to explore strawberry plants, teachers were encouraged to take a pot of a strawberry plant back to their classrooms and replicate the activity with their students). Many teachers found these provided materials helpful in incorporating similar science activities into their lessons.

Shifts in Teaching Practice Across the Year

Teachers described multiple shifts in their perspectives and teaching practice through their participation in RISE. Namely, these changes occurred with respect to their conceptual understanding of science, increased sense of agency, perception of existing barriers, and science-teaching mindset moving forward.

Expansion of Scientific Understanding

Several teachers looked back to their science teaching prior to the RISE PD and admitted that they have had a limited understanding of what science can look like. They recalled that they considered science to be “those boring experiments” with “beakers and mixing stuff,” but came to realize that science learning opportunities exist beyond such direct instruction activities. Through the use of the science framework, as well as hands-on activities that are relevant to their everyday lives or involve materials that are easily accessible and obtainable, the teachers have found that “what you think [is] not science [is] science.” With this idea came another realization that *science is everywhere*. Teacher 14 narrated:

Everything is science. Now you think about it, it's like... you're now walking or driving or whatever, and you're constantly thinking, ‘Oh, yeah, look, that's science. Or, oh, the car – how does the car work? How do the wheels turn? What makes a car work? Or you see random stuff and you're like, ‘Yeah, everything is science.’ Everything we do *is* science.

Validation of Existing Practice

With this newly acquired notion that science learning opportunities can be found in everyday spaces, teachers also experienced a sense of validation as they became aware that what they have been doing in their classrooms already involved science. Teachers repeatedly shared that they became aware that they “do science every day but sometimes... don’t notice.” Carmen further elaborated on this phenomenon with an example from her classroom:

Knowing what we really do in the classroom is science, but we are doing so often and so general that we don't know there was a science for that way... You just do it automatically... Example that we took three days ago: Okay, kids, this is the material. You glue the way you want it. You do whatever you want. But hey, the glue is going to stick to the material. That's science. What the glue has to make to hold those materials.

By noticing the science teaching taking place in their daily practices, teachers were able to proactively seek more opportunities for incorporating science in their classrooms.

Empowerment and Agency

More shifts in how teachers view their teaching practice was evident by their sense of empowerment and increased perceptions of agency. The pedagogical methods they internalized during PD, coaching, and peer professional learning community meetings helped the teachers see themselves as someone who can “make the children think more and not just... yes or no [questions].” One teacher shared about finding herself pondering “what else [she] can provide” from her expertise to the students in her classrooms. Teacher 4 labeled what she learned from PD as a tool that teachers can utilize, stating:

...it's powerful to know that [this type of science teaching] integrates step for children to learn because we're guiding them... I think it's just a powerful tool that we teachers could use to teach children.

Another visible shift in teachers' self-conceptualization as capable of teaching science was observed specifically among the teaching assistants. During their pre-interviews, participants who are

TAs (as opposed to lead teachers) had distinguished their roles in the classrooms from those of other, often certified teachers, whom they see as more knowledgeable. For example, Teacher 12 had mentioned that she as a TA often “[doesn’t] know what to do,” sharing that she is “mostly out there cleaning and being after the kids.” However, as the teachers understand how to locate and expand on science learning opportunities in their daily practices, it could be observed that TAs have gained a greater sense of agency as instructors in the classroom. Teacher 3’s reflection below highlighted this shift:

I'm not the teacher, I'm the TA. I don't have the level of study that teachers have. And I was like, ‘Oh, science is for people already in college, people with other degrees.’ But that struck me... when we were taught at RISE to introduce the science that it is everywhere and around us... you can teach a little child the same thing.

Overcoming Previous Barriers

Teachers’ new understanding of what science looks like, as well as their increased sense of agency as a teacher, also allowed for some teachers to overcome the barriers they initially identified. One of these shifts was observable in how teachers think of supplies; many teachers acknowledged their realization that it “doesn't take that much stuff to do science.” Others shared that they began looking for preexisting, everyday objects such as cooking utensils or recycled materials to conduct science activities in their classrooms. For example, Teacher 15, who had initially pointed out the lack of materials as a barrier to teaching science in her classroom, responded to the same question (“Are there any barriers when to teaching science in your classroom?”):

Well, maybe when you don't have the products we need, but everywhere there is science, right?

No, I don't think I had a challenge. It's that wherever you turn we can do science.

Another challenge that teachers initially experienced but overcame was the fear of and low comfort level with science teaching. With the new understanding of what science can look like, teachers realized that teaching science is “not as hard as [they] think it is” and even fun. For example, Teacher 7,

who initially introduced herself as “not a teacher that was in love with science,” eventually wondered “why I don't like the science if it's not a big deal?”

Determination for Future Science Teaching

With the deeper understanding of what science looks like, teachers also seemed to see the compatibility between preschool classrooms and science education more clearly. They were able to understand that science education helps with school readiness, vocabulary building, and learning of other academic domains such as language or math. Teacher 9 pointed out:

You have science in everything. Look, science encompasses mathematics, it encompasses language, it encompasses many things that they are going to learn... In science you are teaching an advanced language, in science you are learning mathematics, to put the measurements, which is bigger, which is heavier, which is smaller, it is light.

Another teacher, Teacher 14, also acknowledged her increasing ability to connect and extend the different units within their curriculum:

How everything basically, I guess you could say connects... We started connecting like, Okay, we're already talking about plants, might as well bring in the farm as well. Because where do plants come from? From the farm anyway. So we went farm, farm animals, animals. So we started connecting everything. Whereas before I was like, okay, this month we have to do transportation, and then we're going to jump into I believe it was farm. And then we're going to jump from farm to community workers.

With such increased motivation for science teaching, teachers also exhibited increased determination for improved science teaching in their classrooms. Teachers began to ask themselves questions such as “what is the purpose of doing this activity?” or “how can I build science into [the curriculum]?” They also showed determination in purposefully using more science vocabulary in their lessons for more vocabulary exposure.

Self-Improvement beyond Teaching Practice

Teachers' growth in mindset was evident even outside of their teaching philosophies; some teachers also shared that they were able to address their personal challenges in the context of RISE PD, such as shyness, language barriers, and communication skills. Teacher 18, who shared that she was "a little nervous to present in front of everybody," eventually "felt super confident" to share her classrooms' activities and progress in front of the whole group during PDs. Another teacher, Teacher 5, also mentioned that she is usually "super shy" but became "more comfortable with people and work with more people" as the trainings progressed.

Teacher 17, who is a non-Spanish speaker, also shared her story of overcoming the language barrier with some Spanish-speaking families in her classroom as a result of science activity-related conversations. She reflected:

Because of the language barrier, I feel like I have very hesitance to communicate with the parents. But after that, after working with the project and then with this project, I think I just say... For example, my Spanish ability is super limited. And I just say it. I just say it. And then I just say... *hoy practicamos escribir la figuras en paper* [today we practiced drawing shapes onto papers]. Then when I finish, I say, *como es mi espanol?* [how is my Spanish?]. And all the parents say, *Bien, bien, bien.* [Good, good, good.] Say, *Comprendes?* [Are you able to understand?] And they look at me like, *Ay.* Like that.

Yet another teacher reflected on learning about how to work with others through collaborative hands-on activities. Regarding an activity where teachers were to pack a myriad of items into as few suitcases as possible, she reflected:

... we all had our own ideas of how many suitcases we needed to have, and we needed to work together to get everything to fit. And sometimes in life, it's hard to work together as a team and how to figure out ways to get things to fit together. So, I think that with life in general, that helped.

Through these collaborations, teachers not only observed different ideas from their peers but also developed skills to effectively communicate and work together in general.

Remaining Barriers

Despite the improvements to various aspects of preschool science teaching, teachers did recognize that some barriers still remain around their teaching circumstances. In their classrooms, large age ranges among the students continued to challenge building science lessons that accommodate students aged from less than three up to five. Additionally, children's activity preferences continued to play a role in who engages in an activity and who does not (e.g., a child refusing to touch a fruit because it "looks yucky").

Outside of their classrooms, certain district policies also added complications to executing science lessons. For example, Teacher 4 mentioned a certain school policy against activities involving food ("They just told us that we were not allowed to give the children to try the tea, so they could only smell it"). Another barrier for specific activities involving family engagement was some parents' medical clearance requirements for site visits. Teacher 4 shared that because many parents are immigrants with their medical records not readily available, the school does not allow for parents to visit for longer than 15 minutes, which sometimes interferes with science activities that may involve the students' families.

Member Checking Outcomes

The results reported above were presented to five teachers (Teachers 4, 13, 14, 16, and 20) eight months after their original participation for validation purposes. These teachers were randomly selected by the school district director based on availability. Teachers acknowledged that these findings accurately described both their science teaching in preschool classrooms and their RISE participation experiences. More detailed reflections on understanding the compatibility of preschool science, feeling validated in their existing teaching practice, and remaining barriers around school policies were shared. Suggestions on expanding the current RISE program to upper grade levels (e.g., elementary school), involving parents in training for strengthened home-school connections, and relaunching of a previous family engagement

initiative by the district were made during the conversation; such ideas are to be addressed in the future phases of the larger RISE project.

Discussion

Science pedagogy and preschool education are highly compatible and their integration beneficial in various ways (Bustamante et al., 2017; Greenfield et al., 2009; McWayne et al., 2022; NASEM, 2024; Saçkes et al., 2009). However, studies show that many children – especially those from low-income or multi-language learning (MLL) backgrounds – experience educational inequity around science learning opportunities. Vygotsky's (1978) sociocultural lens as well as Nespor's (1987) finding that *teacher beliefs impact teaching practice* suggest that preschool teachers play a vital role in reshaping inequitable learning environments (NASEM, 2024). Despite an increasing number of studies examining the frequency and quality of science education in preschools, the lack of focus on teachers' own perspectives still poses a gap in the literature.

Using thematic analysis, the current study aimed to illuminate the elements of preschool science teaching that can hinder or facilitate science learning as well as the impacts of science-focused teacher professional development. Through a constructivist framework (Schwandt, 1994), teachers are viewed as the experts of their own teaching practice and, therefore, their reflections are the most illustrative of what their teaching experiences entail. Examining preschool science teaching and the impact of professional development through teachers' perspectives allowed for a confirmation of findings from previous research as well as an unfolding of the stories behind these findings, and three potential pathways to strengthening preschool science teaching support.

Under-Recognition of Preschool Science as a Potential Root Cause for Current Challenges

As previous studies suggest, preschool teachers find science teaching challenging mainly due to their limited scientific knowledge (Andersson et al., 2020; Curran, 2019; O'Connor et al., 2021; Raven & Werner, 2023) and the low prioritization of science in preschool curricula (Greenfield et al., 2009; Hadani & Rood, 2020; Saçkes, 2014; Saçkes et al., 2011). The stories from the present study's participants

suggest that these barriers may be traced back to the low level of acknowledgment for the utility of science education in preschool settings.

In alignment with the NASEM (2024) report, the present study's teachers varied in their levels of education and their past training experiences (PD and coaching). Even for those teachers with more exposure to professional learning opportunities, the levels of exposure to science teaching-focused guidance showed a wide range of variation. This observation raises a question of whether this lack of exposure to science teaching training is specific to preschool educators or common across teachers of other early grade levels. Given that the National Science Education Content Standards are established starting from the kindergarten level, and that the national effort towards higher quality science curriculum focuses specifically on K-12 (Yoon, 2018), it can be inferred that lack of opportunities for preschool science teaching training – at least partially – is still grounded in the notion that science education is not compatible with the way young children learn (Andersson et al., 2020; Greenfield et al., 2009; Nayfeld et al., 2011; Roth et al., 2013).

Additionally, several studies including Schachter et al. (2021) have pointed out that the early childhood workforce often feels like their profession is undervalued and “not accorded the same status and value as their counterparts who work with older children” (p. 1183; also see Faulkner et al., 2016; Henderson et al., 2024; Quinones et al., 2021). Such dismissal of preschool education generally further adds to, as Fleer (2009) delineates, “the need for convincing others of the worth of early childhood science education” (p. 1070). It is possible that the field of teacher professional development, both in the forms of pre-service teacher education and in-service professional support, still requires more persuasion regarding the importance of early science education and therefore the training of teachers to facilitate it.

This negligence of science education in preschool is also reflected in the preschool curricula. Teachers' interviews from this study confirmed previous studies' findings that many preschool curricula do not have designated science lessons (Saçkes et al., 2009; Saçkes, 2014). As the teacher-participants expressed, this prevents *every* student from engaging in science learning regardless of available learning

opportunities because without a designated time, student participation is voluntary. Therefore, despite science being labeled as a fruitful learning context for low-income and MLL children because of its ubiquitous learning opportunities, hands-on nature, and low English language demand (Bustamante et al., 2018; Greenfield et al., 2009; McWayne et al., 2020), having to make these learning opportunities engaging enough to be preferred by children still remains a barrier for those who develop preschool curricula as well as the teachers who implement them.

Professional development sessions from this larger study seemed to alleviate some of these barriers (McWayne et al., 2021). This analysis looked closely at how teachers reflected on these experiences and uncovered three pathways through which professional development programs can address these challenges while encouraging more preschool science teaching.

Expanding Conceptual Knowledge Attenuates the Effects of Existing Barriers

Preschool teachers' low confidence has been identified as a major barrier to early science education (O'Connor et al., 2021; Raven & Wright, 2023), and the interviews in this study further verified this. Studies have indicated a strong connection between teachers' limited scientific knowledge and their low confidence levels, suggesting that teachers may fear science teaching because they themselves are not familiar with the subject (Andersson et al., 2020; Appleton & Kindt, 1999; Bustamante 2018; Roth et al., 2013). This relationship can also be traced back to the previous idea about insufficient training around science teaching, further adds to the teachers' feeling unprepared and afraid to teach science.

However, the current study's analysis revealed that broadening teachers' ideas of what counts as science can help overcome confidence barriers and encourage more science teaching in preschool classrooms. With the help of the Early Childhood Science Framework Reference Sheet grounded in NGSS, teachers were able to identify everyday classroom practices that can connect to scientific concepts. The framework provoked a conceptual understanding of what science can look like beyond teachers' original expectations, allowing them to "recognize when science learning was or should be occurring" (Raven & Wenner, 2023).

Such shifts in teachers' perspectives of science learning opportunities highlight the distinction between having factual knowledge and conceptual understanding (Krathwohl, 2002). Bransford and Donovan (2005) elaborates on this distinction in the science learning context, stating that teaching previous scientific discoveries or asking to follow experimental procedures is not sufficient for learners to understand "what it means to 'do science'" (p. 398). Learning how to draw connections between everyday practices and scientific concepts through RISE PD helped teachers obtain more than just subject matter knowledge; it prompted them to view everyday elements that are traditionally not considered scientific as potential science learning activities (e.g., considering different structures and functions when children are building with blocks, noticing how force is used when pushing children on the swings at the playground). Furthermore, it allowed for teachers to incorporate more science learning opportunities into their regular classroom activities, such as exploring how vehicles operate on a daily walk or asking what makes glue stick to paper during an arts-and-crafts activity. In their post-interviews, many teachers displayed their increased comfort level with science teaching, describing science as not scary, "easier than [they] thought," and even fun.

With their increased understanding of what science looks like, teachers can now use this same limitation of knowledge to "[open] up a real opportunity for investigation, both for the children and themselves" (Roth et al., 2013). It further alleviates the pressure for teachers to rely heavily on their curriculum to teach science, because teachers can now incorporate science activities into any existing curriculum even without designated science lessons (Bustamante et al., 2018). Teachers can leverage the "freedom that preschool teachers often have in terms of what and how they teach" (Raven & Werner, 2023, p. 489) and incorporate various scientific concepts into lesson plans that have not been defined as scientific. On this note, teachers displayed strong determination to use more scientific vocabularies and ask purposeful questions during upcoming activities to incorporate more science learning into their existing curriculum.

Hands-on Practices during PD Foster In-Class Implementation

A constructivist approach to learning claims that “learners construct understanding” instead of simply “[mirroring] what they are told or what they read” (Resnick, 1983, p. 477). This suggests that teachers benefit from directly engaging in science activities, just as their students do, rather than being lectured to or shown demonstrations in professional development settings. During their participation in hands-on activities, teachers’ “direct sensory experiences... provide opportunities for [them] to experience for themselves (assimilate) the phenomena or materials under study,” allowing for a more direct and impactful understanding of the scientific ideas behind the activities (Saunders, 1992, p. 138). Interview responses from teacher participants aligned with this notion as teachers, in unison, acknowledged how helpful the activities offered in PD were in learning the associated scientific concepts.

Furthermore, teachers can leverage their dual identities as learners and instructional providers while engaging in hands-on scientific activities during PD. As science learners, teachers achieve the learning objectives of these science activities (i.e., understanding targeted scientific concepts); at the same time, as instructional providers attending PD, they form ideas about how to execute similar activities in their classroom setting. Because learning builds on prior knowledge (González et al., 2005; Resnick, 1983), their participation in these learning opportunities activates both their ‘science’ schema and ‘pedagogical techniques’ schema. The activities provided in PD were simultaneously a lesson and a practice opportunity for the participants as they constructed their experiences as both a learner and an educator. With practice, teachers grew more comfortable executing such exploratory science lessons in their classrooms.

In addition, because the hands-on and exploratory nature of science learning closely aligns with children’s natural curiosity (McWayne et al., 2022; NSTA, 2014), involvement in these hands-on activities allowed for teachers to understand their students’ perspectives while they are learning. During the activities, particularly the ones in which teachers were divided into smaller groups and rotated through multiple stations, teachers came up with various predictions, made different suggestions that took each

group's exploration in different directions, or asked follow-up questions that inspired another activity in the future. Teachers shared that understanding what questions or challenges may arise for the students helped with their lesson planning because they knew what to expect. Observing how other groups' activities turned out differently also opened their eyes and allowed them to consider more ways to unpack an activity or a lesson topic.

Positive Relationships are Key to Successful Teacher Growth

The present study also revealed that teacher training matters beyond just the content of what is being taught; the impacts of high-quality professional development and coaching seemed to be amplified when teachers had good relationships with the training team and were supported throughout their learning process. Teacher responses indicated that the respectful, attentive, and cordial connections with the coach and the research team members strongly contributed to their increased confidence and encouraged them to implement science practice in their classrooms. Such repeated mention of positive relationships in relation to the effectiveness of RISE PD, as well as the sense of validation and empowerment they received from those relationships, indicate that participating teachers made a strong connection between their personal relationships with the research team and their learning experience. This finding aligned with a major focus of RISE on co-construction, which consists of “[establishing] mutual respect and trust among partners... and [validating] and [naming] partners’ expertise” (McWayne et al., 2020). In a preschool context, the aforementioned misconception of preschool as not a significant educational space may add more weight to the need for this validation.

This observation expands on Chen and McCray's (2012) Whole Teacher Approach, which denotes a teacher's attitudes (social/emotional), knowledge (cognitive), and practice (behavioral) as the three key aspects of a teacher's growth. In addition to a teacher's attitude “about a content area or an instructional practice” (p. 9), their sense of *dignity as a teacher* fulfilled by validation and empowerment also seem to contribute to what counts as a “whole teacher”. Potvin and Penuel (2023) describe a dignity-affirming learning environment as “honoring and validating [learners'] diverse identities and experiences,

[creating] community and [encouraging] healing,” and “creating an environment that [recognizes] and [elevates learner] voice” (p. 2020). Teachers in this study reported feeling respected, validated, and heard, experiencing belongingness in a community, and building confidence, which suggests that they found the RISE PDs dignity-affirming. While establishing a sense of self-worth may ultimately be an individual process, the present study’s analysis demonstrated that positive relationships with the training professionals (researchers and coaches) and with teachers’ peers undoubtedly contribute to this pride-building. As teachers found purpose and significance in their existing practice, they seemed to appropriate the provided guidance more and showed greater intention to implement science learning opportunities that they learned from PD into their classrooms.

Teachers’ Internalization of Their Profession Beyond Classroom Practice

Several studies have claimed that professional development is a source of not only a teacher’s pedagogical advancement and increased content knowledge but also professional identity evolution (Mistry et al., 2020; Wong & Liu, 2022; Zhao, 2022). Teacher identity, according to Graus et al. (2022), encompasses a teacher’s “acquisition of professional knowledge and skills” as well as their “awareness of a self-image in which personal and professional perspectives interact to create an image of who one is as a teacher” (p. 2). Their sense of teaching as a profession is closely linked to their sense of self. In fact, James-Wilson (2001) denotes that “the ways in which teachers form their professional identities” are at least partially influenced by “how they feel about themselves” (p. 29). Additionally, a previous study on elementary school teachers’ professional identities found that the majority of teachers linked ‘being a teacher’ with ‘being [oneself]’ in the classrooms (Nias, 1989).

With such close linkage between their teaching profession and personal identity, teachers may experience a *professional* development session as a *personal* development opportunity. In this study, teachers’ interview responses also displayed that some teachers gained more than just science pedagogical tactics through the RISE programs; some teachers have also shared the personal improvements beyond their teaching practice that they experienced. Throughout their RISE participation, teachers found

opportunities to address their personal challenges, such as overcoming shyness or speaking a foreign language they were not previously familiar with. These stories demonstrated that teachers may seek opportunities to challenge themselves or take in life lessons from a professional training.

Implications

Throughout this study, ways to strengthen preschool teachers' science teaching were both directly suggested by the participants and uncovered through data analysis. In addition to Desimone's (2009) definitions of effective professional development as subject-specific, active, coherent with the school system, sufficient in length, and participatory, the present study demonstrates the need for a collaborative and relationship-based approach to teacher professional development. McWayne et al. (2020) introduce the idea of *co-construction*, in which researchers and trainers (coaches) acknowledge the expertise of teacher- and parent-partners and build the curriculum together. This allows for the convergence of theory-predicated, empirically-supported efforts that the researchers are knowledgeable of and the practical, lived knowledge of teacher and parent participants to create a curriculum that embraces students' backgrounds while directing their learning towards future success. Additionally, relationship-based training allows for mutual respect and reciprocal interaction between the researchers, coaches and the teachers, creating a non-hierarchical and confidence-building space for shared learning opportunities.

The findings also suggest that the school system can support teachers' science pedagogy through making various resources readily available to the teachers. As many teacher participants from the present study found examples from other classrooms and past phases of RISE useful in obtaining new ideas, creating a data pool of previous examples and activity plans would provide an ample amount of inspiration to teachers in their future lesson planning. In addition, having a cross-classroom communication platform, such as virtual professional learning communities, would allow for teachers to further collaborate on lesson plans, share and learn from others' ideas, support and validate one another, or simply communicate with their peers.

Lastly, pre-service teacher education programs would also benefit from incorporating the science framework into their teacher education curricula and prepare teachers in finding everyday science learning opportunities. More options for age group-specific science education training will also address some fundamental barriers, allowing teachers to see the compatibility of science education with preschool education as well as how to build preschool-appropriate activities.

Limitations and Future Directions

Despite the presented meaningful findings, the current study also has limitations and room for extension. The author was not involved in data collection and thus had limited interaction with the participating teachers. Because the project took a largely community-based participatory approach, absence of direct relationship with teachers may have hindered the author's interpretation of teachers' interview responses. However, as a RISE research team member, the author had been annotating video and audio recordings of PD sessions and was still able to get to know the teachers at least indirectly. This uncertainty was further addressed during the member checking session, where the author was able to meet with five of the 21 original participants in person and confirm that interpretations of the data accurately reflected their responses and experiences.

In addition, due to the author's limited Spanish proficiency, interviews conducted in Spanish had to be translated to English prior to data analysis. Because it was the English-translated version of these interviews that were analyzed, some context may not have been preserved in its entirety during the translation and analysis processes. Direct data collection with on-site translation might allow for any clarification of context when Spanish responses do not fully translate to English. While the entire interview transcripts were translated by a bilingual research assistant to minimize loss of information, an opportunity for the author to directly interact with the participants while asking clarifying questions as needed through synchronous translation would be ideal for future studies.

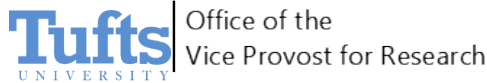
With respect to the structure of the interviews, the larger RISE study was focused on three key principles – HSC, STE, and Co-Construction; thus, teacher interview questions in the present study were

not entirely focused on science teaching. Given time constraints, interview questions did not allow for more in-depth exploration of science teaching experiences that teachers may have been able to offer had they been asked or had more time. In the future, questionnaires targeted to science teaching could be used to scrutinize the teachers' science teaching in more detail and track the shifts in their scientific perspectives through their professional development experiences.

Finally, the present study can be further expanded by utilizing different methodological approaches and measurements. Future research could include a longitudinal study with a cohort of teachers to observe long-term effects of PD on their teaching practices. Member-checking groups in this study provided for a general sense of how teachers are carrying forward the lessons from PD nearly one year later, but much more nuanced data could be collected to ascertain the longer-term effects of the RISE program. Student outcomes should also be measured to understand how teacher growth translates to pedagogical effectiveness on student learning. In addition, the present study should be repeated with a larger sample size to capture more stories from teachers of various demographic backgrounds.

Appendices

Appendix A: Institutional Review Board Approval Form for Current Study



APPROVAL

June 27, 2023

Christine McWayne
 Tufts University
 Christine.McWayne@tufts.edu

Dear Christine McWayne:

On 6/27/2023, the IRB reviewed the following submission:

Type of Review:	Continuing Review
Title:	Building Bridges, Community, and Capacity for Sustaining a Home-to-School Approach in Head Start
Investigator:	Christine McWayne
IRB ID:	CR-01-STUDY00002805
Funding:	Tufts University, Grant Office ID: (none) Eliot-Pearson Department of Child Study and Human Development, Funding Source ID: (none) Eliot-Pearson Department of Child Study and Human Development

The IRB approved the Continuing Review [Expedited 6 & 7] on 6/27/2023. The approval is effective from the date of this letter and expires on to 6/26/2024 inclusive. Before 6/26/2024 or within 30 days of study close, whichever is earlier, you are to submit a completed continuing review and required attachments to request continuing approval or closure. You can submit a continuing review by navigating to the active study and clicking Create Modification/CR.

If continuing review approval is not granted before the expiration date of 6/26/2024, approval of this study expires on that date.

In conducting this protocol, you are required to follow the requirements listed in the SBER IRB Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system.

If obtaining signatures on standard written consent/permission/assent forms, the approved, stamped consent documents must be downloaded directly from eIRB. Approved study documents can be found on the main study dashboard, in the “Documents” tab under “Final Site/Study Documents.”

Sincerely,

Linda Spang

Linda Spang
 IRB Analyst II

Appendix B: Teacher Interview Protocols

The following interview protocols were used by two Spanish-bilingual doctoral level researchers during their interviews with the teachers. Upon teacher preferences, some interviews were conducted in Spanish based on the same protocols presented below.

1. Pre-Interview Protocol

Introduction:

Can you tell me a little about:

- How long have you been working with preschool children/ in Santa Ana?
- Tell me a little about the background of the families and children served in your district.
- Here at the beginning of the project with RISE, what are you most excited about? Concerned about?

Now, we're going to talk about the different components of RISE.

We would like to have you reflect upon each component of and let us know your experience.

PD:

Let's start with the PDs.

What have you found most important about the RISE PDs? (*could think of the following bullets as potential probes*)

- Talk about a specific experience in a RISE PD that stands out for you.
- What have you enjoyed most about PDs?

What has been most valuable/ useful to your teaching/ practice?

- [prompt: Give some examples of what you have taken from the PDs into the classroom or in your work with families.]
- What would make PDs even more useful to you? [Can you think of examples of what we might do differently?]

- In what ways are RISE PDs similar or different from PDs/trainings you have attended before in your district?

Coaching:

Let's think of coaching now.

- Tell me about your prior experiences with the coaching before your participation in the RISE project. [prompt: If you have had coaching before, what was the person's professional title? What was the nature of your work with them? How frequently did you meet with them?]
- What have you particularly liked about the coaching with RISE?
- What's been most useful/ valuable to your practice? [prompt for specific examples]
- What else can your coach do to support you?

Home-School Connections (home-to-school approach):

Now let's talk about the home-to-school approach.

- Prior to the start of RISE, tell us what you did to connect with families in your classroom.
- We have focused a lot on the Home-to-School direction (i.e., getting information about children's daily life) and using the information to inform curriculum planning). What about our HSC approach have you connected with? What do you like about it? How has the home-to-school approach in RISE made you think differently about engaging with families?
- What are some specific examples of home-to-school activities that you have tried? What has worked? What has been challenging?
- What would you like to try with specific support from us? Tell us about any barriers you experience in engaging families.

Attitudes toward STE:

Now let's focus on the science, technology, and engineering (STE) component of RISE.

- At this point in the project, tell us about your comfort level with STE. [prompt for specific examples]

- What does science currently look like in your classroom? [Prompt for examples of materials, specific space, time dedicated to science during the day, specific activities]
- Did you receive specific preparation for teaching science in preschool prior to this year? If so, what was that like?
- What are you most excited about? What are barriers to implementing a science curriculum in your classroom?

Closing:

- Overall, what about the RISE approach has had the biggest impact on you?
- Is there anything else you would like to comment about?

2. Post-Interview Protocol

Introduction:

Briefly thank the teacher for their participation throughout the year.

This interview protocol builds upon the initial interview conducted at the beginning of the RISE project and aims to understand your experience throughout the year. I'll be covering the different components of RISE, and would like to have you reflect on each component.

PD:

- How did the PDs throughout the year contribute to how you approached your curriculum?
- Did specific PDs stand out for you? [Can you give me an example?]
- Were there topics or areas where you felt the PDs could have been improved? [Can you give me an example?]
- How can we improve PDs in the future?

Coaching:

- How did the coaching contribute to your teaching practice? [Can you give me an example?]

- Were there specific instances where coaching was particularly helpful? [Can you give me an example?]
- Was there anything else your coach could have done to support you?

Home-School Connections (HSC):

- How has the HSC approach made you think differently about engaging with families?
- How did the HSC approach work for you in connecting with families?
- Compared to before the project, how has your relationship with parents changed?
- Did incorporating HSC activities into the curriculum lead to any positive changes? [Can you give me an example of an HSC activity that worked really well?]
- Were there any challenges you faced implementing the HSC approach?
- How will you continue to build home-school connections moving forward?
- Can you tell me what 'accessing families' funds of knowledge' means to you?
- As you participated in the RISE project, did you discover any existing structures or resources at the school that facilitated communication and interaction with parents that you hadn't noticed before? How did the RISE project encourage you to utilize these structures for stronger home-school connections?

STE Integration:

- Describe your current comfort level with teaching STE concepts compared to the beginning of the year.
- What were some of the most successful STE activities you implemented?
- What strategies or approaches did you find most effective in incorporating hands-on science learning activities into your classroom?
- Did you encounter any barriers to implementing STE in your classroom?
- How has your participation in the RISE project impacted your beliefs and practices in teaching science to young children?

- How do you plan to continue integrating STE into your teaching in the future?

Overall Impact:

- Looking back on the entire year, what aspect of the RISE project had the most significant impact on your teaching practice?
- How do you think the RISE project will influence your approach to teaching in the future?
- Is there anything else you would like to share about your experience with the RISE project?

Closing:

Thank the teacher for their time and valuable insights.

Appendix C: Science Framework Reference Sheet

Science Framework Reference Sheet

Adapted from California PreKindergarten Learning Foundations
For Three-to-Five-and-a-Half-Year-Old Children in Center-Based, Home-Based, and TK Settings

Science Practices	
Making observations	<i>Observe and actively explore objects and events using their senses and describe their observations.</i>
Comparing and contrasting	<i>Compare and contrast objects and events and describe similarities and differences based on observable properties.</i>
Asking questions	<i>Demonstrate curiosity and raise simple questions about objects and events in their environment.</i>
Defining problems	<i>Identify problems during play and everyday interactions and try simple solutions on their own or in collaboration with peers and adults.</i>
Making predictions	<i>Make simple predictions, give simple reasons for their predictions, and, with adult support, check the predictions through concrete experiences.</i>
Planning and carrying out investigations	<i>Carry out simple experiments or investigations, on their own or in collaboration with peers and adults, to test their ideas about their observations.</i>
Using tools	<i>Identify and use some observation and measurement tools, with adult support.</i>
Documenting observations and using models	<i>Record observations or findings and use simple representations, including drawings, models, movement, role play, and other methods, to convey their observations and understanding of science concepts, with adult support.</i>
Mathematical thinking and analyzing data	<i>Use mathematical thinking to analyze and quantify their observations and answer questions that arise in everyday activities, with adult support.</i>
Formulating and communicating explanations and solutions	<i>Formulate and communicate simple explanations and solutions, in collaboration with peers and adults, based on information gathered through observations and playful explorations.</i>

Crosscutting Concepts	
Patterns	Events, processes, and structures repeat in ways that can be observed, described, and used as evidence.
Cause and effect	Certain actions lead to specific reactions.
Scale, proportion, and quantity	Things differ in size and quantity.
Systems and system models	Things are made of parts that work together and interact as organized systems.
Structure and function	How things are built and/or structured determines what they can do and how they do it.
Stability and change	Some things change, and some things stay the same. Some changes are reversible, other changes are not.

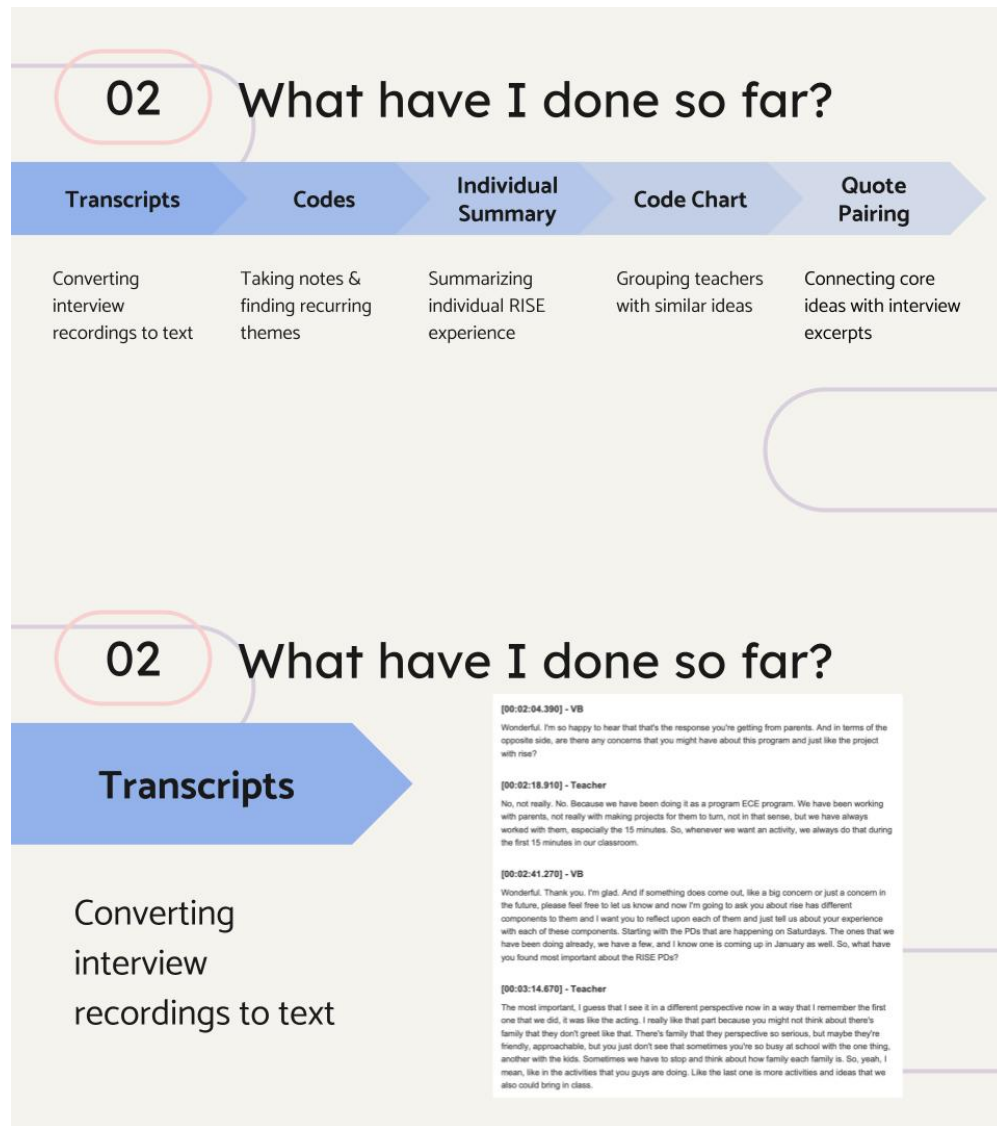
Core Ideas	
Physical Science	
Characteristics of objects and materials	<i>Investigate and describe the characteristics and physical properties of objects and of solid and nonsolid materials (size, weight, shape, color, texture, smell, and sound).</i>
Light and sounds waves	<i>Explore sound, light, and shadows by manipulating objects and materials and by using their senses, during play and collaborative investigations, with adult support.</i>
Exploring changes in objects and materials	<i>Explore and describe changes in objects and materials (e.g., change in color, shape, texture, temperature), using their senses, during play and collaborative investigations, with adult support.</i>
Force and motion	<i>Observe and describe the way objects' speed and direction change and explore the effect of their own actions (e.g., pushing, pulling, rolling, dropping) on making objects move or stop.</i>
Energy	<i>Demonstrate an awareness, with adult support, that things (living and nonliving) need sources of energy to function.</i>
Life Science	
Characteristics of living things	<i>Identify and describe characteristics of a variety of animals and plants, including appearance (inside and outside) and behavior, and begin to categorize them.</i>
Bodily processes	<i>Indicate emerging knowledge of bodily processes (e.g., eating, sleeping, breathing, walking) in humans and other animals.</i>
Living and nonliving things	<i>Expect animate objects (people and animals) to self-initiate movement and to have different insides and biological processes that make them behave differently from inanimate objects.</i>
Heredity and traits	<i>Name and describe similarities and differences they observe between grown animals, including humans, and their offspring.</i>
Habitats	<i>Identify the habitats* of people and familiar animals and plants and communicate their understanding that living things have different habitats.</i>
Growth, needs, and the life cycle of living things	<i>Observe and explore growth and changes in humans, animals, and plants and communicate understanding that living things change over time in size and in other capacities as they grow and age.</i>
Growth, needs, and the life cycle of living things	<i>Recognize that animals and plants require care and show an emerging understanding that feeding and watering support the growth and survival of humans, animals, and plants.</i>
Earth and Space Science	
Characteristics of earth materials	<i>Investigate and describe the characteristics (e.g., size, weight, shape, color, texture) of earth materials such as sand, rocks, soil, water, and air.</i>
Natural objects in the sky	<i>Observe and describe natural objects in the sky (sun, moon, stars, and clouds) and how they appear to move and change</i>
Weather	<i>Notice and describe changes in weather. Notice the effects of weather and seasonal changes on their own lives and on plants and animals.</i>
Earth and human activity	<i>Notice, with adult prompting and support, how humans' actions and use of resources impact the environment and their community; participate in activities related to caring for the environment.</i>
Engineering, Technology, and Application of Science	
Engineering and design process	<i>Engage collaboratively with peers and adults in engineering design by identifying problems in play and everyday activities, planning and creating simple solutions to the problems they identify, and, with adult support, testing and refining their solutions.</i>
Design solutions and society	<i>Notice and explore how tools and design solutions help address their own and other people's needs and goals in everyday life.</i>
Using digital devices	<i>Demonstrate an emerging understanding that different digital tools and devices* serve different functions (e.g., taking videos or photos) and use digital tools with adult support to meet their needs and goals in everyday situations.</i>

Appendix D: Member Checking Procedure

The following slides on my coding (see Figure D1) as well as summary of findings (see Results, Figure 2, and Figure 3) were presented to 5 teachers from the original participant pool.

Figure D1

Presentation Slides Describing Data Analysis Process to Member Checking Participants



02 What have I done so far?

Codes

Taking notes & describing themes

[[00:17:11.450] - Teacher
Yes, I believe so, because there's always something new in each RISE PD that we attend. So it's not the same information being presented in a different way because in the past, we retain information that has been presented from other presenters, but it's, like, repetitive. And so there's times that you're like, okay, but we already heard this from a different presenter, but it's the same topic that we already learned. So you just want to get new ideas and like I said, implement new strategies. And with the RISE project, it has been interesting to attend and see what other people are doing. And so, like, science is not the main thing. And it's also incorporating more science into the classroom that I know for a fact. We haven't really touched a lot into it. It's been more like language arts and math and physical fine motor skills, gross motor skills. But science has not been our main priority. So now I feel that it's changing because now we're focusing more on science for the children to have hands-on, do activities with more science stuff. We have done it in the past. Ms. Julian and I like to do, always like hands-on and give the children the opportunity to experience. And so now with this, it came in handy because now we're able to expand more science projects with the children and incorporate new ideas and also send home strategies how they could do it at home with their parents as well.

[[00:18:47.850] - VB
Wonderful. Thank you for sharing and moving on a little bit from the PDs and now starting to think about the coaching. And have you had prior experiences with coaching before participating in the RISE project?

[[00:19:01.950] - Teacher
No.

[[00:19:04.030] - VB
Never had a coach like one on one.

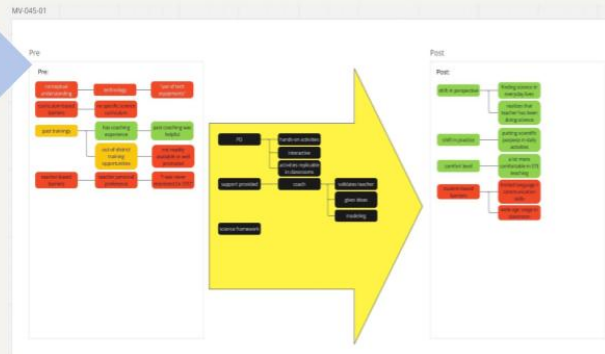
[[00:19:07.630] - Teacher
None, Never!

Chat messages:
Kim, Yeoni: science is not priority
Kim, Yeoni: no past coaching experience

02 What have I done so far?

Individual Summary

Summarizing individual RISE experience



02 What have I done so far?

Code Chart

Grouping teachers with similar ideas

	A	B	C	D	E	F	G
	Categorical Code	Descriptive Code					
1	change	"opened my mind"	GA-505-03	PP-001-02	WA-003-01	WA-003-03	
2	change	"science is everywhere" / "everything is science"	GA-505-01	GA-505-03	GA-506-01	GA-506-02	PP-001-02
3	change	"science is fun"	GA-505-03	WA-003-01	WA-003-03		
4	change	"science will be easier" / "science is less scary"	GA-505-01	GA-505-03	PP-P01-02	PP-P01-03	WA-003-01
5	helpful?	age-appropriate concepts/activities	WA-004-01				
6	change	applying science to everyday lives	GA-505-02	WA-003-02	WA-003-03		
7	goal / future	children learning young -> more efficient learning	GA-505-02				
8	goal / future	children learning young -> school readiness	GA-505-01				
9	challenge	children's limited language/communication skills	MV-045-01	PP-P01-01	WA-004-03		
10	challenge	children's personal preference (against certain science activity)	GA-505-02	GA-506-01			
11	challenge	children's young age (wide age range within classroom)	MV-045-01	MV-045-02	PP-P01-02		
12	helpful	coach accessibility	GA-505-01	WA-046-01	WA-003-01	WA-003-03	WA-004-03
13	helpful	coach clarifies confusion	MV-046-01	WA-003-01			
14	helpful	coach expands teachers' ideas	GA-506-02	MV-045-02	PP-001-02	PP-P01-01	PP-P01-02
15	helpful	coach explains/elaborates on PD	PP-P01-02				
16	helpful	coach gives ideas	GA-505-02	GA-505-03	GA-506-02	MV-045-01	PP-001-02
17	helpful	coach guidance helpful	GA-505-02	GA-505-03	WA-004-02		
18	helpful	coach is flexible	PP-P01-02	WA-003-02			

02

What have I done so far?

Quote
Pairing

Connecting
core ideas with
interview excerpts

RISE

Activities

- Hands-on / Interactive**
 - Well, I liked this one because of all the questions that are asked, then everyone is sharing, they give everyone the opportunity to speak, they give us the activities so we can do them right there, ourselves, also other programs. That's why I think it's different, because yes, sometimes we're just listening, but here there are activities that we're doing as well.
 - I don't think I've ever been to a PD that has been so hands on and so interactive with you and actually listening to you since the beginning.
- Replicable in classroom**
 - It gave us more ideas to do in the classroom and that made us think outside the box. Things that we can bring into the classroom that we learned in our trainings.
 - And everything, every time that, would you do an example in PD's class, I would, my brain started thinking, "Oh, we can do this. Oh, we can do this. Oh, we can do it this way. We can do it that way."
- Practice before in-class implementation**
 - Because I could see that now on the perspective of the kids because I was putting myself on the training. You will go and you put yourself not as a kid. I put myself like, Oh, you know what? Maybe that we could transfer it to the classroom and see as a kid, now that I experience the training, come into the classroom and show the kids and I know how they're going to feel. They get interest in our into hands-on activities.

After the presentation, teachers were also asked the following questions:

- Do my ideas accurately reflect your experience with Preschool Science Teaching?
 - What idea/quote stood out to you the most?
 - What ideas are different from your own experience?
- Does the diagram accurately describe your RISE PD/coaching experience?
- Are there other suggestions you have for future professional development targeting preschool science education?

Teachers were given approximately 30 minutes to freely reflect on these questions and converse.

References

- Adair, J. K., & Colegrove, K. S.-S. (2021). *Segregation by experience: Agency, racism, and learning in the early grades* (1–1 online resource (214 pages): illustrations). University of Chicago Press; WorldCat.
<https://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=2706776>
- Adeoye-Olatunde, O. A., & Olenik, N. L. (2021). Research and scholarly methods: Semi-structured interviews. *JACCP: Journal of the American College of Clinical Pharmacy*, 4(10), 1358–1367.
<https://doi.org/10.1002/jac5.1441>
- Andersson, K., Gullberg, A., Danielsson, A. T., Scantlebury, K., & Hussénus, A. (2020). Chafing borderlands: Obstacles for science teaching and learning in preschool teacher education. *Cultural Studies of Science Education*, 15(2), 433–452. <https://doi.org/10.1007/s11422-019-09934-x>
- Appleton, K. (1992). Discipline knowledge and confidence to teach science: Self-perceptions of primary teacher education students. *Research in Science Education*, 22(1), 11–19.
<https://doi.org/10.1007/BF02356874>
- Appleton, K., & Kindt, I. (1999). Why teach primary science? Influences on beginning teachers' practices. *International Journal of Science Education*, 21(2), 155–168.
<https://doi.org/10.1080/095006999290769>
- Barenthien, J., Oppermann, E., Anders, Y., & Steffensky, M. (2020). Preschool teachers' learning opportunities in their initial teacher education and in-service professional development – do they have an influence on preschool teachers' science-specific professional knowledge and motivation? *International Journal of Science Education*, 42(5), 744–763.
<https://doi.org/10.1080/09500693.2020.1727586>
- Bransford, J. D., & Donovan, M. S. (Eds.). (2005). How students learn: History, mathematics, and science in the classroom. *Washington, DC: The National Academies Press.*

- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101.
- Burns, A. (1992). Teacher Beliefs and Their Influence on Classroom Practice. *Prospect*, 7.
- Bustamante, A. S., White, L. J., & Greenfield, D. B. (2017). Approaches to learning and school readiness in Head Start: Applications to preschool science. *Learning and Individual Differences*, 56, 112–118. <https://doi.org/10.1016/j.lindif.2016.10.012>
- Cabell, S. Q., DeCoster, J., LoCasale-Crouch, J., Hamre, B. K., & Pianta, R. C. (2013). Variation in the effectiveness of instructional interactions across preschool classroom settings and learning activities. *Early Childhood Research Quarterly*, 28(4), 820–830. <https://doi.org/10.1016/j.ecresq.2013.07.007>
- California Department of Education. (2023). Cumulative Enrollment Data. <https://www.cde.ca.gov/ds/ad/filesenrcum.asp>
- Chen, J.-Q., & McCray, J. (2012). A Conceptual Framework for Teacher Professional Development: The Whole Teacher Approach. *NHSA Dialog: A Research-to-Practice Journal for The Early Intervention Field*, 15, 8–23. <https://doi.org/10.1080/15240754.2011.636491>
- Child Care Aware of America & National Association for the Education of Young Children. (2023). Early Care and Education Professional Development: Training and Technical Assistance Glossary.
- Cofie, N., Braund, H., & Dalgarno, N. (2022). Eight ways to get a grip on intercoder reliability using qualitative-based measures. *Canadian Medical Education Journal*. <https://doi.org/10.36834/cmej.72504>
- Creswell, J. W., & Miller, D. L. (2000). Determining Validity in Qualitative Inquiry. *Theory Into Practice*, 39(3), 124–130. https://doi.org/10.1207/s15430421tip3903_2

- Curran, F. C. (2019). Estimating the Relationship Between Preschool Attendance and Kindergarten Science Achievement: Implications for Early Science Achievement Gaps. *Education Finance and Policy, 14*(2), 210–241. https://doi.org/10.1162/edfp_a_00247
- Curran, F. C., & Kellogg, A. T. (2016). Understanding Science Achievement Gaps by Race/Ethnicity and Gender in Kindergarten and First Grade. *Educational Researcher, 45*(5), 273–282. <https://doi.org/10.3102/0013189X16656611>
- Desimone, L. M. (2009). Improving Impact Studies of Teachers' Professional Development: Toward Better Conceptualizations and Measures. *Educational Researcher, 38*(3), 181–199. <https://doi.org/10.3102/0013189X08331140>
- Early, D. M., Iruka, I. U., Ritchie, S., Barbarin, O. A., Winn, D.-M. C., Crawford, G. M., Frome, P. M., Clifford, R. M., Burchinal, 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. <https://doi.org/10.1016/j.ecresq.2009.10.003>
- El-Moslimany, H., Lange, A. A., & Brenneman, K. (2017). Designing a STEM Professional Development Program for Preschool Teachers, with Supports for Dual Language Learners. *American Educational Research Association*.
- Faulkner, M., Gerstenblatt, P., Lee, A., Vallejo, V., & Travis, D. (2016). Childcare providers: Work stress and personal well-being. *Journal of Early Childhood Research, 14*(3), 280–293. <https://doi.org/10.1177/1476718X14552871>
- Ferguson, D., Pinerua, I., & Gerdeman, D. (2022). Improving Prekindergarten and Elementary Science Teaching: A Synthesis of Recent DRK-12 Program Investment in This Field. *American Institutes for Research*. Retrieved from <https://par.nsf.gov/biblio/10358412>.

- Fleer, M. (2009). Supporting Scientific Conceptual Consciousness or Learning in 'a Roundabout Way' in Play-based Contexts. *International Journal of Science Education*, 31(8), 1069–1089.
<https://doi.org/10.1080/09500690801953161>
- Geijsel, F., & Meijers, F. (2005). Identity learning: the core process of educational change. *Educational Studies*, 31(4), 419–430. <https://doi.org/10.1080/03055690500237488>
- Goldblatt, H., Karnieli-Miller, O., & Neumann, M. (2011). Sharing qualitative research findings with participants: Study experiences of methodological and ethical dilemmas. *Methodology in Health Communication Research*, 82(3), 389–395. <https://doi.org/10.1016/j.pec.2010.12.016>
- González, N., Moll, L., & Amanti, C. (2005). *Funds of knowledge: Theorizing practices in households, communities, and classrooms*. Lawrence Erlbaum Associates, Publishers.
- Gort, M., & Sembiente, S. F. (2015). Navigating Hybridized Language Learning Spaces Through Translanguaging Pedagogy: Dual Language Preschool Teachers' Languaging Practices in Support of Emergent Bilingual Children's Performance of Academic Discourse. *International Multilingual Research Journal*, 9(1), 7–25. <https://doi.org/10.1080/19313152.2014.981775>
- Graus, M., van de Broek, A., Hennissen, P., & Schils, T. (2022). Disentangling aspects of teacher identity learning from reflective blogs: The development of a category system. *Teaching and Teacher Education*, 111, 103624. <https://doi.org/10.1016/j.tate.2021.103624>
- Greenfield, D., 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., Jirout, J., Dominguez, X., Greenberg, A., Maier, M., & Kook, J. (2009). Science in the Preschool Classroom: A Programmatic Research Agenda to Improve Science Readiness. *Early Education and Development - EARLY EDUC DEV*, 20, 238–264.
<https://doi.org/10.1080/10409280802595441>
- Greenfield, D., Zan, B., McWayne, C., Harris, M., Alexander, A., Ochoa, W., & Mistry, J. (2024). Early childhood science practices observation tool (EC-SPOT): assessing science practices across

- multiple classroom contexts. *International Journal of Science Education*, 46(18), 1963–1981.
<https://doi.org/10.1080/09500693.2024.2305634>
- Guskey, T. R. (2002). Professional Development and Teacher Change. *Teachers and Teaching*, 8(3), 381–391. <https://doi.org/10.1080/135406002100000512>
- Hadani, H. S., & Rood, E. (2018). The Roots of STEM Success: Changing Early Learning Experiences to Build Lifelong Thinking Skills. *Center for Childhood Creativity at the Bay Area Discovery Museum*.
- Hancock, R. E. (2017). Global Citizenship Education: Emancipatory Practice in a New York Preschool. *Journal of Research in Childhood Education*, 31(4), 571–580.
<https://doi.org/10.1080/02568543.2017.1346731>
- Henderson, L., Disney, L., Bussey, K., & Geng, G. (2024). “Disregarded and undervalued”: early childhood teacher’s experiences of stress and anxiety during the COVID-19 pandemic. *Early Years*, 1–16. <https://doi.org/10.1080/09575146.2024.2374059>
- James-Wilson, S. (2001). The influence of ethnocultural identity on emotions and teaching. In *Annual Meeting of the American Educational Research Association*. New Orleans.
- Kallery, M., & Psillos, D. (2001). Pre-school teachers’ content knowledge in science: Their understanding of elementary science concepts and of issues raised by children’s questions. *International Journal of Early Years Education*, 9, 165–179. <https://doi.org/10.1080/09669760120086929>
- Krathwohl, D. R. (2002). A Revision of Bloom’s Taxonomy: An Overview. *Theory Into Practice*, 41(4), 212–218. https://doi.org/10.1207/s15430421tip4104_2
- La Paro, K. M., & Pianta, R. C. (2000). Predicting Children’s Competence in the Early School Years: A Meta-Analytic Review. *Review of Educational Research*, 70(4), 443–484.
<https://doi.org/10.3102/00346543070004443>
- McWayne, C. M., Doucet, F., & Mistry, J. (2019). Family-School Partnerships in Ethnocultural Communities: Reorienting Conceptual Frameworks, Research Methods, and Intervention Efforts

- by Rotating Our Lens. In C. M. McWayne, F. Doucet, & S. M. Sheridan (Eds.), *Ethnocultural Diversity and the Home-to-School Link* (pp. 1–18). Springer International Publishing.
https://doi.org/10.1007/978-3-030-14957-4_1
- McWayne, C. M., Greenfield, D., Zan, B., Mistry, J., & Ochoa, W. (2021). A Comprehensive Professional Development Approach for Supporting Science, Technology, and Engineering Curriculum in Preschool: Connecting Contexts for Dual Language Learners. In S. Tatalović Vorkapić & J. LoCasale-Crouch (Eds.), *Supporting Children's Well-Being During Early Childhood Transition to School* (pp. 222–253). IGI Global. <https://doi.org/10.4018/978-1-7998-4435-8.ch011>
- McWayne, C. M., & Melzi, G. (2023). Young children co-constructing science: The importance of their families and cultural communities. *Science Education*, *107*(6), 1655–1669.
<https://doi.org/10.1002/sce.21823>
- McWayne, C. M., & Melzi, G. (2024). Immigrant Children and Families: Committing to Cultural Inclusion in Early Childhood Education and Care Settings. *The Educational Forum*, *88*(4), 492–517. <https://doi.org/10.1080/00131725.2024.2383146>
- McWayne, C. M., Mistry, J., Brenneman, K., Zan, B., & Greenfield, D. B. (2020). A Model of Co-Construction for Curriculum and Professional Development in Head Start: The Readiness through Integrative Science and Engineering (RISE) Approach. *Teachers College Record: The Voice of Scholarship in Education*, *122*(11), 1–46. <https://doi.org/10.1177/016146812012201111>
- McWayne, C. M., Ochoa, W., Segovia, J., Zan, B., Greenfield, D., & Mistry, J. (2023). Engagement in the preschool classroom: Brief measures for use with children from ethno-racially diverse and low-income backgrounds. *Early Childhood Research Quarterly*, *64*, 177–185.
<https://doi.org/10.1016/j.ecresq.2023.03.002>

- McWayne, C. M., Zan, B., Ochoa, W., Greenfield, D., & Mistry, J. (2022). Head start teachers act their way into new ways of thinking: Science and engineering practices in preschool classrooms. *Science Education*, *106*(4), 956–979. <https://doi.org/10.1002/sce.21714>
- Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook* (Third edition). SAGE Publications, Inc.
- Miller, M., Hanley, D., & Brobst, J. (2019). The Impacts of a Research-Based Model for Mentoring Elementary Preservice Teachers in Science. *Journal of Science Teacher Education*, *30*(4), 357–378. <https://doi.org/10.1080/1046560X.2019.1573127>
- Mistry, J., Segovia, J., Li, L. W., McWayne, C., Zan, B., & Greenfield, D. (2022). “I woke up to science”: Teacher narratives of growth in a culturally sustaining preschool STEM program. *Journal of Applied Developmental Psychology*, *83*, 101456. <https://doi.org/10.1016/j.appdev.2022.101456>
- 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. <https://doi.org/10.3102/0013189X16633182>
- National Academies of Sciences, Engineering, and Medicine. (2016). *Science Teachers' Learning: Enhancing Opportunities, Creating Supportive Contexts* (p. 21836). National Academies Press. <https://doi.org/10.17226/21836>
- National Academies of Sciences, Engineering, and Medicine. (2024). *A New Vision for High-Quality Preschool Curriculum* (S. Bredekamp, L. Espinosa, R. Hutton, & A. Stephens, Eds.; p. 27429). National Academies Press. <https://doi.org/10.17226/27429>
- National Institute for Early Education Research. (2019). Benchmarks for High-Quality Pre-K. In National Institute for Early Education Research. <https://nieer.org/research-library/download-nieers-benchmarkshigh-quality-pre-k>
- National Research Council. (1996). *National Science Education Standards* (p. 4962). National Academies Press. <https://doi.org/10.17226/4962>

- National Science Teaching Association. (2014). NSTA Position Statement: *Early Childhood Science Education*.
- Nayfeld, I., Brennehan, K., & Gelman, R. (2011). Science in the Classroom: Finding a Balance Between Autonomous Exploration and Teacher-Led Instruction in Preschool Settings. *Early Education & Development, 22*(6), 970–988. <https://doi.org/10.1080/10409289.2010.507496>
- Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies, 19*(4), 317–328. <https://doi.org/10.1080/0022027870190403>
- Nias, P. J., & Nias, J. (1989). *Primary Teachers Talking: A Study of Teaching As Work* (1st ed.). Routledge. <https://doi.org/10.4324/9780203032527>
- O'Connor, G., Fragkiadaki, G., Fleer, M., & Rai, P. (2021). Early Childhood Science Education from 0 to 6: A Literature Review. *Education Sciences, 11*(4), 178. <https://doi.org/10.3390/educsci11040178>
- Phillips, D. A., Gormley, W. T., & Lowenstein, A. E. (2009). Inside the pre-kindergarten door: Classroom climate and instructional time allocation in Tulsa's pre-K programs. *Early Childhood Research Quarterly, 24*(3), 213–228. <https://doi.org/10.1016/j.ecresq.2009.05.002>
- Piaget, J. (1952). *The origins of intelligence in children*. (M. Cook, Trans.). W W Norton & Co. <https://doi.org/10.1037/11494-000>
- Potvin, A. S. & Penuel, W. R. (2023). Educators' ideas about dignity and how to support it in schools. In Blikstein, P., Van Aalst, J., Kizito, R., & Brennan, K. (Eds.), *Proceedings of the 17th International Conference of the Learning Sciences - ICLS 2023* (pp. 2019-2020). International Society of the Learning Sciences.
- Quinones, G., Barnes, M., & Berger, E. (2021). Early childhood educators' solidarity and struggles for recognition. *Australasian Journal of Early Childhood, 46*(4), 296-308. <https://doi.org/10.1177/18369391211050165> (Original work published 2021)
- Resnick, L. B. (1983). Mathematics and science learning: A new conception. *Science, 220*(4596), 477–478. <https://doi.org/10.1126/science.220.4596.477>

- Rhodes, M., Leslie, S.-J., Yee, K. M., & Saunders, K. (2019). Subtle Linguistic Cues Increase Girls' Engagement in Science. *Psychological Science*, 30(3), 455–466.
<https://doi.org/10.1177/0956797618823670>
- Roth, W.-M., Goulart, M. I. M., & Plakitsi, K. (2013). *Science Education during Early Childhood* (Vol. 6). Springer Netherlands. <https://doi.org/10.1007/978-94-007-5186-6>
- Rush, D. D., & Shelden, M. L. (2020). *The early childhood coaching handbook* (Second Edition). Paul H. Brookes Publishing Co.
- Saçkes, M. (2014). How often do early childhood teachers teach science concepts? Determinants of the frequency of science teaching in kindergarten. *European Early Childhood Education Research Journal*, 22(2), 169–184. <https://doi.org/10.1080/1350293X.2012.704305>
- 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. <https://doi.org/10.1002/tea.20395>
- Sackes, M., Trundle, K. C., & Flevares, L. M. (2009). Using Children's Literature to Teach Standard-Based Science Concepts in Early Years. *Early Childhood Education Journal*, 36(5), 415–422. <https://doi.org/10.1007/s10643-009-0304-5>
- Saldaña, J. (2009). *The coding manual for qualitative researchers*. Sage.
- Schwandt, T. (1994). Constructivist, Interpretivist Approaches to Human Inquiry. *Handbook of Qualitative Research Thousand Oaks, California: Sage*.
- Santa Ana Unified School District (2023). Early Childhood 2023-2024 Parent Handbook. <https://www.sausd.us/domain/9463>
- Santa Ana Unified School District (2023). ECE SAUSD Preschool Info At-A-Glance. <https://www.sausd.us/cms/lib/CA01000471/Centricity/ModuleInstance/53510/ECE%20FAQs.pdf>
- Santa Ana Unified School District (2024). District Overview. <https://www.sausd.us/Page/5>

- Schachter, R.E., Jiang, Q., Piasta, S.B. et al. "We're More Than a Daycare": Reported Roles and Settings for Early Childhood Professionals and Implications for Professionalizing the Field. *Early Childhood Educ J* 50, 1183–1196 (2022). <https://doi.org/10.1007/s10643-021-01252-8>
- Schwandt, T. (1994). Constructivist, Interpretivist Approaches to Human Inquiry. *Handbook of Qualitative Research Thousand Oaks, California: SAGE.*
- Shtulman, A., & Walker, C. (2020). Developing an Understanding of Science. *Annual Review of Developmental Psychology*, 2(1), 111–132. <https://doi.org/10.1146/annurev-devpsych-060320-092346>
- Smith, J. A., Flowers, P., & Larkin, M. (2009). *Interpretative phenomenological analysis: Theory, method and research.* SAGE.
- Tu, T. (2006). Preschool Science Environment: What Is Available in a Preschool Classroom? *Early Childhood Education Journal*, 33(4), 245–251. <https://doi.org/10.1007/s10643-005-0049-8>
- U.S. Census Bureau (2020). *Total population, Santa Ana City, California.* Decennial Census. Retrieved September 22, 2024 from https://data.census.gov/profile/United_States?g=010XX00US
- U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics. (2015). National Assessment of Education Progress, science 2011, national results. Retrieved from http://www.nationsreportcard.gov/science_2011/
- U.S. Department of Education, Office of Educational Research and Improvement, National Center for Education Statistics. (2000). NAEP 1999 trends in academic progress: Three decades of student performance (NCES 2000–469). Retrieved from <http://nces.ed.gov/nationsreportcard/pdf/main1999/2000469.pdf>
- Vygotsky, L. S. (1978). *Mind in Society.* Harvard University Press; JSTOR. <https://doi.org/10.2307/j.ctvjf9vz4>
- Wallerstein, N., Duran, B., Oetzel, J. G., & Minkler, M. (2017). *Community-Based Participatory Research for Health: Advancing Social and Health Equity.* Wiley.

<https://books.google.com/books?id=Gkk3DwAAQBAJ>

Wang, M. C., Haertel, G. D., & Walberg, H. J. (1993). *Toward a Knowledge Base for School Learning*.

Weiss, E. H. B., Kreider, H., Lopez, M. E., & Chatman, C. M. (2002). *Preparing Educators to Involve Families: From Theory to Practice*.

Wong, C. Y. E., & Liu, W. C. (2022). Evaluating the Teacher Professional Identity of Student Teachers: Development and Validation of the Teacher Professional Identity Scale. *Journal of Education*, 204(1), 131-144. <https://doi.org/10.1177/00220574221101375> (Original work published 2024)

Yoon, S. A., Goh, S.-E., & Park, M. (2018). Teaching and Learning About Complex Systems in K–12 Science Education: A Review of Empirical Studies 1995–2015. *Review of Educational Research*, 88(2), 285-325. <https://doi.org/10.3102/0034654317746090>

Zhao Q. (2022). On the Role of Teachers' Professional Identity and Well-Being in Their Professional Development. *Frontiers in psychology*, 13, 913708. <https://doi.org/10.3389/fpsyg.2022.913708>