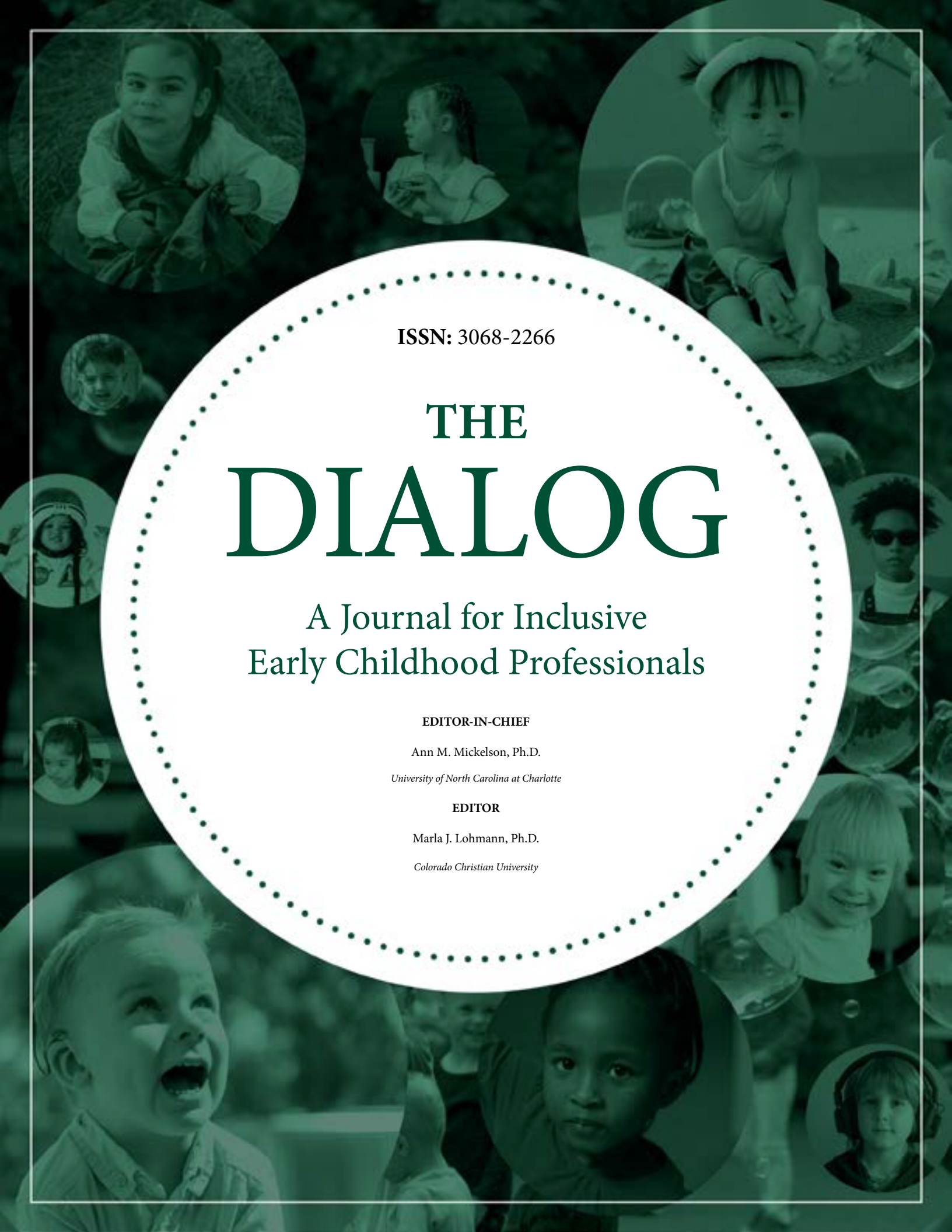




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THE DIALOG

A Journal for Inclusive
Early Childhood Professionals

EDITOR-IN-CHIEF

Ann M. Mickelson, Ph.D.

University of North Carolina at Charlotte

EDITOR

Marla J. Lohmann, Ph.D.

Colorado Christian University



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THE DIALOG

A Journal for Inclusive
Early Childhood Professionals

From the Editors Introduction to the Special Issue

Ann M Mickelson Ph.D.
University of North Carolina at Charlotte

Marla J. Lohmann, Ph.D.
Colorado Christian University

What better way to close out the last days of summer than with the summer issue of *The Dialog*!

We want to thank you for your support and patience as *The Dialog* has continued to proceed through substantial changes, particularly in our online platform and submission portal. We are thrilled with the outcomes and continue to work on implementing changes and improvements so that the journal can continue to support inclusive early childhood education professionals.

News and Updates

In our last issue, we announced that Dr. Ann Mickelson had stepped into the role of Editor-in-Chief. Over the summer, Dr. Marla Lohmann joined her in the role of Editor. In coming weeks, we will begin building our editorial team with a search for additional inclusive early childhood professionals to join us as associate editors, editorial review board members, and ad hoc reviewers. Watch for the call to be posted on the journal website and our social media!!

Over the next several months, we will be announcing our editorial board, as well as many other exciting changes. We urge you to follow us on Facebook, LinkedIn, Bluesky, and X. In addition, please consider submitting a manuscript to be considered for publication in an upcoming journal issue.

We are excited to bring you the Summer 2025 issue of *The Dialog: A Journal for Inclusive Early Childhood Professionals*! This *Dialog* Special Issue, *Science, Technology, Engineering and Mathematics in Early Childhood (STEM)*, curates a collection of five research articles with corresponding research-to-practice summaries to support your work.

STEM in early childhood education involves integrating science, technology, engineering, and mathematics into fun, hands-on learning experiences for young children. It's not about formal lessons, but rather about fostering curiosity, problem-solving, and critical thinking through play and exploration. This approach helps children develop essential skills and a strong foundation for future learning in STEM fields...and beyond!

Research Articles

In *Examining the Influence of Practice-Based Teacher Education Approaches on Primary Grades Teacher Candidates' Development of Inclusive and Equity-Based Mathematics Teaching*, Polly shares a study that examined how practice-based teacher education (PBTE) approaches in two elementary education mathematics pedagogy courses influenced teacher candidates' enactment of Inclusive and Equity-Based Mathematics Teaching (IEB-MT), a synthesis of theory and research for effective mathematics teaching for all students. Polly concludes the article with implications for both course activities and clinical practice experiences

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INTRODUCTION

for teacher candidates to support their capacity to teach mathematics effectively.

In our second article, *Fostering STEM in Early Childhood Programs: Practices of Preschool Parents with STEM Backgrounds*, Keengwe presents a qualitative study that explored the experiences of families with backgrounds in STEM (Science, Technology, Engineering, and Mathematics) and the strategies they use to support their young children's STEM learning. Analysis of interviews revealed that family role models, preschool curricula, and a child's intrinsic motivation and passion play key roles in fostering early interest in STEM.

Third, Platas, examined whether students in early childhood teacher education programs gained more knowledge in relation to supporting early mathematical development in the subsequent decade since a previous study. In her article, *Does a Decade Make a Difference? Changes in Pre- and In-service Preschool Teachers' Knowledge of Early Mathematical Development*, she compares data on pre- and in-service teachers' knowledge of mathematical development gathered during 2008 as measured by the Knowledge of Mathematical Development Survey (KMDS) and compares it to data gathered in 2017-2018.

In *A Head Start on STEM: Investigating the Relationship of Early Childhood Educator Knowledge and Self-Efficacy*, Thompson and colleagues describe their research on teacher knowledge and self-efficacy for STEM instruction. The authors used a

multiple method design including scales, surveys, and self-reflection logs of 13 Head Start preschool educators over 11-months. The findings suggested a significant increase from pre-survey to post-survey in the participants' self-efficacies for supporting preschool-age children's STEM instruction.

Finally, Urquhart and colleagues' article, *Choosing and Disusing Educational Technology: Examining Parents' Decision Making about Math and Literacy Apps for Their Young Children* shares their research on parent decision making for selecting mathematics and literacy apps for their children.

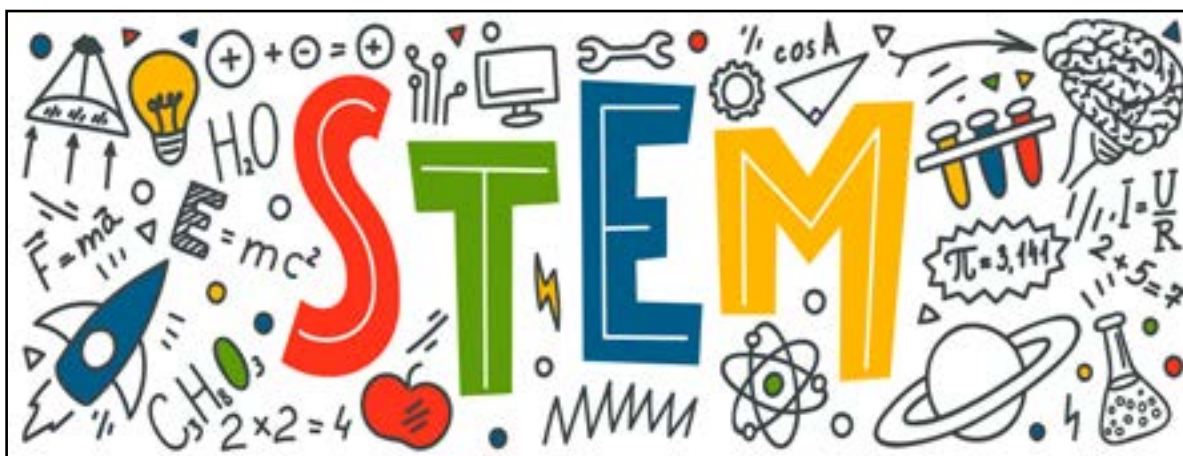
Research-to-Practice Summaries

To supplement the five research articles included in this issue, each author team also contributed a research-to-practice summary to share practical implications of their research for your work with young children and families. They are presented after the research articles.

We hope you enjoy this summer 2025 issue of The Dialog!

Ann M. Mickelson, Editor-in-Chief

Marla J. Lohmann, Editor



Examining the Influence of Practice-Based Teacher Education Approaches on Primary Grades Teacher Candidates' Development of Inclusive and Equity-Based Mathematics Teaching

Drew Polly, Ph.D.

University of North Carolina at Charlotte

ABSTRACT

This article proposes the construct of Inclusive and Equity-Based Mathematics Teaching (IEBMT), a synthesis of theory and research for effective mathematics teaching for all students. There is a critical need for educator preparation programs to intentionally design course activities and clinical practice experiences to provide teacher candidates (TCs) with ample, worthwhile experiences to develop the knowledge and skills required to be an effective teacher for all students. The study examines how practice-based teacher education (PBTE) approaches in two elementary education mathematics pedagogy courses influenced TCs enactment of IEBMT. The inductive analysis of teacher candidates' projects and reflections indicated that they were adequately prepared to support learners who had knowledge of the counting sequence and were able to accurately count a set of 5 objects. However, teacher candidates reported and demonstrated in their project a desire and a need for further opportunities to develop classroom-based skills at observing or listening to primary grade learners and quickly making effective instructional decisions about future activities and questions based on what they notice. The article concludes with implications for both course activities and clinical practice experiences for teacher candidates to support their capacity to teach mathematics effectively.

KEYWORDS

Early childhood education, elementary education, mathematics education, problem solving

Introduction

Framing Inclusive, Equity-Based Mathematics Teaching (IEBMT)

There is compelling evidence that early childhood learners (Pre-Kindergarten through Grade 2) vary in their mathematics achievement based on multiple factors, such as their previous opportunities to learn, access to effective teachers and research-

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-based learning experiences, as well as ethnic and racial backgrounds (Domingo-Martos et al., 2022; Musu-Gillette et al., 2017). This article includes inclusive and equity-based mathematics teaching (IEBMT), a synthesis of empirically- and theoretically-based constructs designed to support learning for all students (Table 1). IEBMT includes two primary pillars: 1) Access to grade-level aligned, research-based experiences and 2) Opportunities for the exploration of problems embedded in meaningful contexts. Within each of those pillars, there are two aspects, for a total of four aspects.

Access to Grade Level-Aligned, Research-Based Practices

Aligned to grade-level content. All learners deserve access to grade-level aligned, research-based practices (Musu-Gillette, et al., 2017; Unbound Ed, 2021a). For those learners whose data suggests that they need learning experiences on concepts from previous grade levels, learning activities should

serve as access points to grade level content, and be clearly evident to grade level concepts (Unbound Ed, 2021b). Historically, studies have found that students whose data suggests that they lack foundational concepts often do not receive opportunities to engage in grade-level activities (Liljedahl, 2020; Unbound Ed, 2021a).

Therefore, early childhood teachers and TCs must be equipped with the knowledge and skills related to knowing characteristics of grade-level aligned and developmentally appropriate activities. Further, teachers and TCs need to know how to modify activities so that they align to grade-level concepts and provide access to all learners (Bostic et al., 2021; CAST, 2024; National Association for the Education of Young Children [NAEYC], 2020).

Access to research-based practices. Additionally, early childhood TCs must be given opportunities to learn what supports are research-based and how to use them in a way that supports learners' development (NAEYC, 2020; Zhang & Cutler,

Table 1

Aspects of Inclusive, Equity-Based Mathematics Teaching

Pillar	Aspect	Description
Access to grade-level aligned, research-based experiences	Alignment to grade level content	Learners should engage in activities aligned to current grade-level Standards (Gutiérrez, 2009; NCTM, 2014; Unbound Ed, 2021a). Concepts prior to grade-level Standards should be connected to grade-level concepts (Tomlinson, 2017; Unbound Ed, 2021b)
	Access to research-based experiences	Learners will engage in activities that are aligned to research-based teaching practices proven to increase student learning and achievement (Cioè-Peña, 2017; Gutiérrez, 2012).
Opportunities for the exploration of problems embedded in meaningful contexts	Exploring problems	When appropriate, learners will explore problems and select the strategies that they will use to solve problems (Buchheister et al., 2019; NCTM, 2014). Gutiérrez (2009) describes this as Power.
	Meaningful mathematics contexts	Learners engage in activities that are contextualized in real-life situations that are meaningful to learners and build upon their cultural and academic assets (Buchheister et al., 2019; Chao et al., 2015; Domingo-Martos et al., 2022).

2024). Part of the process of preparing TCs to enact IEBMT with young learners in mathematics is ensuring that they are prepared to incorporate hands-on, concrete learning experiences with manipulatives to support children's understanding of mathematics concepts (NAEYC, 2020). Piaget (1952) posited that young learners must first experience mathematics using concrete objects before learning mathematics with pictures and abstract symbols. Early childhood teacher education programs need to ensure that TCs know how to use manipulatives, when to use them, and when to help students transition to pictures and abstract symbols (Zhang & Cutler, 2020). This includes ensuring that TCs are aware of various levels and progressions of learning mathematics concepts including the use of concrete manipulatives, pictorial representations, and the use of abstract symbols.

Opportunities for Exploring Problems Embedded in Meaningful Contexts

The second pillar of IEBMT focuses on providing learners with opportunities to explore problems, when appropriate, that are embedded in meaningful contexts.

Student exploration of problems. Syntheses of research indicate that students benefit by having meaningful experiences to explore mathematics concepts and develop a solid understanding of content before learning specific procedures (NCTM, 2014; Sinha & Kapur, 2021). The process of providing learners with opportunities to explore and the autonomy to choose strategies does not mean that learners have free reign while the teacher sits back. Rather, students use mathematics tools (e.g., manipulatives, paper/pencil for drawings or symbolic work) and explore problems while the teacher scaffolds and guides them with specific questions and feedback (Buchheister et al., 2019; NCTM, 2014). In her influential work on equity-based mathematics practices Gutiérrez (2009, 2012) referred to this idea as giving students Power, and recommended that teachers give learners opportunities to explore and the freedom to select which strategies they want to use to solve problems that are relevant to them. Syntheses of research find benefit in allowing students to engage in productive struggle (failure) prior to discussions of specific strategies of solving

problems (NCTM, 2014; Sinha & Kapur, 2021).

Activities in meaningful contexts. Additionally, these activities must be relevant to learners and embedded in meaningful contexts that learners can relate to (Unbound Ed, 2021a, 2021b). Constructs, such as culturally responsive teaching, are grounded in evidence that students are more likely to persist and engage in challenging activities when they are grounded in relevant contexts related to their cultural assets and interests (Paris & Alim, 2017). Similar to the other aspects of IEBMT, teachers and TCs need opportunities to develop knowledge about their students' cultural assets and interests of their students (Domingo-Martos et al., 2022).

Context of Educator Preparation Programs

There have been long-running recommendations to intentionally align the course work within educator preparation programs, teacher candidates' (TCs) clinical practice experiences, and the actual work done daily by teachers (American Association for Colleges of Teacher Education [AACTE], 2016; Putman & Polly, 2021; Zeichner, 2021). Historically, research has documented discrepancies between what TCs experience during education courses, specifically those focused on pedagogies, and their experiences with clinical practice in school settings (Zeichner, 2021). Additionally, recommendations in the past decade have explicitly asked for educator preparation programs to intentionally prioritize the design and implementation of clinical practice experiences that are intended to provide TCs with worthwhile, intensive but supported opportunities to plan instructional activities, teach them, and then reflect on their experiences (AACTE, 2016; National Association for Professional Development Schools, 2022).

This study frames early childhood education broadly to encompass education for learners from Birth through Grade 3 with a specific focus on learners in Grades Kindergarten through Grade 3. In teacher education this involves clinical practice experiences occurring in multiple settings including early childhood education centers, community centers, as well as formal schools which often start in the United States in Pre-Kindergarten or Kindergarten.

When considering the preparation of early

childhood educators, scholars speak to the essential nature of intentionally aligning course activities with clinical practice experiences is critical (Burns et al., 2016; Zeichner, 2021; Putman & Polly, 2021). Historically, university-based course instructors include research- and theory-based approaches to teaching that do not align to what TCs are observing in PK-12 school settings (AACTE, 2016). Additionally, the clinical practice activities that TCs engage in in classrooms do not include the depth needed to adequately prepare them for full-time student teaching internships as well as having their own classroom (AACTE, 2016).

Early childhood TCs who hope to work with primary grade learners need ample experiences working with and learning about children in clinical practice settings in classrooms (Matengu et. al., 2020). These clinical practice activities should include both informal time in classrooms observing and interacting with children as well as more formal opportunities to co-lead or lead instructional activities and reflect on their experiences.

Practice-Based Teacher Education

Practice-based teacher education (PBTE) is a construct used to describe four phases to prepare TCs to learn about and enact research-based pedagogies (Grossman et al., 2009). Table 2 describes the four phases of PBTE: Learn, Practice, Enact, and Reflect (McDonald et al., 2013). McDonald and colleagues wrote in their introductory article about the learning cycle (p. 382),

This cycle intends to offer guided assistance to candidates to learn particular practices by introducing them to the practices as they come to life in meaningful units of instruction, preparing them to actually enact those practices, requiring them to enact the practices with real students in real classrooms, and then returning to their enactment through analysis. Depending on the goals and purposes of the teacher educator, it is possible to start this learning cycle in any of its four quadrants.

Table 2

Phases of Practice-based Teacher Education

Phase	Description
Learn	Learn research-based pedagogies by participating as learners in an example lesson, watching videos, and/or other experiences.
Prepare	Prepare to enact the research-based pedagogies with young learners. This may include selecting activities, writing lesson plans, and rehearsing/practicing teaching with peers (aka other TCs) and receiving feedback on their rehearsal.
Enact	Enact research-based pedagogies with students in a school setting. This experience may include the collection of artifacts from the enactment such as student work samples, audio recordings, video recordings, or observation notes from an observer.
Reflect	Reflect on the enactment based on TCs' experiences, student data, or recordings of the enactment.

“The learning cycle is rooted in theory that posits that learning is situated within meaningful learning experiences and refined through empirical studies on teacher candidates’ learning.”

The learning cycle is rooted in theory that posits that learning is situated within meaningful learning experiences (see Rogoff, 1997; Wenger, 1998) and refined through empirical studies on teacher candidates’ learning (Grossman, 2013; Kazemi et al., 2009; Windschitl et al., 2012). While the learning cycle has four distinct phases, based on TCs background, teacher educators may begin the cycle with any phase.

In the **Learn** phase TCs are introduced to specific research-based pedagogies through various means including, but not limited to, an instructional activity where the teacher education models the pedagogies as TCs take on the role of learners, conducting live observations of a teacher enacting this practice, watching a video of a teacher implementing the pedagogy with students, or analyzing written vignettes from teachers or researchers about classroom-based enactments of the pedagogies. The priority in this phase is that TCs gain a deeper understanding of what the practice looks like with learners in actual schools.

Typically, the **Prepare** phase also occurs during a course meeting when TCs practice using the research-based pedagogies with peers in what is often called rehearsals. During this phase, the course instructor and peers give feedback to help refine the use of the pedagogy before TCs enact it with children in classrooms.

The **Enact** phase occurs in a classroom when TCs teach an instructional activity and use the research-based pedagogies with students. Lastly, the **Reflect** phase includes TCs analyzing student work, recordings, or thinking about their experiences during the enactment phase.

Research on PBTE approaches have indicated that this process, especially the Practice phase with Rehearsal activities have positively influenced TCs’ perceptions of feeling prepared to enact research-based pedagogies (Colonnese et al., 2022;

Shaughnessy & Boerst, 2018; Shaughnessy et al., 2019). Additionally, the PBTE phases contributed to TCs posing more questions about elementary school students’ mathematical thinking and ideas instead of just asking more basic questions about the answer that they received (Polly, 2021).

In light of the context of educator preparation programs and the need to support early childhood educator preparation programs in preparing TCs to be more inclusive of primary grades learners, PBTE has a lot of potential that needs to continue to be explored as a possible approach to support TCs enactment of research-based pedagogies. To that end, this paper explores the following broad question: How do course activities in early childhood mathematics pedagogy courses influence TCs’ performance during Practice and Enactment activities?

Methods

Context

This study examined data sources from two elementary education mathematics pedagogy courses focused on teaching primary grades learners (Kindergarten through Grade 2) taught by the author at a large university in the southeastern United States. Course A is a traditional face-to-face course taken by undergraduate students who are earning their undergraduate degree in Elementary Education and their initial teaching license in Grades Kindergarten through Grade 6. Course A required TCs to attend face-to-face courses for 3 hours each week for a 16-week semester. The course also included clinical practice activities in which TCs enacted a number sense activity (aka a number talk) and three lessons focused on word problems.

Meanwhile, Course B was an online course with both synchronous and asynchronous coursework taken by post-baccalaureate students during a 10-week summer session. Each of the TCs in Course B had a degree in a non-education related field and were earning their initial teaching license in Grades Kindergarten through Grade 6. During this section TCs completed 8 asynchronous modules and participated in 3 synchronous sessions, two of which involved practice and rehearsal activities. Enactment and reflection were not required in this course since the course occurred in the summer.

Due to the differences in the course formats, the purpose of this study is to examine each course separately in light of the research question: How do practice-based teacher education (PBTE) course activities in early childhood mathematics pedagogy courses influence TCs' enactment of Inclusive and Equity-based Mathematics Teaching (IEBMT)? Both courses were included since PBTE approaches have not been studied thoroughly in both face-to-face and online, bichronous settings (Polly, 2021; Shaughnessy et al., 2021).

Description of Course Activities

Number Sense Activity

Course A. In Course A TCs participated in number sense activities (aka number talks) as learners three times during the first two weeks of the semester. Each of these activities focused on having TCs look at and talk about pictures of dots that were arranged differently based on the research-based activity of subitizing (Clements, 1999; Figure 1). The goal of the activity was to think about different ways to count the total number of dots. While there are various ways to arrange manipulatives inside of a ten frame the purpose of these arrangements was to promote conceptual subitizing (Clements, 1999) so that TCs could clearly see two distinct groups with a constant total amount. In the activity all the pictures had a total of 10 dots with varying dots in each of the ten frames. In Figure 1 when asked about what they notice, TCs may state ideas such as:

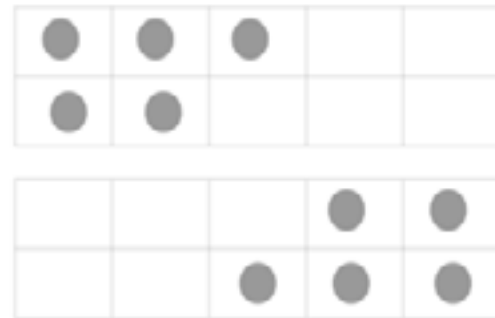
- "I see 5 on the top and 5 on the bottom and I know that 5 plus 5 is 10."
- "I see that the bottom dots can be moved up to fill the empty boxes so that all 10 boxes on top are full to make a total of 10."
- "I went from left to right and counted by 2s. I landed on 10 which is the total."

During the discussion after the activity, TCs spent time talking about their experiences as learners and the benefits of the number sense activities. Part of the discussion during the course focused on the specific questions that the instructor (the author) asked during the activity with a focus on how

those questions elicited students' thinking about the mathematical concepts embedded within the activity.

FIGURE 1

Screen shot of image from number sense activity



During the fourth class meeting TCs came to class with a number sense activity prepared and questions planned. The TCs spent time practicing their number sense activity in small groups of 5 or 6 people. After each round of practice each TC who practiced received feedback from their peers.

Course B. Since Course B was an online course with asynchronous modules and a few synchronous sessions, TCs experienced two examples of a number sense activity during the first synchronous session and then watched a video example of a number sense activity during a subsequent online module. In the second synchronous session the TCs practiced their number sense activity with colleagues. Similar to Course A, after each round of practice each TC received peer feedback.

Problem Solving Lessons

Course A. In the undergraduate face-to-face course TCs spent two class periods in the Learn phase where they analyzed and solved different types of word problems. During this time the instructor modeled how to teach a word problem using an inquiry-based approach that involved the teacher posing the word problem, asking a series of questions about the problem, and then allowing students to solve the problem.

During the course meetings the instructor (the author) provided examples of ways to support primary grades students. For example, consider the word problem: There are 4 dogs in the park. Then 3 more dogs show up. These scaffolds that were shown to TCs included asking questions about the problem to guide students through the problem-solving process and providing them with a number path and hands-on counters to help students who need help keeping track of the numbers in the problems (Figure 2).

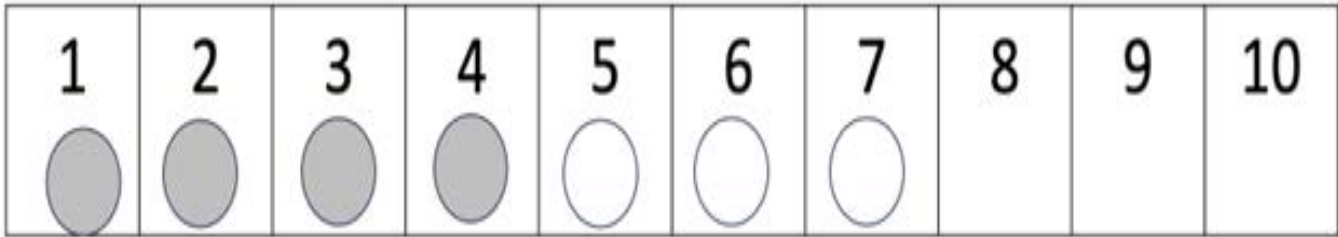
The instructor walked through the process with TCs in the following way:

- *Instructor:* I want us to think about this situation. *There are 4 dogs in the park. Then 3 more dogs show up.*
- *Instructor:* How many dogs are in the park?
- *TCs:* There are 4.
- *Instructor:* How can we use our counters to show that?
- *TCs cover the numbers 1, 2, 3 and 4 on the number path.*
- *Instructor:* What is the action in our problem?
- *TC:* 3 more dogs showed up.
- *Instructor:* Use your counters to show the 3 dogs that showed up.
- *TCs put counters that are a different color on the numbers 5, 6, and 7.*
- *Instructor:* The question we are going to answer is “how many dogs are now in the park? What is the answer?
- *TC:* The answer is 7.
- *Instructor:* How do you know?
- *TC:* I have 4 counters and 3 counters. That is a total of 7.

TCs then spent time during a class meeting creating word problems to use in each of their three lessons. The template that was given to students required five word problems per lesson. TCs were required to create an opening word problem and then four follow up word problems. TCs were asked to create two of the four follow-up problems to be easier than the opening problem, meaning the numbers were smaller OR there would be more guidance from the TC while teaching young learners. Additionally, two of the follow-up problems were expected to be more challenging than the opening problem with larger numbers and possibly focusing on the use of pictures instead of hands-on manipulatives and less teacher guidance. After students created word problems, they had a class session where they practiced teaching one of their word problems using the process that was detailed above. Similar to the number sense activities, peers provided feedback.

Course B. Course B, the 10-week online bi-synchronous course, was markedly different from Course A regarding the Learn phase of the problem-solving process. TCs examined different types of word problems in the first two asynchronous modules and received feedback about their word problems from the author via an assignment that they submitted. In the second module TCs wrote their five word problems for each lesson. These word problems were similar to Course A with one opening problems and four follow-up problems, two that were easier and two that were harder compared to the opening problem. In the course’s second synchronous session, which occurred during Week 4 of the course, TCs practiced teaching one

FIGURE 2
Picture of Number Path and Counters



of their word problems using the same process described in Course A. TCs attended Zoom sessions in groups of four to six where each TC taught their peers as if they were young learners. After each rehearsal peers gave glows and wonderings. Glows were positive things from the rehearsal and rehearsals included things that peers had questions about. Most peers gave glows and there were few wonderings. The author, as the course instructor, also gave glows. All suggestions for their tasks or teaching were communicated privately by the author after the practice rehearsal teaching.

Participants, Data Sources, and Data Analysis

This section describes the participants, data sources, and data analysis included in this study.

Participants

In order to examine the research question with a focus on the early childhood grades this study includes data from TCs who completed course activities related to Kindergarten. While the course included 22 TCs in Course A and 28 students in Course B, focusing only on TCs who had placements in Kindergarten reduced the number of participants to seven TCs in Course A and

five TCs in Course B. All TCs in Course A completed clinical practice activities in urban schools where over 85% of the students within the school were experiencing poverty and over 60% of the students identified as Black or Latinx. While TCs in Course B did not complete clinical practice activities during the summer course, each of them had completed clinical practice activities in previous semesters in either urban or rural schools where over 80% of the students within the school were experiencing poverty. The students in the schools where TCs in Course B previously had completed clinical activities included diverse populations of students including those who identified as White, Black, and Latinx.

Data Sources and Data Analysis

In order to examine the research question multiple data sources were examined (see Table 3). The data from each course was examined separately since the courses included different populations (undergraduates and post-baccalaureate teacher candidates) and activities. These data sources came from the two primary course activities that included practice (both courses) and enactment (only Course A).

Table 3

Data Sources Used the Study

	Course A	Course B
	Undergraduate Face-to-Face Course	Online Post Baccalaureate Course
Number Sense Activity	Practice:	Practice:
	TC's written reflection	TC's written reflection
	Enactment:	<i>No Enactment Data</i>
	TC's written reflection	
Problem Solving Lessons	Practice:	Practice:
	Planning Map of word problems and questions	Planning Map of word problems and questions
	TC's written reflection	TC's written reflection
	Enactment:	<i>No Enactment Data</i>
	TC's written reflection	

In order to examine the research question, data was analyzed using an inductive process using open coding (Bingham, 2023; Bogdan & Biklen, 2006). Bingham (2023) proposed a five-stage process which was used. First, data was organized with all the data sources inserted into google documents. Second, data was sorted into categories based on the course. Third, the author coded data. The codes were informed by the two pillars on inclusive, equity-based mathematics teaching (Table 1). Codes were assigned to excerpts of the data by the author. Examples of codes include TC's actions such as posing word problems, posing questions, supporting students and direct teaching. Examples of codes related to student actions included solving word problems, using manipulatives, and choosing strategies.

Fourth, codes were organized by similar topics to generate themes. The themes were then checked by revisiting the original data excerpts in order to help establish trustworthiness. Lastly, findings were explained. Due to the limited context of the study, Bingham's suggestion of advancing theory was not included. As stated earlier, based on the limited context, this was an exploratory study to better understand the influence of PBTE activities in early childhood teacher education programs, and the study was not designed to advance theory or make generalizations.

Findings

This study was framed around the research question: How do practice-based teacher education (PBTE) course activities in early childhood mathematics pedagogy courses influence TCs' enactment of Inclusive and Equity-based Mathematics Teaching (IEBMT)? The findings are organized by the two pillars of Inclusive and Equity-Based Mathematics Teaching ([IEBMT]; Table 1): 1) access to grade-level aligned research-based experiences and 2) opportunities for exploring problems embedded in meaningful contexts.

Access to Grade-level Aligned Research-based Experiences

Teacher candidates (TCs) in both courses planned learning experiences that were aligned

with the Kindergarten grade-level standards. All candidates wrote word problems and number sense activities that provided scaffolds to support primary learners' access to the word problems. Specific themes related to this pillar of IEBMT included progressions of questions in the number sense activity and the use of visuals and manipulatives.

Progression of questions in number sense activity. In terms of the number sense activity, all seven TCs in Course A had planned for a series of questions that progressed from low-level to more higher-level. When the seven teacher candidates did not ask the questions that they had come prepared with; instead, they made up other questions on the spot that were basic and low-level questions. In Course B all five TCs planned for and asked questions that progressed from low-level to higher-level questions.

Examples of the higher-level questions that were asked were similar to those asked during the examples provided by the instructor (the author) during the **Learn** phase, such as: "How is this strategy of finding the total number similar to the strategy we saw earlier?" And "How do you know that your thinking is correct?" Similar to what happened during the Learn phase, TCs in both Course A (face-to-face) and Course B (online) mimicked what they saw the instructor (the author) do and implemented the progression from low-level to higher-level questions with a high degree of fidelity.

One TC from Course A who decided to make up her own questions wrote in her reflection, "I did not feel comfortable asking the harder questions since I was still unsure what a correct answer would look like and how I would respond to my classmates." Despite the activities that this TC went through she still chose not to ask higher-level questions due to her uncertainty about the correct answer and how to respond to answers.

A TC from Course B wrote, "Even though the synchronous time before we practiced was brief, it helped to see an example on video and also be part of one that [the instructor] led. These activities definitely helped me feel prepared to practice my own activity."

Only TCs in Course A enacted this activity with primary grade learners. In their reflection, six of the seven TCs reported a positive experience from

teaching the activity to a small group of primary grade learners. One TC who had a positive experience wrote, "The questions that I had planned for worked very well and my students were able to do the activity and share their thinking."

The TC who did not report a positive experience was one of the TCs who abandoned her planned questions during the **Practice** phase. She wrote in her reflection, "When I was teaching my students the activity was too easy, so I had to make up more problems and questions on the spot." This reflection speaks to the idea that her planned activity did not align well to students' strengths and needs.

In summary, TCs in both courses were able to practice the number sense activity in ways that aligned with the instructor had intended. TCs in Course A enacted the activity with students and had a positive experience, except for one individual who reported that her students were bored and she had to plan her activity on the spot since the original activity was too easy.

Use of manipulatives and visuals. All the TCs across both courses planned for and used manipulatives such as counters or cubes during each of the lessons. This was consistent and evident during each TCs **Practice** activity. During the reflection of the practice TCs wrote questions though about when they should have their students use manipulatives compared to drawing a picture about the math problem. One TC wrote, "I always make them use counters or can I give them the option of counters or a picture?" Another TC wrote, "I know my students will always want counters but some may not need them. How do I take them away and have them draw pictures?"

All TCs were aligned with the desired pedagogies by using manipulatives such as counters or cubes along with Number Paths (Figure 2). TCs reported confusion and uncertainty knowing when they should encourage students to transition from manipulatives to pictures in ways that are positive and non-threatening. Following the **Practice** this was discussed in a class session for Course A, and through an email to TCs in Course B. The instructor gave ideas about how they may encourage students to create a representation with manipulatives and then draw a picture of the concrete objects, or

when ready begin their work by trying to first draw a picture to solve the problem.

When the TCs in Course A enacted their lesson, they reported that their students found the use of counters to be very helpful and some primary grade learners demonstrated misconceptions when they had to draw pictures instead of manipulatives. One TC wrote, "If my students have counters they get them all correct. If they have to draw a picture then 3 of my 5 students will need help just getting started." This TC had firsthand evidence that the transition from manipulatives to pictures was hard and needed more support in the future.

In summary, TCs demonstrated some degree of fidelity to the desired pedagogies by planning for and using manipulatives such as counters and cubes in their **Practice** activity. TCs, though, reported a lot of uncertainty across both courses on how to help students transition from manipulatives to pictures.

Opportunities to Explore Problems Embedded in Meaningful Contexts

Opportunities to explore problems. The analysis of data related to the problem-solving lessons indicated that all 12 TCs across both courses had planned to allow students to explore word problems with TCs scaffolding by providing manipulatives and questions to support students. This matched both the face-to-face course session for Course A and the asynchronous modules in Course B. The planning and preparation of their lessons included scaffolds for learners since it went systematically step by step using questions to guide students.

However, four of the seven TCs during the Practice phase of Course A; two TCs taught directly how to solve a problem with direct teaching and did not ask any questions, and two TCs taught posed the word problem and provided no questions or guidance to support students. In all these four instances, the practice either provided too much scaffolding with direct teaching or not enough scaffolding by simply giving the word problem. In their reflection of the practice, one TC who practiced in a direct instruction method that did not match the desired pedagogies wrote, "As soon as I got into my practice I know I needed to teach every step of the problem since my students will need to be given all

the information like that when I teach it." This TC had a predetermined notion of her students that they needed direct instruction instead of inquiry-based instruction and she decided to practice using that approach.

During the enactment with primary grades' learners, TCs from Course A all used a step-by-step inquiry-based approach. The debrief of the Practice activity provided TCs with more examples and clarification about what the lessons should look like, which led to a higher degree of fidelity during the enactment with students. In her reflection, one of the TCs who taught with direct instruction during practice but inquiry-based during enactment said, "I still was skeptical during my lesson with kids until I saw how my Kindergarteners had their own ideas and strategies on how to solve the problem. They had enough of a foundation to be successful and share their ideas with me and their classmates."

In terms of Course B, during a synchronous session, two of the five TCs practiced their word problem with classmates in a step-by-step approach that provided scaffolds and an inquiry-based approach where the teacher taught by asking a lot of questions. There were three TCs who directly taught each step and did not use an inquiry-based approach. These TCs who directly taught how to solve word problems included comments in their reflection about how their schools have completed clinical practice experiences in teaching mathematics this way with direct instruction about specific strategies instead of inquiry-based approaches. One TC who taught her practice lesson in a direct instruction manner wrote, "This is what my school does. They teach step by step while students listen and watch and then they will eventually get to practice."

Data analysis indicated that the number sense routines included plans for and evidence during the practice activities of students having Power and being able to determine which strategy they want to use to count the total number of dots. Additionally, the number sense activities all included alignment to grade level content since subitizing and the questions posed aligned to the state mathematics standards. Identity was not explicit since number sense activities are non-contextualized problems, but the scaffolds provided by the TCs were designed to empower primary grade learners that they are capable

of being successful in mathematics.

In regards to the idea of Power, one TC from Course A wrote in her reflection after the enactment, "It was transformative to hear my students' ideas during the number talk. They had such creative, correct ways to find the answer." One TC from Course B wrote in her reflection after the practice, "It makes me nervous to ask questions about what my students are thinking because I do not know what they will say, but I know that it is good for them and I want to keep doing that even if it is a bit nerve wracking."

In terms of the problem-solving lessons, all of the TCs across both courses provided word problems that were embedded in real-life situations which were intended to be relevant to learners, which helps to develop their identity. As stated above, not all TCs demonstrated during the Practice pedagogies that give students power since some TCs taught using direct instruction the exact steps about how to solve a word problem. Additionally, when TCs (and teachers) teach using direct instruction where students are not actively doing mathematics for a time that has potential to negatively impact their identity since they may feel not capable of doing mathematics without the teacher first demonstrating each step.

Problems embedded in a meaningful context.

Additionally, each of the TCs were able to write word problems that included contexts that were meaningful to their students. In the lesson plans for the problem-solving lessons TCs provided a written rationale about how their word problems were embedded in a meaningful context. Examples from teachers' rationales included references to students' cultural backgrounds or businesses near their school. One TC in Course A wrote: "Many of my students speak Spanish at home so I decided to make word problems about Spanish food." A TC wrote in Course B, "There is a park down the street from my school and so I wrote word problems about the park since students are always talking about the park."

In summary, there was evidence that TCs were able to write word problems in a meaningful context when they embedded the problems in students' cultures or community assets such as parks or stores. In terms of allowing students to explore problems,

data only came from Course A since Course B TCs did not enact lessons in Kindergarten classrooms. For TCs in course A, some TCs had preconceived notions that their primary grade learners needed direct instruction of specific strategies instead of opportunities to explore, so they practiced that. Fortunately, for the TCs in Course A, the debrief after the practice activity provided clarity which led to all TCs teaching word problems in an inquiry-based approach during the Enact phase.

Discussion and Implications

The purpose of this inductive, exploratory qualitative study was to examine the broad research question, How do practice-based teacher education (PBTE) course activities in early childhood mathematics pedagogy courses influence TCs' enactment of Inclusive and Equity-Based Mathematics Teaching (IEBMT)? Data from TCs reflections and instructor's notes were used as primary data sources. In this section, I connect the findings to current research and provide possible implications for future work. This section focuses specifically on the potential of practice-based teacher education (PBTE) and the consideration of inclusive, equity-based teaching in early childhood educator preparation programs.

Potential of Practice-based Teacher Education (PBTE)

In this paper, the data analysis led to findings that the process of Practice-based Teacher Education (PBTE) and its four phases led to direct alignment between desired research-based pedagogies associated with IEBMT. Specifically, evidence of these practices were more clearly evident in TCs plans and their practice teaching during each course related to the number sense activities and number talks. TCs used activities that were aligned to state mathematics standards and a series of questions that progressed from lower-level to higher-level which matched what TCs had experienced when they were learning about these activities. In the case of number sense activities, the course activities and PBTE processes of **Learn and Practice** led to TCs using the desired pedagogies across both Course A (face-to-face) and Course B

(online). This finding supported previous studies (Colonnese & Polly, 2022; Shaughnessy et al., 2021) in that there was documented evidence that the PBTE framework was linked with evidence of TCs learning as noted on both TC reflections on clinical documents (Colonnese & Polly, 2022) as well as performance-based tasks that embody the daily work of teaching mathematics (Shaughnessy et al., 2021).

"TCs in both courses wrote word problems that were embedded in meaningful contexts relevant to their students"

In this study, the PBTE process was associated with TCs posing word problems that had embedded research-based scaffolds, such as number paths and manipulatives. Additionally, TCs in both courses wrote word problems that were embedded in meaningful contexts relevant to their students. However, there was evidence of a lack of alignment for some TCs in each course between the desired approach to teach these problem-solving lessons using an inquiry-based approach focused on asking students questions, and a direct instruction approach that some TCs used during their practice teaching. This direct instruction approach to teaching how to solve word problems was evident in both Course A and Course B. This complexity about the lack of alignment between course concepts and the actual enacted pedagogies that TCs observe in clinical classrooms affirms the critical need to better align pedagogies in clinical placements and the research-based practices taught in teacher education courses (AACTE, 2016; Zeichner, 2021).

However, the alignment between course activities and clinicals appeared to be influenced by the specific course. Since Course A included the **Enact** phase with primary grade learners and Course B did not, all TCs in Course A received feedback and developed more clarity about how to teach using an inquiry-based approach and used that approach with students in classrooms. In the case of TCs in Course B since it was a summer course without

clinical practice experiences and an **Enact** phase there is no evidence about how the TCs would teach word problems to students. This finding contributes to the literature since it provides empirical data that while PBTE has potential as a process to support TCs adoption and use of research-based pedagogies, there is a need for the instructor to be attentive to TCs performance during **Practice** and look for ways to support pedagogical shifts between the **Practice** and **Enact** phases.

Recent work has started to look at the influence of mediated field experiences (MFEs) where the course instructor is in the clinical practice setting with TCs to provide ongoing support and coaching during enactment (Colonnese & Polly, 2022; Gesel et al., 2023). Future research is needed to examine which models of supporting both **Practice and Enactment** are best, especially in the cases of on-line teacher education courses and programs. Additionally, the research base still needs studies that examine the influence of approaches like PBTE on the enactment of research-based practices as well as student learning outcomes. In order for these types of approaches to be more widespread in educator preparation programs these topics need to be empirically investigated to associate these efforts to teacher candidate learning and, when possible, PK-12 student learning.

Preparing TCs to Enact (IEBMT) in Early Childhood Settings

As stated earlier, inclusive, equity-based teaching practices were framed in two ways in this study: 1) providing access and support to grade level content, and 2) integrating equity-based mathematics pedagogies that are relevant to primary grade learners.

Providing access to grade-level aligned, research-based experiences

The data analysis indicated that TCs in both courses were able to successfully create number sense activities and word problem lessons that aligned to grade level content, and TCs were also able to think about how to provide access to manipulatives such as counters and cubes as a support to do the mathematics. As indicated in the findings,

though, is that TCs asked questions and reported a lack of clarity on how to help students transition from manipulatives to pictures; more specifically, when students show that they may not need the supports of the manipulatives anymore they were uncertain on how to remove them in a non-threatening way. In some cases, TCs reported not knowing when they should think about and consider removing the manipulatives from students, instead strongly encouraging the use of pictures. This finding supports a seminal mathematics education study that found that teachers tended to focus on isolated aspects of mathematics teaching such as manipulative use, but in a superficial way where hands-on manipulatives were used but teachers did not demonstrate efforts to help learners make connections between the manipulatives and the actual mathematics concepts (Cohen, 1990). Additionally, there is a need for educator preparation programs to ensure that ample experiences are included to support TCs enactment of IEBMT.

Future research studies need to examine ways that educator preparation programs can provide both course and clinical practice experiences related to providing support and scaffolds for learners. This includes the process of preparing TCs to recognize in the moment of teaching or afterwards while examining student work information or data that scaffolds may no longer be needed or need to be modified. Additionally, research is needed about how to best support TCs use of transitions of scaffolds as they move from more intensive to less intensive supports. In the case of this study, TCs in Course A planned and enacted three problem solving lessons to small groups of students where manipulatives were used in nearly each case. In the teacher education program that Course A is part of, previous studies found that having TCs enact lessons and instructional activities to small groups of students makes these clinical practice activities easier to enact compared to requiring whole group teaching experiences (Polly, 2021; Colonnese & Polly, 2022; Putman & Polly, 2022). Part of the reason that small group activities appear to be a better context for TCs to enact inclusive, equity-based practices is that clinical educators who host TCs are more apt to give TCs control of a small group of students compared to a whole group of students. One equity-based, inclusion practice that was com-

-plex in this study was TCs decision to use manipulatives or encourage young learners to represent their word problem with pictures on paper. In some cases, in Course A, TCs required manipulative use but reported that in some cases, in retrospect, they likely should have encouraged pictures instead of manipulative use. As scholars continue to think about inclusion and meeting students' academic needs, one-size-fits all approaches do not work, and teacher education programs have a responsibility to develop TCs who are flexible and responsive to data when deciding how to best support young learners.

Opportunities for Exploration while Solving Problems in Meaningful Contexts

The second aspect of inclusive, equity-based teaching focuses on providing learners with opportunities for exploration while solving problems in meaningful contexts. The findings from this study provide evidence that TCs were able to successfully create (both courses) and enact (only Course A) word problems in contexts that were embedded in relevant and meaningful contexts to primary grade learners. However, in their reflections, some TCs shared that although they planned to engage learners in activities that provided student exploration and inquiry-based approaches, they were afraid it would be too challenging, and instead opted to use direct instruction pedagogies in their practice activities, which did not align to what the TCs had learned and used in the PBTE activities in the course. This dissonance between planning (intended practices) and how TCs taught (enacted practices) occurred only in Course A because TCs enacted their lessons. Meanwhile, in Course B, this potential disconnect was not as clearly evident since enactment was not required with early childhood learners.

This potential disconnect between PBTE and other course-based activities dealt with providing early childhood learners with opportunities to explore problems and use their choice of strategies while solving problems. In order for IEBMT to come to fruition in early childhood settings, TCs need course activities that encompass PBTE approaches and also include scaffolded enactments with young learners. In the case of Course A possi-

ble revisions could include video or audio recordings of enactments with a time for TC reflection, instructor feedback or additional rehearsals in between enactments. The ideas of mediated field experiences (Colonnese & Polly, 2022; Gesel et al., 2023) may provide promise in the efforts of supporting TCs enactment of pedagogies aligned with IEBMT.

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Fostering STEM in Early Childhood Programs: Practices of Preschool Parents with STEM Backgrounds

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ABSTRACT

This study explored the experiences of families with backgrounds in STEM (Science, Technology, Engineering, and Mathematics) and the strategies they use to support their young children's STEM learning. Using a qualitative research design, interviews were conducted with four parents recruited from childcare centers in a small urban town in a Midwestern U.S. state. The findings revealed that family role models, preschool curricula, and a child's intrinsic motivation and passion play key roles in fostering early interest in STEM. Parents emphasized the value of accessible, hands-on activities that can be easily integrated into busy family routines. They also recommended using "plug-and-play" resources, connecting children with STEM professionals, and making learning experiences fun, engaging, and interactive. Importantly, parents advocated for hands-on activities that go beyond simple repetition to promote deeper understanding and sustained interest in STEM.

KEYWORDS

STEM Teaching Practices, Preschool Children, Parent Involvement

Parent involvement is a key predictor of children's academic success, particularly when it involves parents' field-specific social capital. STEM-related social capital, including parents' STEM education, plays a significant role in students' decisions to pursue and persist in STEM fields (Tilbrook & Schifrer, 2021). Children of parents with STEM degrees are more likely to pursue STEM majors than those whose parents lack such degrees.

The Early Childhood STEM Working Group emphasizes that parent and family involvement is critical for fostering STEM learning in early childhood education. They recommend that programs provide resources and opportunities to engage families in STEM education, highlighting the key role parents play in shaping early STEM experiences at home and advocating for high-quality STEM education in schools. However, many parents lack the knowledge or confidence to support early STEM education, so the group calls for robust support systems to build self-efficacy in STEM for both children and adults.

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Parental expectations are strong predictors of STEM achievements (Wang & Yang, 2019), and higher socioeconomic parents tend to use more effective STEM-supporting strategies. Motivational practices, such as encouragement and positive reinforcement, significantly influence long-term STEM achievement (Ing, 2014; Rashmi, 2016). Programs that help parents understand the value of STEM education for their child's academic success are more likely to foster engagement in STEM activities at home (Pepper, Faulkner, & Barlow, 2017).

Parents who value STEM are more likely to engage in informal STEM learning activities, which are crucial in developing curiosity and problem-solving skills. These activities like nature walks, museum visits, or home experiments encourage children to explore and ask questions, building critical thinking skills. Positive parent involvement in STEM interventions also boosts student engagement, especially for girls (Heddy & Sinatra, 2017).

Despite the benefits, meaningful partnerships with families in supporting STEM learning are often lacking (Steiner et al., 2019). Parent involvement has been identified as a major predictor of students' STEM learning and career decisions (Rivera & Li, 2020). Studies have shown that parental engagement not only motivates students but also fosters intrinsic motivation, improving achievement and self-concept in STEM subjects (Jungert, Levine, & Koestner, 2020; Simpkins, Price, & Garcia, 2015). Parents who actively engage in STEM activities at home play a crucial role in enhancing their children's STEM interest and academic success.

STEM in the Early Years

Introducing STEM concepts early helps foster curiosity, problem-solving skills, and creativity. Research shows that engaging young children in STEM activities, like building structures or conducting experiments, develops critical thinking and a deeper understanding of cause and effect, laying the foundation for future learning (Kuo, 2024).

STEM education also promotes creativity, as it combines systematic inquiry with creative expression. Early exposure enables children to think creatively about solving challenges, leading to an innovative mindset (Bevan, 2017). Activities like

building machines or solving problems with available materials enhance both imaginative and analytical thinking. Additionally, STEM often involves group work, promoting communication, teamwork, and social skills. Collaborative learning environments help children express ideas, negotiate, and share resources, which are crucial for both academic and social development (Darling-Hammond, 2020). STEM activities also support language development, as children discuss hypotheses and describe experiments, strengthening both verbal and non-verbal communication skills (English, 2021).

Introducing STEM early can help bridge gender and diversity gaps in these fields. Studies show that exposing all children to STEM activities counteracts biases and encourages both boys and girls to explore these areas (Hill, Witherspoon, & Bartz, 2016). Early STEM exposure also impacts long-term academic success, with children more likely to pursue STEM subjects and careers (National Science Foundation, 2019). STEM education often involves solving real-world problems, making learning more meaningful. Activities like recycling projects or nature exploration show children the practical applications of STEM concepts, increasing their motivation and investment in learning (Couse & Chen, 2010). Additionally, STEM learning is adaptable to various learning styles, ensuring it benefits all types of learners (Kim, et al., 2015).

Technology plays a vital role in early STEM education. Interactive tools like educational apps and robotics enhance learning and equip children with digital literacy skills (Scott & Marsh, 2018). Early exposure to technology familiarizes children with tools they'll use throughout their education and careers. Ultimately, early STEM education is essential for developing critical skills, fostering creativity, and preparing children for future academic and career success. It also helps address gender and diversity gaps and provides a foundation for a range of essential skills. As the world becomes more technology-driven, integrating STEM into early childhood education is crucial.

STEM Careers

Children of parents in STEM occupations tend to perform better academically and persist longer in STEM fields, particularly for female and minority

students (Plasman, Gottfried, Williams, Ippolito, Owens, 2020). For example, girls with STEM-employed parents scored higher on math tests than those with non-STEM-employed parents ((Bowden, Bartkowski, Xu, Lewis, 2017). Key factors influencing STEM career choices include having a parent in a STEM occupation, high STEM social capital, being male, older age, and prior academic achievement, with these factors being especially important for females and students without family STEM connections (Holmes, Gore, Smith, Lloyd, 2017). Role models, particularly female ones, significantly impact women's STEM career choices. Adams, Barber, & Odean, (2018) found that mothers in STEM were linked to a 48% increase in daughters' careers in finance, compared to a 29% increase for fathers in STEM. Similarly, girls with STEM-employed parents, especially mothers, tended to perform better in math (Bowden, et al., 2017). However, qualified women interested in STEM careers are often overlooked, as there's insufficient focus on students with STEM-background parents (Anaya et al., 2021). Parents' involvement in science-related activities and encouragement plays a crucial role in fostering STEM interest. Parents in STEM fields often use practices like role modeling, exposure to STEM, and providing extracurricular opportunities (Chakraverty, 2013). Positive role modeling, in particular, is a strong predictor of students pursuing STEM careers (Heidi & Johnson, 2007). When parents actively support science learning, students are more confident and motivated (Aschbacher & Tsai, 2013). Students with STEM-oriented aspirations often have parents in STEM, and these students tend to exhibit higher self-confidence and academic motivation (Sheldrake, 2018). Similarly, positive parental relationships with mathematics enhance children's math achievement and persistence (Ing, 2014).

This study explores the STEM practices of parents with STEM careers, aiming to provide strategies for non-STEM parents to support their children's STEM learning. By highlighting the cultural resources and social capital of STEM parents, the study offers valuable insights for all parents. The findings could inform new approaches to support STEM learning and provide examples for early childhood educators and teachers to share with students, fostering greater interest in STEM fields.

Conceptual Framework

The decision to pursue a career in Science, Technology, Engineering, and Mathematics (STEM) is shaped by a variety of factors at multiple levels, which can be effectively understood through Bronfenbrenner's (1977) ecological systems theory. This theory highlights how an individual's development and career decisions are influenced by interconnected systems, ranging from the immediate family and school environment to broader societal factors. In the microsystem, factors such as parental involvement, peer influence, and the quality of school experiences play a significant role in determining STEM career interests. For instance, parental support, especially from those with a background in STEM, can encourage children to pursue similar paths, while peer groups and school environments either foster or discourage interest in these fields, especially in the context of gender and social stereotypes (Wang, 2013; Ennes, Jones, Chestnutt, Childers, 2023). Schools that offer resources like advanced courses and extracurricular activities provide opportunities for students to engage with STEM, further shaping their career aspirations.

At a broader level, the mesosystem emphasizes the interactions between various aspects of the microsystem. The synergy between family support, peer influences, and school resources can create a strong foundation for a student's interest in STEM. For example, when parents and teachers work together to encourage STEM activities, or when students have access to community-based programs and mentorships, the likelihood of pursuing STEM careers increases (Beasley & Fischer, 2012; Hill, Witherspoon, & Bartz, 2016). In contrast, the exosystem refers to external factors, such as the work environments of parents or the availability of community-based resources, that indirectly influence career decisions. Parents' careers in STEM can expose children to these fields early on, while community resources like internships and local STEM organizations play an important role in offering opportunities, especially in under-resourced areas (Stout, 2011).

The macrosystem and chronosystem encompass larger societal and temporal influences. Societal values, cultural norms, and educational policies significantly shape career pathways, particularly by reinforcing gender stereotypes or providing access to STEM opportunities through national policies (Cheryan, Ziegler, Montoya, & Jiang, 2017; National Science Foundation, 2020). Shifting cultural attitudes and public initiatives aimed at increasing diversity in STEM fields have begun to challenge traditional barriers and encourage more inclusive participation. Additionally, the chronosystem reflects the influence of time and life stages on career choices, highlighting how personal development and societal changes can alter interests in STEM fields over time. As new technologies and emerging fields evolve, they offer fresh opportunities that may inspire students to pursue careers in previously unconsidered areas (Wang & Degol, 2017). By examining all these layers of influence, we can better understand the complex factors that guide individuals toward STEM career paths.

Method

This study examined STEM practices of preschool parents with STEM backgrounds. It was guided with the following research questions:

- What STEM practices do parents with STEM backgrounds engage with their children?
- What kinds of experiences and family interactions have supported and encouraged parents with STEM backgrounds to pursue science related fields?

We employed a qualitative approach, which is particularly useful for examining processes and phenomena where the perspectives of multiple participants are central to understanding the issue or practice (Trainor & Graue, 2014). This approach is also well-suited to research questions that seek to explore a process or phenomenon occurring in a particular context, especially when variables are difficult to control or measure.

Sample & Data Collection

Participants for this study were recruited from a University Children's Learning Center (UCLC) located in a small urban town in the Midwest. Af-

ter receiving approval from the author's institution's Institutional Review Board (IRB), an email outlining the purpose of the study was sent to the program director, who then forwarded it to the parents in the program. The email invited parents who were interested in participating to contact the researcher directly via the provided email address. Four parents expressed interest and reached out to participate. Prior to the interview, participants completed an informed consent form, where they were asked to indicate their voluntary agreement to participate in the study. Their responses were recorded as either "yes" or "no" on the consent form, and this consent was also documented in the audio recording.

The study intentionally recruited participants from this program, as it serves parents primarily from the university community, including both faculty and students, which likely increased the probability of finding parents with STEM backgrounds. In purposive sampling, the researcher relies on participants' knowledge to select the most suitable candidates for the study (Campbell, Greenwood, Prior (2020). For this research, a STEM background was defined as having a career, training, or education in a STEM field. Both mothers and fathers were encouraged to participate to ensure a diversity of perspectives from different STEM backgrounds. Once willing participants were identified, emails were sent to schedule interviews, asking them for their availability. Parents were also sent the interview questions in advance for review.

The six interview questions used in the study were adapted from Chakraverty's (2013) research on parental occupation and science inspiration. The questions were as follows: (1) What childhood experiences or family interactions do you believe were supportive and encouraging in your science pursuits? (2) What types of activities did you engage in that fostered your interest in science? (3) Who were the key people in your life who helped cultivate your science interests? (4) What activities do you do with your children that support their STEM learning? (5) What challenges have you faced in fostering STEM learning? (6) What suggestions do you have for encouraging early science interest in children?

A demographic section was also included in the interview, where parents were asked to provide

information about their STEM background, their current career, the number and ages of their children, and other relevant details. Each parent was interviewed via Zoom for approximately 40 to 60 minutes. The interviews were audio-recorded for later review and analysis.

Parent Demographics

The participating parents had diverse backgrounds in STEM fields. One parent, Tess, held a Bachelor of Arts degree in Biology and had worked in various STEM research roles over the years. At the time of this study, she was employed at a biorefinery lab, a position she had held since 2016. Tess had one daughter who attended the University's Children's Learning Center twice a week and also went to a private home daycare two days a week to help reduce childcare costs. Tess was married and worked full-time from 8 am to 4:30 pm, Monday through Friday.

The second parent, Sandra, held a Bachelor of Science degree in Occupational Safety and Environmental Health. In addition, she was enrolled in graduate school, having completed a year and a half of coursework toward a Master of Science in Homeland Security and Emergency Management. Sandra worked for the Energy and Environmental Research Center at the university. She had a 2-year-old child and two older children in college. Sandra also worked full-time, with a schedule of 8 am to 5 pm on weekdays, and was on-call some weekends.

Parents 3 and 4 were a married couple. Miranda, the wife, held a Master's in Business Administration and a Bachelor's degree in Business Administration. At the time of the study, she was a stay-at-home mom, having left her job after the birth of their second child. The family had moved frequently, so Miranda had not sought new employment opportunities. Before becoming a full-time mom, Miranda worked as an accountant for 5 years and as a financial analyst for 2 years. She and her husband, Dan, had two sons: 2-year-old Joe and 4-year-old Henry. Henry attended preschool, while Joe was at home, waiting to turn three before starting preschool. Dan, the husband, was a military engineer with a Bachelor of Science in Civil Engineering, a Master's in Business Administration, a Master's in Engineering Management, and a

graduate certificate in autonomous assistance.

Data Analysis

A thematic approach was used to analyze the data, which is the process of identifying patterns or themes within qualitative data. The goal of thematic analysis is to identify patterns in the data that are important or interesting and use these themes to address the research questions (Braun & Clarke, 2006). Braun and Clarke's six-phase framework was used to analyze the interview data. In the initial step, reading and re-reading the parent interview transcripts was done to become thoroughly familiar with the entire dataset. Notes were jotted down and early impressions. For instance, one recurring theme was that parents emphasized the importance of encouragement from early childhood. Next, the data was organized in a meaningful and systematic way by applying codes to the script in Step 2. Open coding was used and developed and themes modified as working through the data was done. The purpose was to reduce the data into manageable segments that addressed the specific research questions. For example, we noticed that having someone passionate about STEM in their earlier schooling (e.g., elementary or middle school) or having someone working in a STEM field emerged as a recurring idea in many interviews. After further review of each transcript, preliminary codes were developed. Each interview was coded separately, with every relevant segment marked. The codes were then reviewed and refined as necessary.

In Step 3, patterns or themes within the coded data that captured something significant or interesting about the research questions were looked for. Braun & Clarke (2006) suggest that a theme is a pattern that holds significance. Sometimes, especially with smaller datasets, coding and theme searching can overlap. In this study, several codes were related to the influence of role models—adults who inspired the participants. These codes were grouped together into an initial theme called “inspirations.” By the end of this step, the codes were organized into broader themes that seemed to address specific aspects of the research questions.

Once the initial themes were identified (role models, encouragement, expectations, hands on learning, problem solving approach, STEM pre-

-school curriculum, passion, curiosity), more review and refinement was done in Step 4 making sure that the data connected to each theme truly supported it. Also, consideration was made if there was overlap between themes and whether certain themes needed to be split or combined for clarity. This continued in Step 5, of further refining the themes to identify their relatedness to the research questions and combined them into five themes; role models, encouragement/expectations, hands on learning/problem solving approach, STEM preschool curriculum, passion/curiosity. This similar process was done for the research question on STEM practices with their young children, challenges in STEM fields, and advice to ECE programs. Finally in Step 6, a compilation was made that guided the writing of the findings.

Findings

Family Influencers to STEM

We examined parents upbringing experiences that influenced their interest to STEM. In the interview question we asked parents to describe inspiring childhood experiences and family interactions they perceived were supportive and encouraging in their science pursuits, the kinds of activities they engaged in that fostered their science interest, and the people that were instrumental in their science interest journey. Several major themes were identified. First at the ontogenic level, passion and curiosity were identified as major themes. Second at the microsystem level three major themes were identified, a) role models - passionate teachers, b) parent encouragement and high expectations, c) teaching method- hands on/problem solving approach. Finally, at the macrosystem level, the themes of preschool curriculum and STEM resources in the community were identified.

Microsystem Levels

The **microsystem** is the immediate context in which individuals experience their day-to-day lives. In terms of STEM career choices, several direct influences can shape a person's decision.

Curiosity/Passion. Parents agreed that curi-

“Parents agreed that curiosity played a significant role in fostering interest in STEM career fields. This curiosity was often sparked by role models in their lives—parents and mentors—who, through engaging in STEM activities, nurtured their interest and motivated them to explore more.”

osity played a significant role in fostering interest in STEM career fields. This curiosity was often sparked by role models in their lives—parents and mentors—who, through engaging in STEM activities, nurtured their interest and motivated them to explore more. Preschool programs that integrate STEM activities and provide role models who are passionate about STEM can be instrumental in drawing children into these fields. Tess shared her experience, saying,

My parents fostered my interest, and I was very self-driven in my own way. I wanted to do things, and I wanted to do them better. It was easy for me to dive into topics like biology and life sciences because I enjoyed them and wanted to learn more.

Dan also reflected on his natural curiosity:

I'm a curious person, and that drove me in a biological direction. I'm naturally inclined to ask why behind a lot of things. I've always had a tendency towards research. It wasn't just about my parents' guidance; this part of life just fascinated me.” Sandra's experience echoed this sentiment: “I remember doing activities in school, like density-related experiments—sink or float—and I continued taking science courses throughout high school. I prioritized science, and my experiences at the library really impacted my interest in science.

Parents reported being curious and self-driven from a young age. Tristan shared, “I'm naturally curious. That led me to biology. If I didn't know something, I would find it—either by looking through books or asking others.” Sandra also emphasized the importance of curiosity and curriculum in nurturing

STEM interest in young children. Programs that focus on STEM from an early age help students explore topics they may not have encountered otherwise, providing them with opportunities to engage with STEM communities and develop a love for learning. Teachers and parents can help identify children's interests and guide them to activities and people that will nurture those interests.

These parents also recognized the role of adults in children's lives at this stage of development. Tess shared how her extracurricular activities shaped her path,

Some of my extracurricular activities, like working with animals, put me in touch with biology. I did 4-H and FFA projects, showed cattle, and had a horse. I learned a lot about animals and agriculture. I got involved in both practical and academic ways, and when it was time to go to college, I knew I wanted to study biology, maybe even veterinary science. But the idea of 8 years of school was overwhelming, so I chose to pursue a four-year biology degree instead.

Parents also mentioned the advantages of living in science-rich communities, where exposure to various STEM resources helped them experience science early on. For example, Miranda shared,

My husband was in the army, and I was fortunate to fall into the research field. I lived in Bethesda, Maryland, near the National Institutes of Health, and that opened doors for me. It really spoke to my natural inclinations toward science.

Beyond their own curiosity, parents also noted the influence of passionate teachers. Dan explained,

School played a key part in it. I had teachers who encouraged me to participate in things like Science Olympiad. I started in elementary school and continued through high school. These competitions allowed me to present and share my findings. My teacher supported me, and my parents backed me financially. They drove me to events, but they never helped with my projects. They were clear: you've got to figure it out on your own.

This combination of curiosity, supportive role models, hands-on learning, and a nurturing environment all contributed to the development of these parents' interest in STEM and shaped their

paths toward scientific careers.

Role Models. Parents identified family role models as one of the key influences on their interest in science. They noted that these role models didn't have to be immediate family members but could also be extended family or someone who had a meaningful relationship with the family during their childhood. Moreover, these role models didn't necessarily have to have a STEM career; rather, it was the STEM-related activities they engaged in at home that helped raise awareness of STEM fields. Three out of the four parents interviewed had a family member involved in a STEM field. For example, Tess shared her experience,

Growing up, I was really into animal care. One of my aunts was a veterinary technician. This matched perfectly with my passion for life sciences. From a young age, I combined my love for animals with her career in veterinary technology.

For Dan, Miranda's husband, his interest in STEM developed through working with his dad on home repairs. His childhood environment emphasized a hands-on approach to learning and problem-solving. Dan explained,

Neither of my parents had a STEM background. My mom works as a security administrator, and my dad is in sales. But growing up, working with my dad on home renovation projects—fixing things instead of just buying new ones when they broke—helped me learn a lot. For example, when a lawn mower broke, we'd take it apart and fix it. A lot of it was just hands-on work, like fixing my own car instead of taking it to a shop. It's more of a trade skill, but when you think about carpentry or woodworking, you're constantly thinking about how to make things stronger. That's what led me toward engineering. And with technology, I enjoyed taking apart computers and making them better. It was all about using my hands and making things work, especially when we didn't have a lot of money. That's how I got into it.

Sandra highlighted the significant impact of role models, especially in the context of her stepchildren. Despite coming into their lives later in high school, she was able to encourage them to explore STEM careers. She shared:

One of my stepchildren is in social work, and the other is in aviation. I came into his life when he was in middle school, and I encouraged more science activities, and we had a lot of conversations about science. He eventually switched his major to STEM—he had been pursuing music education but changed to aviation instead.

Expectations & Encouragement. Parents also agreed that having someone who encouraged them to pursue science was incredibly valuable. Having someone who recognized the importance of science and motivated them to start early with hands-on projects, experiments, and thinking beyond what was expected in the classroom made a significant impact. Dan's wife, Miranda, whose parents both had STEM careers, emphasized the importance of developing STEM resilience in children. She believes that pushing students to go beyond the minimum requirements, consistently engaging them in STEM activities, and focusing on specific STEM disciplines fuels their desire to learn. Both Dan and Miranda highlighted that this kind of commitment requires someone who truly believes in fostering an interest in STEM and is dedicated to nurturing it in students. Miranda shared her experience, saying,

I had a bit of a different approach because both my parents were in STEM careers. My dad is an electrical engineer, and he's always fixing things—his passion is taking cars apart. So, math was always emphasized in our house. It was something that was really pushed. My mom, on the other hand, was always into science, particularly biology, and she would encourage us to conduct experiments. If there was something assigned in school that explained a concept on paper, she'd make us find the materials and recreate it practically from start to finish.

Hands-on and Problem-Solving Approach. Parents unanimously agreed that their approach to teaching STEM was hands-on, with a focus on letting children learn through doing while maintaining high expectations. They shared that their own parents or role models had challenged them to figure things out independently. For example, Dan

reflected on learning science through a “nurture vs. nature” lens. He recognized that his upbringing was more aligned with nurture, as he had to figure things out on his own, whereas his wife's upbringing was more rooted in nature, where her parents took a more active role in guiding her through tasks. This highlights how both teachers and parents can apply scientifically supported strategies to foster a love for STEM in children.

The experiences of both Dan and Miranda demonstrate that fostering a passion for STEM is possible regardless of one's background. By challenging children to think creatively, engaging them actively in their learning, and encouraging them to go beyond the basics, we help develop the resilience needed to overcome obstacles and self-doubt in STEM. These parents believe in the importance of fostering problem-solving skills and encouraging children to persist until they solve problems—approaches that can be nurtured both through independent exploration and hands-on involvement. Dan summed up his thoughts on his wife's STEM upbringing, saying,

My wife's upbringing was more about nature, and mine was more about nurture. With my parents, it was always ‘Figure it out on your own.’ If you wanted something, you had to figure out how to get it. But it sounds like her parents were more involved, like ‘We're going to do this together.’

Macrosystem Level

The macrosystem involves the broader societal context, including cultural values, societal norms, and public policies. These larger forces shape the framework in which career decisions are made.

Preschool Curriculum. Parents agreed that the type of preschool they attended played a significant role in sparking their interest in STEM. They highlighted how curriculums that integrated STEM activities, combined with passionate teachers, helped foster a love for science and exploration. Additionally, being in a community rich with STEM resources provided opportunities for deeper immersion in STEM learning. Sandra, for example, shared that the Montessori preschool she attended offered many STEM-focused activities that helped

nurture her interest. She continued, “in early education, I went to a Montessori preschool, and my childcare program took us on library tours twice a week. They had interactive science-related activities at the library, which really sparked my interest in science.”

Rich STEM Communities. Sandra also said, I also grew up in a town with multiple museums, including a state heritage center that now has a science museum for kids. They had some amazing exhibits, like the dinosaur displays, which really pushed me to think more deeply about STEM.

Sandra’s experience highlights the importance of hands-on, immersive learning environments from an early age, where exposure to science and curiosity-driven activities can set the foundation for lifelong interest in STEM.

STEM Practices at Home

We describe the STEM practices that parents reported engaging in to support their children’s STEM learning. Parents identified three broad STEM activities when we asked what they were doing to support their children’s STEM learning after analyzing the interviews; (1) Intentional parent involvement, (2) purposeful selection of STEM resources and, (3) providing STEM related experiences such as spelling and writing related to STEM.

Intentional STEM Parent Involvement

All four parents strongly emphasized their intentional involvement in STEM-related activities at home. They focused on incorporating science concepts into everyday activities and actively helping their children recognize these concepts in real-world contexts. As scientists themselves, they believed in stimulating the scientific process in their children by asking questions and encouraging curiosity.

“All four parents strongly emphasized their intentional involvement in STEM-related activities at home”

Tess shared how she integrates STEM into her daily life,

I’m a huge advocate for getting my daughter into the STEM field. I try to incorporate it naturally. For example, when we go on walks, I point out things in the natural world—like leaves or animal tracks—and we connect what we read in books with what we see in the real world. My husband, who’s a plumber but has a technical degree in industrial maintenance, is great at explaining things too. Our daughter is at the stage where she asks a lot of ‘why’ questions. We give her lots of information without overwhelming her, and we focus on showing her the real science behind it, even if she doesn’t fully understand yet. When we’re working on something, we encourage her to help and see the science in action.

Tess also talked about how she integrates STEM while cooking,

When I’m baking or cooking, she likes to help. I involve her in measuring ingredients, and we talk about what the ingredients do. I ask her to describe things—like the color or texture—so we’re fostering her natural curiosity. She’s a very inquisitive child, and I try not to shut that down. I give her a lot of information before she gets tired of it, but I can see she’s naturally inclined to science. We encourage her to keep asking questions and wondering why.

Parents also reported using everyday home activities, like cooking and nature walks, to teach scientific concepts. In the kitchen, children can learn about measurements, food changes, colors, and math. Nature walks were mentioned as great opportunities to explore questions about the world around them, such as what it takes for a plant to grow. Some parents also used activities like hunting to discuss anatomy and biology. These parents tried to have intentional conversations with their children, guiding them through the science behind their experiences.

Parents also noted the value of purchasing resources to support their children’s STEM development. They discussed actively exposing their children to science-related content, even if it was beyond their current age level. For example, Miranda shared,

For my toddler, we do a lot of science through baking and cooking. I also found an online activity box with monthly STEM projects. We get a subscription box that includes activities like building a volcano. . It's great because I don't have to plan anything—it just arrives in the mail, and we can dive right into the activity. The one we get is from Green Kids Craft, designed for 5-6-year-olds. We also do a lot of outdoor activities. I turn everything back to logic. My husband is a hunter, and we talk about the process, then tie it to anatomy. I'm very intentional about connecting science to real-life experiences. We also have plants in the house, so we talk about why they need water and nutrients to stay alive. He's only three, but he understands that plants need water and sunlight, just like we do.

Parents also used construction and building activities to teach the science of how things are built and how structures get stronger. Many mentioned using Legos and other building toys to encourage problem-solving and observation skills. Dan and Miranda shared how they incorporate these activities into their routine,

We do a lot of building with tracks and Legos. Most of our boys' toys involve building something to get to a specific result. Our younger one, who's about 2, has a mini tool bench where he can drill and hammer. My older son, who's 4, is getting into Legos now. He's learning how to hold pieces, how to count, and how to make things sturdier, like figuring out how to keep things from bending in the middle. Science is a bit harder for them right now because Matt, the younger one, tends to destroy things, but we do basic science experiments. We use food coloring to show how things change, simple experiments like that. For math, we have a lot of number puzzles and games. We also have balancing scales so they can figure out how to balance wooden blocks. We've got a ton of STEM-related books, too.

This intentional approach to STEM at home reflects a shared belief among these parents in fostering curiosity, critical thinking, and problem-solving skills through everyday activities, helping their

children develop a strong foundation in science and other STEM fields.

Purposeful Selection of STEM Resources.

All parents agreed that they were intentional about purchasing materials to support their children's STEM learning at home. These materials included a variety of books, such as encyclopedias, number books, books focused on concepts like more/less, as well as science curriculums, STEM subscription boxes, STEM-focused TV programming, iPad activities, and educational games. They also made it a point to request that gifts for their children be STEM-related. Tess explained,

I buy books with a STEM focus. I also ask people to buy gifts aligned with this goal—things like magnetic tiles, experimental tables, and supplies for running different experiments. As we do these experiments, I try to explain the science behind what's happening. I'm also intentional about the programming I let her watch. I like to pick shows with high-quality content. Right now, her favorite is Helene Wonders Why. Each episode covers a subject and explains it from different perspectives—why things happen the way they do. Teaching science is a strong interest of mine, and I really enjoy it. I still love this stuff, so it's easy for me to choose things that align with that.

Parents also acknowledged that their children were young but emphasized the importance of exposing them to STEM activities early on. They believed that doing so would help them understand their children's personalities and interests, especially if those interests aligned with STEM. By tapping into these interests early, parents felt they could nurture and develop their children's potential. Some parents, like Tess, used high expectations to encourage growth and help determine their child's capabilities. Miranda shared,

He doesn't sit still for books, but I still buy lots of encyclopedia-style science books. For iPad time, we choose science-based activities for him to engage with. We have a YouTube playlist with science videos that he can choose from. We're very intentional about this approach.

Both Dan and Miranda expressed strong support for investing in science-related activities and resources. Miranda added,

For math, we have a number of puzzles and games. We also have balancing scales so they can experiment with things like comparing the weight of wooden and plastic blocks to see which is heavier and how to balance them. We have a ton of books on these topics too.

In addition to their focus on STEM, parents emphasized the importance of giving equal attention to all areas of child development, including language and social-emotional growth. They felt that while preschool often placed strong emphasis on language and social skills, STEM education should receive similar focus. Miranda explained,

I'm an accountant and financial analyst, so I work in math. From my perspective, learning finance is just as important as learning to read. With our kids, we have books focused on numbers as much as we have books on letters. We also put a lot of emphasis on concepts like counting, more/less, and colors, alongside letters.

This approach reflects a holistic view of learning, where all subjects, including STEM, are seen as equally important and worthy of attention and investment.

Challenges of Being in STEM Fields

Parents agreed that obstacles such as gender inequalities, religious beliefs, and lack of preparation can hinder students' interest in STEM and should be addressed early on. By equipping students with the right tools to navigate these challenges, both teachers and parent training programs can help ensure students succeed in STEM fields. Sandra shared her experience of overcoming gender-related challenges in the STEM field. She emphasized the importance of self-belief and hard work for women, noting that this mindset had helped her succeed. She explained,

In my career, I had to pass many professional exams and certifications to gain the same respect as my male counterparts. In some situations, a man's word would be accepted without question, but I had to back up my reasoning to

have it taken seriously. These are the kinds of challenges I've had to navigate.

Sandra encourages girls to focus on what they can control and to push against stereotypes that undermine women in STEM.

To combat negative stereotypes, I always remind people to appreciate women in STEM for their hard work, not for how special they are. It's important to recognize that it's their dedication and persistence that got them where they are. Talk about the journey—how many years of schooling it took them to become professionals, like doctors. Acknowledge the effort and determination it takes to succeed.

Sandra also spoke about the challenges of being a woman in a male-dominated field.

At conferences, there might be 200-300 people, but only about 30 women. Not many people in my profession are at my level, and I've had to adjust to the gender identity challenges that come with it.

Dan highlighted the importance of early preparation for STEM fields, especially to avoid struggles later on. He shared that his parents, who did not come from a STEM background, did not emphasize the level of hard work needed for success in these fields. As a result, he was unprepared for the rigorous math courses he encountered in college.

My parents didn't have a STEM background. They took basic math courses, but nothing that would prepare me for the level of math I needed in college. I failed my first-year calculus course and had to great instructor in calculus 3, I eventually got a B and began to improve.

Dan encourages parents and teachers to emphasize the importance of hard work in STEM.

I wasn't prepared as a first-generation student for how much time I needed to devote to studying. I thought school came easily to me, but I quickly realized that my usual study habits weren't enough. You need to stay on top of your work, or you'll fall behind. STEM requires consistent effort and endurance.

He stresses that students should feel comfortable seeking help from experts when needed.

One parent spoke about the conflict between science and family religious beliefs, particularly regarding evolution,

My family is very religious, so science projects were difficult for me. I remember learning about evolution, and it was a big concern for me because what I was reading seemed to contradict my family's beliefs. I had a lot of questions and had to find a way to work through that conflict.

This situation raises the question of how religious beliefs impact students' STEM development, particularly across different racial, educational, and socioeconomic groups. Understanding the extent to which religious beliefs influence STEM learning and how to navigate such challenges could be crucial in fostering an inclusive and supportive STEM environment for all students.

In conclusion, addressing obstacles like gender biases, lack of preparation, and potential conflicts between science and religious beliefs early on can empower students to succeed in STEM. Providing students with the tools to navigate these challenges, along with support from both teachers and parents, is essential in helping them thrive in STEM fields.

Parent Suggestions for Enhancing STEM in preschool

Parents were asked to share their suggestions for fostering early science interest in children. Many emphasized the importance of providing accessible, hands-on activities that can easily be incorporated into busy family schedules. One key recommendation was for preschool programs to offer pre-made activity packs that parents can take home. These packs would remove the need for parents to plan or gather materials, making it easier for them to engage with their children in STEM activities. Parents expressed appreciation for similar resources available at public libraries, where families can borrow activity kits, take them home, and complete the activities without additional effort.

Parents pointed out that many families may not have the time, money, or resources to seek out STEM activities on their own, so these "plug-and-play" resources would be especially valuable. They suggested that preschool programs consider implementing similar activity kits or creating lending libraries to complement what public libraries are already offering. Additionally, parents recommended that these resources be designed for different age

groups to ensure they're developmentally appropriate.

Another suggestion was for preschool programs to connect children with professionals in STEM fields. Parents emphasized the value of exposing children to role models early on and allowing them to shadow individuals in science-related careers. By doing so, children can make connections between what they are learning and real-world applications, which may help spark their interest in pursuing STEM fields later on.

In terms of teaching strategies, parents encouraged preschool programs to make science fun, engaging, and hands-on. They stressed the importance of creating "aha moments" for children that fuel their curiosity and wonder. Dan shared a few examples of how he fosters his children's interest in science through everyday experiences,

Showing them something that mesmerizes them and asking, 'Do you think this is cool?' then following up with, 'If you thought that was cool, wait until you see this!' Breaking down why things are the way they are is key. For example, my boys love watching construction vehicles at work. When we had our highway repaved, I used that as a teachable moment. I explained how certain materials like asphalt wouldn't stick unless certain processes were followed. There's a lot of math and science involved in road design, and I broke it down in ways they could understand, like how long a road will last based on its construction.

Dan also emphasized the importance of creating hands-on activities that go beyond simple repetition.

We don't just reread books; we recreate projects that allow them to explore concepts on their own, with purpose. For example, when I took Henry for a walk, I asked him to find five acorns. We counted using his fingers, and when he found two, I asked him to drop two fingers and figure out how many were left. It's a simple, rudimentary way of teaching math while integrating nature into the learning process.

These examples highlight the significance of teaching STEM concepts through practical, everyday activities that both engage and educate children, making learning feel more relevant and excit-

-ing. In summary, parents suggested that preschool programs provide accessible, hands-on learning resources, connect children with STEM role models, and encourage curiosity-driven teaching methods. By incorporating these approaches, preschool programs can create a strong foundation for fostering early interest in science and STEM fields.

Discussions & Implications

Parents with STEM resources and expertise play a significant role in shaping their children's learning, both at home and in schools. Macro-level STEM initiatives such as those at the federal, state, and foundation levels are vital in building STEM capacity for both teachers and students. These initiatives are crucial for all students, especially those who lack access to adequate resources and quality instruction. Without proper support, students are at risk of falling behind. Initiatives should aim to train parents on how to engage their children in STEM activities, while also preparing teachers to develop their STEM skills. Additionally, classrooms and curricula must be redesigned to better support STEM learning. Parents involved in the study highlighted the importance of the resources they had access to whether from their own upbringing or through what they now provide for their children. Each child's macrosystem should be enriched with meaningful STEM resources. However, many homes lack the resources needed to provide high-quality STEM learning opportunities. Quality education often requires significant financial investment, and studies show that when schools have sufficient funding for resources and effective teachers, student learning improves (Darling-Hammond, 2004).

Parents in the study emphasized the importance of allowing students time to engage with the scientific process—time to wonder, explore, problem-solve independently, and even have downtime to generate ideas. This suggests that curricula may need to be revised to allow for more open-ended inquiry and exploration in STEM subjects. Parents also need the time and flexibility to work with their children on STEM activities at home. To support this, schools need to implement more student-centered practices, both in the classroom and at home.

Macrosystems must develop new models to measure school success that take STEM learning into account.

Parents also shared how various people, programs, and resources influenced their experiences with STEM. It wasn't just about money; it was about the broader environment, including the teachers they had, the extracurricular activities they engaged in, and the competitions they participated in. This highlights the role of the exosystem, children may not directly interact with higher education programs that train teachers, but they do engage with teachers trained by these programs. When these various groups come together, they create a more diverse and supportive environment for STEM education. Colleges and universities can develop programs that connect teachers and parents with the resources and expertise they need. Efforts should be made to ensure that parents who most need these programs are able to participate. Resources go beyond just financial support, parents should be encouraged to seek out STEM resources available within their communities, such as local libraries, STEM workshops, and educational events.

Parents also shared their knowledge of different STEM tools they use with their children. Parents need access to research and resources that can help them better support their children's STEM learning (Basham, Israel, & Maynard, 2010). Partnerships with local universities and STEM programs can enhance parents' understanding of how to engage their children with STEM activities. These partnerships should help parents identify where to find helpful resources, such as borrowing tools from libraries or learning about new materials online. Building networks for parents to share STEM experiences and lessons learned can be invaluable. These networks could also expand to include business leaders, STEM professionals, and industry personnel who could serve as role models or provide additional resources for students' learning. Additionally, providing teachers, administrators, and school partners with platforms to share instructional ideas and best practices through social networks could help support diverse student needs.

The mesosystem, the interaction between various systems that influence the student is critical in this process. For children to thrive in STEM,

all these systems must align and work together. Parents' STEM teaching at home influences how students engage with STEM at school, while teachers' passion and training shape students' attitudes toward STEM. Efforts should focus on developing or adopting accessible STEM curricula that support all students, both at school and at home. Programs could create STEM materials for parents to use with their children. Curricula should be designed in ways that allow students to engage with the material and demonstrate understanding, and tools should be provided to help parents facilitate this process (Glass, D., Meyer, A., & Rose, D. H., 2013). Both parents and teachers need access to modern instructional tools and professional development opportunities to stay current with the latest educational developments (Edyburn, 2010). Time, commitments, self-efficacy, and resources are the key factors influencing parental engagement in their child's STEM learning (Lee & Nie, 2015). Among these, self-efficacy is particularly important, as it reflects a parent's belief in their ability to positively influence their child's education (Hoover-Dempsey, Walker, Sandler, et al., 2005). Parents without a STEM background may struggle to identify or create at-home activities, often assuming they require costly equipment. Fostering STEM involvement hinges on building confidence to explore projects, even when things don't go as planned. While online resources are available, parents often face difficulty in knowing where to look or how to effectively use the information they find.

Finally, the microsystem which is the direct interactions between the student and their environment, peers, teachers, and family plays a vital role in shaping a student's understanding of STEM. The kind of beliefs, messages that parents share with their children are crucial socializing factors (Mara & Toni, 2020) within these environments. Even though behavioral mechanisms which parents convey their STEM related beliefs are unclear, there is need for studying the quality of parent child interaction in STEM, especially in looking at different backgrounds of families. Teachers and parents must collaborate to provide a meaningful and engaging learning environment. Parent expectations are the most significant factor influencing children's STEM achievements in mathematics (Wang & Yang, 2019). Teacher collaboration on lesson

plans and shared goals can further enhance student learning and foster an educational community that supports STEM growth.

Limitations

The small number of participants should be considered when interpreting the results of this study. Additionally, the researcher both conducted the interviews and performed the study evaluation, which introduces the potential for bias, particularly in the theme analysis. To address this, the researcher cross-checked the interview scripts with the audio recordings, which helped enhance the credibility and validity of the findings (Brantlinger et al., 2005). Triangulation of data, achieved through a literature review and secondary sources, was also employed to verify the consistency of emerging themes. Furthermore, integrating both qualitative and quantitative methods (Leko et al., 2023) could have improved the study design and overall quality. Involving participants in the design phase of the study would also have strengthened the research questions. Further, conducting member checking with participants would have enhanced credibility (Brantlinger et al., 2005).

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Does a Decade Make a Difference? Changes in Pre- and In-service Preschool Teachers' Knowledge of Early Mathematical Development

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ABSTRACT

This study examines whether, in the wake of considerable research since 2007 on the importance of supporting early mathematical development, students in early childhood teacher education programs gained more knowledge in the subsequent decade in this essential area of development. The analysis compares data on pre- and in-service teachers' knowledge of mathematical development gathered during 2008 as measured by the Knowledge of Mathematical Development Survey (KMDS) and compares it to data gathered in 2017-2018. Results showed that while the KMDS mean scores of students in each of the education groups (beginning versus seniors versus math course) statistically differed for each collection year, there was no statistically significant difference between 2008 and 2017-2018 collection years for beginners. However, there was a statistically significant difference between 2008 and 2017-2018 collection years in average scores in the seniors and math course groups, resulting in lower mean scores in 2017-2018 than those in 2008.

KEYWORDS

Early mathematics, early childhood education, preservice, in-service, teachers

In 2007, Duncan and colleagues published an influential longitudinal study across three countries on kindergarten-entry predictors of academic success at third and fifth grade. Controlling for socioeconomic status and mother's education, the authors concluded that early math skills at entry to kindergarten had the greatest predictive power.

Long before Duncan et al. (2007) contemplated such analyses, appeals for increased classroom support for early mathematical development appeared in academic journals (American Educational Research Association, 2005; Clements, 2001; Ginsburg & Golbeck, 2004), at national conferences and meetings (Clements, 2004; Copley & Padron, 1998; National Research Council, 2005),

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in position papers and standards (Administration for Children and Families, 2005; National Association for the Education of Young Children & National Council of Teachers of Mathematics, 2002; National Council of Teachers of Mathematics, 2000) and in myriad of well-regarded texts on education (Baroody, 1987; Bowman et al., 2001; Ginsburg et al., 1998; Ginsburg et al., 2006). In 2001, the National Research Council and Mathematics Learning Study Committee stated, “The responsiveness of preschool teachers to the developmental level of a child in the domain of mathematics, helping to put in place the concepts that are prerequisites to success in first grade arithmetic, can provide the foundation for performance in the school years” (p. 83).

Since 2007, numerous studies have added to the evidence base on the importance of early mathematical development to later academic achievement (Duncan & Magnuson, 2011; Geary et al., 2013; Jordan et al., 2009; Kwok et al., 2021). In 2010, multiple research teams published additional analyses of the 2007 longitudinal study, resulting in similar outcomes with additional subgroup effects (Foster, 2010; Grimm et al., 2010; Hooper et al., 2010; Pagani et al., 2010).

Relatedly, research studies have shown that early childhood programs that increase math skills can have lasting effects on academic achievement (Gormley et al., 2018; Mattera et al., 2021). Researchers have found beneficial effects of quality mathematics curriculum on language and literacy outcomes (Sarama et al., 2012) and large effect sizes of math interventions on early math development (Joo et al., 2020; Wang et al., 2016). Researchers continue to investigate which mathematical skills are important (Fyfe et al., 2019; Nguyen et al., 2016).

Specific to Head Start, studies have found that Black and Latino students may be the recipients of the largest gains in math and language skills among children attending Head Start programs (National Academies of Sciences, Engineering, and Medicine, 2023). However, the authors of these reports express concern that enrollment in early childhood programs does not always result in better outcomes for children (p. 67). The quality of the program, including its curriculum and teachers’ abilities to support learning, has significant effects on child

outcomes.

Prior to 2007, numerous studies examined mathematical activities in early childhood classrooms. Many of these concluded that math activities that involved teacher and child interactions were not common (Ginsburg et al., 1999; Graham et al., 1997; Sarama et al., 2004). As an example, in a study on 26 preschool classrooms (Klibanoff et al., 2006), authors reported that activities around cardinality (including object counting) existed in all classrooms, but verbal counting sequence activities in fewer than 70%. Fewer than 31% of classrooms engaged children in number ordering activities (e.g., “What number comes after seven?”). Significantly, researchers found the growth in math knowledge over the course of the school year was positively related to the amount of math talk in the classroom (pp. 62-64), making the lack of math talk problematic.

Studies published since 2007 also demonstrate concern about the level of support for early mathematical development in preschool classrooms. In a 2021 study of 27 prekindergarten classrooms, results showed that teachers displayed low- to medium-support of early mathematics learning (Cerezci, 2021). In a study of 30 private preschool centers, Bachman et al. (2018) found that 4- to 5-year-old children were exposed to an average of two minutes of math per day.

Concern has also been expressed before and after Duncan and colleagues’ (2007) publication that teacher educators may not have the experience or information necessary to prepare early childhood teachers to provide mathematically rich environments and instruction (Ginsburg et al., 2006). Wright and colleagues (2021) reported that prekindergarten teacher accreditation policies across the United States are not aligned with state standard expectations, with only eight of 64 certification programs including a course on mathematics. An example of the misalignment between standards and teacher preparation programs is the inclusion of a new mathematics standard (Standard 8) and related teacher performance expectations in California (California Commission on Teacher Credentialing [CTC], 2023a). Teacher preparation programs for preschool through 3rd grade in the state must now prepare teachers to demonstrate that they can,

Plan and implement mathematics instruction

appropriate to children's age, grade, and developmental levels (including children's linguistic, cognitive, social and emotional strengths and learning needs) that is grounded in an understanding of California's most current Mathematics Standards and Framework and the most current Preschool Learning Foundations and Curriculum Framework. (CTC, 2023b)

Relatedly, in a recent study across eight states (including two of the states included in this study) that surveyed early childhood education programs in community colleges and universities across each state, Copeman Pettig and colleagues (2018) revealed that faculty reported teaching math content in courses for practitioners who worked with preschoolers at "higher rates than they reported feeling capable of teaching that content" (p. 19). This indicates that teacher educators may have been recruited to teach math courses or encouraged to include more math content in their curriculum and development courses despite their (self-reported) insufficient skill level in understanding and teaching about early math development. In a recent review of early childhood teaching credential programs, Schachner et al. (2023) noted that mathematics teaching was one of the domains with the least amount of coursework.

Given the considerable evidence for supporting early mathematical development, coupled with concerns about insufficient classroom support for that development, is there evidence that we have increased instruction on mathematical development for our pre- and in-service teachers? This study compares data on pre- and in-service teachers' knowledge of mathematical development gathered during 2008 and compares it to data gathered in 2017-2018, a ten-year span. Because teachers also gain knowledge through their everyday interactions in the classroom with colleagues and children, the study also examines whether two or more years of classroom teaching experience influences their knowledge of mathematical development.

The timing of this study is particularly significant given that many teacher education programs were derailed beginning in the spring of 2020, so measurement prior to COVID's interference in instruction is a valuable window on a time when fewer confounds (i.e., absence of in-person observa-

tion and practicum courses and the high frequency of online instruction in early childhood education teacher preparation programs) may have affected instruction. Consequently, teachers who completed some or all of their coursework and/or began their teaching careers during COVID may have experienced differences in preparation for teaching. The instrument utilized in this study is the Knowledge of Mathematical Development Survey (KMDS).

Knowledge of Mathematical Development Survey

In order to provide effective support for early mathematical development, research suggests teachers must develop a) comprehensive knowledge of mathematical content and concepts (Litowski et al., 2020; Ma, 1999); b) an awareness of young children's mathematical development, including developmental trajectories that build on past knowledge and build the foundation for future knowledge (Sarama & Clements, 2009; Turrou et al., 2021); and c) pedagogy that engages children and advances development through the use of meaningful representations and activities (Baroody et al., 2006; Clements et al., 2023; Seo & Ginsburg, 2004). It has also been argued that effective teaching of mathematics also requires respect for the mathematical thinking of the child (Ball, 1993; Ginsburg, 2016). This suggests that curriculum and development courses must include math-specific content and pedagogy, and that teacher educators must possess this knowledge themselves if they are to provide instruction in this domain.

"Effectively supporting early mathematical development in the preschool classroom also requires teachers to attend to children's interests and provide meaningful opportunities for their engagement."

Effectively supporting early mathematical development in the preschool classroom also requires teachers to attend to children's interests and provide meaningful opportunities for their engagement. Mathematical activities in these supportive classrooms are integrated, playful, useful, fun, and culturally inclusive (Stipek & Johnson, 2020). All in all, when combined with the need for deep understanding of mathematical concepts and appropriate pedagogy, this is a steep ask of early childhood teachers and their educators.

Considerable attention has been paid to the mathematics pedagogical and content knowledge of elementary school teachers. Hill and colleagues' (2008) seminal paper on pedagogical content knowledge has been cited over 3000 times. However, to date, the measurement of pre- and in-service preschool teachers' knowledge of mathematical development has been limited. Researchers have used interviews (McCray & Chen, 2012; Rosenfeld, 2012), achievement tests of mathematical pedagogical content knowledge (Dunekacke et al., 2015; Dunekacke et al., 2016), and questionnaires (Anders & Rossbach, 2015). This paper explores pre- and in-service early childhood teachers' knowledge of mathematical development in the year after Duncan and colleagues' (2007) publication and ten years later.

The KMDS was developed in 2007. The 20-item survey includes questions on the verbal counting sequence, object counting, ordinal number words, addition and subtraction, division of sets (fair/equal sharing), and written number symbols and words. Each item requires the respondent to choose which activity typically comes first in development (e.g., Saying the counting words in order from 1-10 [i.e., "1, 2, 3, 4, 5, 6, 7, 8, 9, 10] or Saying the counting words in order from six to ten [i.e., "6, 7, 8, 9, 10]), or mark "Same" or "I don't know." Rationale for selecting the items reflected two assumptions: they should be (a) representative of empirical research on early mathematical development and (b) indicative of activities that can and do occur in preschool classrooms (Platas, 2014). The development of numeracy skills, including those described in the items on the KMDS, represent the most predictive early math skills on later academic achievement (Chu et al., 2015; Duncan et al., 2007; Duncan & Magnuson, 2011; Nguyen et al., 2016).

The instrument validation and reliability were supported through two pilot studies ($N = 20$; $N = 55$) and a validation study with 346 pre- and in-service preschool teachers (citation omitted). The instrument has subsequently been used in several studies as described below.

Cox (2011) surveyed 207 teachers from 51 preschools examining dimensions of math anxiety and knowledge and beliefs about children's mathematical development and classroom mathematics curriculum. The range of preschool classroom experience was 1 to 30+ years, with 89% with 2 or more years. Cronbach's alpha for the KMDS for this sample was .88, with an average score of 11 correct out of 20. Participants' KMDS scores were positively correlated with their beliefs that support for math development is age-appropriate in preschool ($r = .25$, $p \leq .001$) and that math development is an important goal in the early years. There was no relation between the KMDS score and math anxiety by category (high positive affect, high negative affect, or mixed), although there was a trend with higher KMDS scores present in the high positive affect group.

Using the KMDS in a study that examined differences between 98 preservice and 77 in-service preschool teachers' knowledge of and beliefs about early mathematical development, Kim (2013) found significant differences between the KMDS scores ($\alpha = .81$) of the two groups ($M = 12.27$ and 15.80 , respectively; $F(1,173) = 47.79$, $p < .001$) resulting in a large effect size ($\eta^2 = .22$). Teachers in the in-service group all had either a bachelor's or master's degree, and 87% had participated in a professional development course on preschool mathematics in the previous three years.

Lange et al. (2022) utilized the KMDS to measure change in knowledge of mathematical development during 23 preschool teachers' engagement in a STEM professional learning model (control = 24). Results showed a statistically nonsignificant increase of .39 in scores from pretest to posttest. However, comparisons between posttest scores of the treatment group versus the control group resulted in a difference of 1.77 points, an effect size of $d = .45$.

The present study contributes to our knowledge base on teacher preparation programs and their ability to support current and future teachers'

understanding of early mathematical development. In particular, this study examines whether, in the wake of considerable research since 2007 on the importance of supporting early mathematical development in the early years, early childhood teacher education programs have improved instruction over the intervening ten years on this essential area of development. This study uses the KMDS to ask the following research questions:

1. Is there a difference between 2008 and 2017-2018 in knowledge of mathematical development as measured by the KMDS in the following groups:
 - Beginning: Students at the beginning of a post-secondary early childhood education degree
 - Seniors: Students at the end of a BA/BS in early childhood education with no math course
 - Math course: Upper division and master's students at the end or at completion of a 3-unit semester early math development course
2. Does two or more years of experience in preschool classrooms make a difference in the KMDS score within each of the three groups in 2008 and 2017-2018?

Methodology

Data Collection

The study was approved by the author's university Institutional Review Board as well as a community college research review board. Instructors of courses were contacted via e-mail and provided with a description of the study and a request for permission for the author to recruit participants and survey students. In 2008, all instructors contacted granted access. In 2017-2018, two instructors stated insufficient time left in the semester to allow survey administration and two indicated that the majority of the students enrolled were taking the requested class for general education units. The remaining instructors granted access to their classrooms and students. Participants were given a \$10 gift card as an incentive and assured that instructors would not be notified of participation status. Gift cards were funded through a competitive university research mini-grant. Return rate for

completed surveys ranged from 75% to 100% per classroom with an average in 2008 of 97% and in 2017-2018 of 98%. Completion of the surveys took 10-25 minutes. The last page of the survey requested demographic information, including previous and current employment in the field of early childhood education, information on enrollment in a mathematical development course, year of birth, and ethnicity. Students were allowed to choose multiple ethnicities.

Participants

In 2008, 346 participants were recruited through a stratified purposeful sampling method in order to obtain participants with differing experience, education, and exposure to an early math development course. Participants included students from four community colleges in California (seven classrooms), three universities in California (six classrooms) and four MA/BA mathematical development courses in two states (western and eastern United States).

In 2017-2018, 338 participants were recruited through an identical sampling method as 2008. Participants included students from three community colleges in California (three classrooms), four universities in California (eight classrooms), and four MA/BA mathematical development courses in three states (western and eastern United States; three from the same states and systems as in 2008).

For the purposes of these study, students who had a complete score for the KMDS and were categorized as beginning (first- and second-year students enrolled in child development entry courses at community colleges and four-year universities), seniors (seniors with no math course), and math course (graduate master's and undergraduate upper division students who had completed a 3-semester unit math development course) were included in the analyses. To reduce ambiguity and confounds, students who indicated that they had at one time or were currently taking a math course (18 students in 2008 and 11 in 2017-2018) but were not enrolled in the math courses surveyed, were not included in the analysis. Cronbach's alpha for the KMDS for combined years 2008 and 2017-2018 was .76, indicating good reliability.

Demographics

The average student age in 2008 was 27.37 years ($N = 252$; $SD = 9.502$) and in 2017-2018 24.28 years ($N = 268$; $SD = 6.704$). This difference was significant $t(518) = 4.254$, $p = <.001$. Eleven students in 2017-2018 did not provide a birth year.

Students who identified as female in 2008 and 2017-2018 ($N = 236$ and 258 , respectively) far exceeded the number who identified as male ($N = 20$ and 20 , respectively). There was no significant change in gender identification from 2008 to 2017-2018 $\chi^2(1) = .786$, $p = .870$, two sided.

Between 2008 and 2017-2018, the proportion of students across ethnicities changed significantly, specifically in the percentages of Latino, and White students $\chi^2(5) = 51.770$, $p < .001$. Figure one shows the distribution of students in each reported ethnicity for each of the two reported years. The black portion of each bar represents the percentage of students in the beginning group, the medium gray the number of students in the senior group, and

the light gray the number of students in the math course group.

Analyses by group showed that among seniors there was a change in the percentage of Asian and White students $\chi^2(5) = 21.111$, $p < .001$. In the math course groups there was a change in the percentage of Latino and White students $\chi^2(4) = 37.774$, $p < .001$. There was no change in ethnicity in the beginning group.

Results

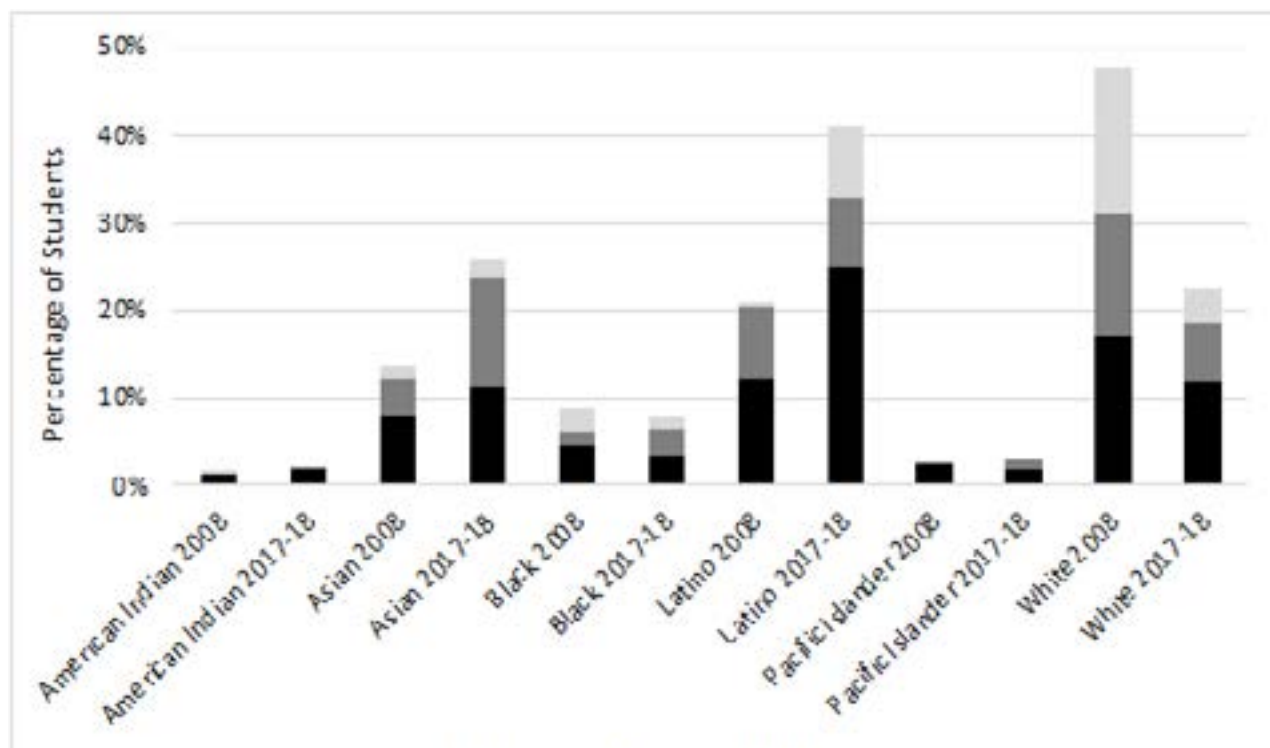
Differences between groups' KMDS scores within years were examined through analysis of variance (ANOVA) with appropriate post hoc tests. Differences between (a) 2008 and 2017-2018 KMDS scores and (b) effects of two or more years of experience within groups in 2008 and 2017-2018 were measured by a univariate analysis.

Research Question #1:

Is there a difference in students' knowledge of math-

Figure 1

Ethnicity in 2008 and 2017-2018



-emational development as measured by the KMDS in 2008 or 2017-2018 between education groups?

Table 1 shows that there were statistically significant differences in 2008 between all groups in the mean KMDS scores, with scores increasing from beginning students to seniors to those who had taken a math course. In 2017-2018, mean KMDS scores increased in the same direction as 2008, with statistically significant differences between the mean scores of the beginning group and the math course group and between the seniors group and the math course group (see Table 1). However, the difference in mean KMDS scores between the beginning and seniors groups in 2017-2018 did not reach significance.

As noted in Table 2, there was no statistical difference between 2008 and 2017-2018 KMDS mean scores in beginning students; there were statistically significant differences between 2008 and 2017-2018 KMDS mean scores in seniors and math

course students.

The significant difference in KMDS scores between 2008 and 2017-2018 in the math course group warranted further analysis, in particular because of the differences in student levels (undergraduate versus graduate) within this group. The range of KMDS mean scores in 2008 in this group was 14.33 to 15.82. In 2017-2018, the range was 12.47 to 15.08. To further explore where these differences arose, ANOVA was used to examine the variance within each year among courses included in the math course group. These 3-unit courses included courses that served only master's students, only bachelor's students, and some that included both bachelor's and master's students. In separate analyses by year, there were no statistically significant differences in the mean KMDS scores between these courses.

TABLE 1

KMDS Score Means in 2008 and 2017-2018 between groups

Group	N	Mean (SD)	<i>p</i> -value	
			Beginning	Seniors
2008 ¹				
Beginning	121	11.18 (3.89)		
Seniors	73	12.81 (2.70)	.002	
Math course	64	15.30 (2.27)	<.001	<.001
2017-2018 ²				
Beginning	149	10.58 (3.56)		
Seniors	84	11.63 (3.42)	.070	
Math course	46	13.54 (2.68)	<.001	.007

1Levene Statistic significant; Tamhane's T2 post hoc test used

TABLE 2

Differences in KMDS Score Means between 2008 and 2017-2018

	N		Mean (SD)		<i>p</i> -value
	2008	2017-2018	2008	2017-2018	
Beginning	121	149	11.18 (3.89)	10.58 (3.56)	n.s.
Seniors	73	84	12.81 (2.70)	11.63 (3.42)	.020
Math course	64	46	15.30 (2.27)	13.54 (2.68)	<.001

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However, in a comparison of mean KMDS scores from all math courses in 2008 and 2017-2018 combined, there were significant differences between Course H and courses A, B and C. Note

that Table 3, with mean scores in descending order, shows that undergraduate versus graduate student status does not necessarily dictate the course KMDS score mean.

TABLE 3

ANOVA by Math course by year and graduate status¹

BA/BS											
Course	(B)/ Master's	Year	N	Mean (SD)	A	B	C	D	E	F	G
(M)											
					<i>p</i> -value						
A	M	2008	17	15.82							
B	B/M	2008	16	(1.59) 15.50	n.s.						
C	M	2008	19	(1.97) 15.26	n.s.	n.s.					
D	B	2017-2018	12	(2.62) 15.08	n.s.	n.s.	n.s.				
E	B/M	2017-2018	9	(1.31) 14.33	n.s.	n.s.	n.s.	n.s.			
F	M	2008	12	(2.74) 14.33	n.s.	n.s.	n.s.	n.s.	n.s.		
G	B	2017-2018	5	(2.81) 12.67	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	
H	B	2017-2018	18	(1.86) 12.47	.001	.008	.012	n.s.	n.s.	n.s.	n.s.
				(3.01)							

¹Levene Statistic non-significant; Bonferroni post hoc test used

Research Question #2

Does two or more years of experience in classrooms make a difference in the KMDS mean scores within each of the three groups in 2008 and 2017-2018?

A combined univariate analysis of students in 2008 and 2017-2018 with and without two or more years of classroom experience for the three student groups showed a statistically significant difference only in those students in the math course group. On average, KMDS mean scores increased by 1.02, for those 2008 and 2017-2018 students who had taken a math course and had two or more years of classroom experience when compared to those who had less or no experience ($t[40.06] = 2.09$, $p = .039$, $\eta^2 = 0.039$). When separated into cohorts, neither 2008 nor 2017-2018 student groups with and without two or more years of classroom experience reached a statistically significant difference in KMDS mean scores.

Discussion

This study was initiated to examine whether there were differences in pre- and in-service teachers' knowledge of mathematical development in 2008 when compared to 2017-2018. Given the extensive research on the importance of supporting young children's mathematical development over the decades, and in particular since 2007, it could be expected that teacher education programs and teacher educators would have provided increased instruction and resources to their students around mathematical development and pedagogy.

The results showed that while the KMDS mean scores of students in each of the education groups (beginning versus seniors versus math course) statistically differed for each collection year, there was not a statistically significant difference between 2008 and 2017-2018 collection years for beginners. However, there was a statistically significant difference between 2008 and 2017-2018 collection years in average scores in the seniors and math course groups. Surprisingly, the senior and math course groups achieved a lower KMDS mean score in 2017-2018 than those in 2008.

Because of the differences between bachelor senior and masters students (i.e., admissions requirements and cost) included in the math course group,

further investigation into whether there was a difference in scores by undergraduate versus graduate programs versus mixed programs was warranted. In an analysis by year and graduate status, with one exception, there was no significant difference between the scores. The one exception was an undergraduate math course that resulted in the lowest of all of the KMDS averages, but was only statistically different from three of the highest performing courses. As indicated in Table 3, KMDS scores did not differ by graduate program status.

In an attempt to explain the differences between 2008 and 2017-2018 in the senior and math course groups, I refer back to Copeman Pettig and colleagues' 2018 study that found that teacher educators across eight states (including two of the states in this study) reported that they were teaching math content in courses beyond their comfort level. While we do not have a comparable study in 2008, it could be reasonable to expect that those who included math development in their curriculum and development courses and/or were teaching math development courses in 2008 were likely to be more comfortable as the pressure to include early math development courses in early childhood education programs had not yet begun in the field, better ensuring that those who taught those courses were more familiar with mathematical development. In support of this notion, of the four instructors teaching the surveyed math development courses in 2008, all had authored journal articles on early mathematical development. Despite a considerable search in 2008, it was very difficult to find early math development courses. Frequently courses were listed in college and university course catalogs but had not been taught for some time. By the time 2017-2018 rolled around, many more math courses were being taught, but only one of the instructors of the courses surveyed had authored journal articles on the topic (with one exception, the 2008 instructors were not teaching that year).

As to the findings that two or more years of pre-school teaching increases knowledge of mathematical development only for those who had taken a math course, it appears that teaching alone does not provide sufficient support for teachers in gaining knowledge of early mathematical development. However, for students who had completed a math development course, it seems that their ability to

put that knowledge to practice serves to increase their understanding of that development even more.

Early childhood teachers want what is best for the children for whom they provide care and education. However, their efforts are stymied by a lack of engagement in early mathematical development and pedagogy during their teacher education paths. Early childhood teacher educators also want what is best for the teachers they prepare. However, they themselves frequently are likewise not well prepared to support or understand mathematical development (Ryan et al., 2014). Researchers examining ways to support children in their mathematical development throughout their education have suggestions. Aligning teacher requirements and preparation (and pay) between preschool and elementary school teachers could provide a path forward. This could engender shared expertise within teacher preparation programs, where faculty understanding of content knowledge, child development, and children's mathematical development converge (Stein & Coburn, 2023).

Efforts are underway in the United States to provide better support for the understanding of mathematical development in teacher education and training programs (Association of Mathematics Teacher Educators, 2017; McCormick et al., 2020). States are beginning to increase their teacher training standards in early mathematics, partly in response to more robust early math standards for young children (California Commission on Teacher Credentialing, 2023a; Math In Pre-kindergarten Through Twelfth Grade Act, 2023; Scherer et al., 2020). We have also learned that providing support for early academic skills like mathematics in preschool without a plan for sustaining that support in later years can result in a failure to support children as they build on these foundational skills (Bailey et al., 2020; Clements et al., 2013; Stipek et al., 2017). This coordination requires both teacher standards and academic standards to be aligned from preschool through high school. Unfortunately, long-standing traditions result in the housing of these policy systems separately (Whitaker et al., 2022). Programs like Head Start that engage in activities that support coordination between these programs and elementary schools have been shown to increase children's language and mathematics skills

(Cook & Coley, 2019). Although perhaps an optimistic perspective, there is growing recognition that acquiring the skills to support children's early mathematical development is an essential outcome of teacher education programs. Perhaps the next decade will make a difference.

“We have also learned that providing support for early academic skills like mathematics in preschool without a plan for sustaining that support in later years can result in a failure to support children as they build on these foundational skills”

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A Head Start on Stem: Investigating the Relationship Of Early Childhood Educator Knowledge and Self-Efficacy

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ABSTRACT

Research substantiates that providing high-quality STEM experiences at an early age is important for young children to become college and career ready (Moore et al, 2016). However, not all early childhood educators are as knowledgeable and/or confident in supporting early STEM instruction. How educators feel, think, and motivate themselves on the job is often influenced by their self-efficacy beliefs. Individuals with strong self-efficacy tend to commit to goals that challenge their current capabilities (Bandura, 1993). Therefore, educators may be more inclined to implement early STEM lessons if they feel knowledgeable and confident. The study used a multiple method design including scales, surveys, and self-reflection logs of 13 Head Start preschool educators over 11-months. The findings suggested a significant increase from pre-survey to post-survey in the participants' self-efficacies for supporting preschool-age children's STEM instruction.

KEYWORDS

Early STEM, self-Efficacy, Head Start, STEM instruction, professional development, early childhood educator preparation, preschool

Why STEM Instruction?

Between 2019 and 2029 in the United States, science and engineering careers are predicted to grow by nearly 10% (Bureau of Labor Statistics, 2020). During this timeframe, new jobs requiring strong skills in science, math, technology, and engineering (STEM), such as science and engineering managers, health care practitioners and technicians, and computer/mathematical scientists are predicted to grow the most. To meet the nation's workforce needs, it is essential that PK-12 educators provide high-quality STEM instruction to positively impact future generations in college and career readiness (McClure et al., 2017). "By providing practitioners with the tools they need to continue facilitating progressive STEM

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learning, we are leveraging a growth-based approach that supports success beyond the early childhood years,” (Frank Porter Graham Child Development Institute, 2022). To address the United States (U.S.) workforce needs, many professional organizations (e.g., National Association for the Education of Young Children (NAEYC), National Council of Teaching Mathematics (NCTM), National Science Teachers Association (NSTA)) through standards, frameworks, guidelines, and position statements advocate for the inclusion of STEM curriculum during the early years.

Why Early STEM Instruction

According to the American University’s School of Education (2020), birth to age five is when young minds are most malleable and capable of developing lifelong thinking skills. During this time-period, young children are rapidly making connections and creating neural pathways in the brain at an unparalleled rate. If these connections are not developed and fostered during the early years; the neural pathways will be lost. To prevent this from occurring, early childhood (EC) educators must support the development of these essential pathways by tapping into young children’s inherent curiosity (NSTA Position Statement, 2014). Young children want to know how things work and why things happen. According to the National Science Teachers Association (2014), on average, preschool-age children ask 100 questions per day. In addition to asking questions, they also have the capacity and propensity to observe, explore, discover, and make sense of the world around them (National Research Council, 2001). The National Association for the Education of Young Children (NAEYC & NCTM, 2010) stated that young children can and should engage in developmentally appropriate science and engineering practices (i.e., making predictions, carrying out experiments, and collecting data) to set the foundation for successful K-12 learning. Throughout these early STEM experiences, young children are not only gaining STEM knowledge but simultaneously developing character traits such as critical thinking and persistence (Sarama et al., 2018). These traits may help young children build foundational background knowledge and interest in STEM over time. Because STEM is inextricably

linked to other disciplines, the experiences may enhance learning and academic achievement in other content areas (American University’s School of Education, 2020). Early STEM investigations and results can be used to launch discussions and elicit written expressions to better understand STEM concepts thus, creating a direct link between science and/or math instruction and the improvement of literacy and language learning (Clements & Sarama, 2014; Sarama et al., 2018). Therefore, when early childhood educators provide intentional and ongoing early STEM opportunities, young children’s academic knowledge can continuously grow and advance, which increases the likelihood of career readiness for STEM-based jobs.

Young children’s STEM readiness

While STEM experiences offer many benefits to young children, there are external factors that can hinder young children’s preparedness and success with STEM instruction. EC educators face several challenges in supporting young children’s STEM learning, including their varied levels of understanding, experiences, and skills (Lange et al., 2019). Young children considered at risk of school failure often come from low-income homes and/or are minorities. Young children considered at risk are often underserved and face barriers that negatively affect their STEM readiness and academic achievement. Recently, ACT scores for underserved students correlate with a cumulative suppressing effect on college readiness (ACT, 2017). Furthermore, a significantly lower percentage of high school students who represent more than one of the underserved student criteria (e.g., minorities, low income) met the nation’s ACT STEM Benchmark (Allen & Radunzel, 2017).

Since 1965, the federal Head Start program has provided care and education services to our nation’s most vulnerable young children, often at-risk for school failure. Examples of risk factors include living in poverty, receiving special education services, experiencing homelessness, and receiving public assistance. Poverty can impact many areas of a child’s life, such as limited access to food, adequate living conditions, health care, and quality care and education (e.g., childcare, preschool). Currently, the maximum income for a qualifying Head Start

family of four is \$31,200.00 (Office of the Assistant Secretary for Planning and Evaluation, United States Health and Human Services, 2024).

Since Head Start educators are charged with supporting these vulnerable populations, steps must be taken to provide the knowledge, skills, and dispositions necessary to promote school and future career readiness for the young children they serve. EC educators and those that support EC educators (i.e., managers, instructional coaches) must be confident and equipped to plan and implement STEM instruction for young learners. Unfortunately, research shows that several factors hinder EC educators' abilities to do so.

EC Educators' STEM Beliefs, Attitudes, and STEM Subject Matter Knowledge

Many EC educators' beliefs and attitudes about STEM are sometimes negative or steeped in feelings of anxiety, possibly due to previous personal experiences. Lange et al. (2019) reported EC educators' lack of confidence as a limiting factor to young children's STEM success, stating that past experiences and current attitudes, often lead EC educators to be less inclined to provide STEM opportunities for young children. To address these past issues and current beliefs, Lange et al. (2019) suggested immersing EC educators in engaging, inquiry-based, and purposeful STEM-based teaching practices. These purposeful experiences should provide opportunities for EC educators to revise their beliefs and begin to cultivate positive attitudes toward STEM instruction so they may be more inclined and equipped to be effective role models during STEM activities with young children.

According to Wilson et al. (1987) content knowledge refers to knowledge specific to the disciplinary concepts, skills, or topics being taught. Kind et al. (2022) reiterated that content knowledge allows educators to be better equipped to design and implement high-quality instruction for any given discipline(s). If educators have a good understanding of content knowledge relevant to the lesson being taught, they can strategically select "instructional strategies appropriate for a student group, justify choices by explaining how these meet student learning needs; and track students' learning and adapt in-class activities accordingly"

(Kind et al., 2022, p. 331). In other words, strong content knowledge allows educators to interpret and respond to learners' needs more effectively and intuitively when teaching in educational settings. Therefore, EC educators should be provided with opportunities to learn content knowledge specific to the concepts and skills they teach to young children within the four STEM disciplines.

For science, educators must have knowledge related to the Next Generation Science Standards (NGSS) (NRC, 2013) Cross Cutting Concepts (i.e., structure and function, cause and effect, and patterns) as they apply to the four domains or Disciplinary Core Ideas (DCIs) (Physical Science, Earth Science, Life Science, and Engineering Technology and Applications of Science). According to the NGSS Standards (2013), educators also need knowledge, skills, and dispositions related to Science and Engineering Practices which emulate what scientists do to investigate the world as well as how engineers design and build systems so that they can effectively teach STEM to young children.

For math, NAEYC along with NCTM (2010) and Clements & Sarama (2014) stated educators must understand the mathematical learning trajectories to provide developmentally appropriate instruction that serves as a foundation for future learning. EC educators, themselves, require foundational knowledge of mathematical concepts such as number and operations, geometry, spatial relationships, and measurement, as well as having background knowledge of essential mathematical process skills (e.g., composing and decomposing, and unitizing) to support young learners' mathematical understanding.

However, having mathematical and science content knowledge does not necessarily make one an effective STEM educator. Educators must also have pedagogical content knowledge (Wilson et al., 1987) to effectively convey the meaning of STEM concepts in a way young children can understand and apply to new situations (Lange et al., 2019). It is recommended that high-quality early STEM experiences incorporate educators' pedagogical content knowledge through use of the following strategies (Lange et al., 2019):

- provide and facilitate hands-on, exploratory learning opportunities
- provide opportunities for young children

to “play” within the STEM disciplines using blocks, games, socio-dramatic play, and/or manipulatives

- ask open-ended questions to make young children think and wonder
- listen, observe, and take anecdotal notes about alternative conceptions and what young children understand about STEM concepts
- use anecdotal notes to tailor and individualize future instruction
- promote creativity and encourage multiple responses or different ways to solve problems or complete tasks even if “incorrect”
- make connections within STEM disciplines and other cross-curricular subjects
- encourage young children to communicate and explain their thinking using evidence
- refer to young children as scientists, mathematicians, or engineers as they design, test, and improve plans or prototypes through trial-and-error experiential learning
- suggest ways to extend the investigation to explore emerging ideas

The importance of early STEM instruction is supported by research; however, increasing knowledge of the STEM disciplines and/or learning how to teach early STEM concepts, using child-centered strategies may be overwhelming and intimidating for many EC educators (Clements & Sarama, 2016; NSTA, 2014), possibly due to past experiences and confidence levels related to one or more of the STEM disciplines.

EC Educators’ Self-Efficacy for STEM Instruction

According to Bandura (1977), self-efficacy is an individual’s belief in one’s ability to reach a specific goal. Unfortunately, many EC educators reported a lack of confidence, having low self-efficacy related to their abilities for designing and facilitating early STEM instruction (Lange et al., 2019). A study by Gerde et al. (2018) found that self-efficacious educators were typically more willing and motivated to incorporate newer approaches such as those often aligned with STEM instruction. However, they also noted when EC educators lacked self-efficacy in STEM, they were less likely to provide STEM expe-

riences for the young children they served. Accordingly, EC educator self-efficacy is yet another factor that may impact young children’s future STEM preparedness and success with STEM.

To increase EC educators’ STEM self-efficacy, it is recommended that they participate in ongoing and interconnected professional development (PD) opportunities that are intentionally designed to grow STEM content knowledge and to model developmentally appropriate pedagogy (McClure et al., 2017). When EC educators partake in PD that models the same hands-on, engaging learning experiences and practices recommended for young children, it can positively impact their pre-existing anxiety and/or attitudes about STEM. For instance, a recent study (Chen et al., 2021) indicated that EC educators who participated in STEM-related activities and/or STEM PD, reported higher levels of STEM self-efficacy. In 2016, Zee and Koomen found that teachers who held positive affective attitudes were more likely to implement and further develop innovative pedagogical beliefs. The findings supported PD opportunities for educators as an effective means of increasing self-efficacy and promoting STEM instruction.

Professional Development and Early STEM Instruction

There are many research-based recommendations for designing and implementing quality STEM instruction. According to Sarama et al. (2018), effective PD opportunities should support EC educators in three areas including (1) learning developmentally appropriate STEM concepts and practices; (2) becoming familiar with pedagogical strategies that strengthen early STEM learning; and (3) applying strategies to promote inclusiveness and cultural responsiveness to form home connections with families, caregivers, and the community. However, PD should not be done using a “one and done” approach (Darling-Hammond et al., 2017). To be effective, PD opportunities for EC educators should be ongoing, connected to their personal teaching practice, and/or instructional setting, and tailored to the EC educator’s changing needs (Desimone, 2009; Sarama et al., 2018). When designing PD opportunities for EC educators, research suggests maximizing the benefits by including one or

more of the following (Sarama et al., 2018, p. 4):

- one-on-one coaching
- well-structured professional learning communities or cohorts (i.e., a group of educators who participate in multiple PD opportunities together over time)
- opportunities to rehearse, analyze, reflect on instructional practice, and set goals
- engagement of teachers as leaders who facilitate early STEM PD activities and provide a range of supports to their colleagues.

Relatedly, Blonder and Vescio (2022) found that PD opportunities with formative feedback from peers, coaches, and/or instructors, as educators applied what they were learning, increased educators' self-confidence. A conceptual framework for effective PD suggested by Desimone (2009) indicated that active learning, coherence, and collaboration are three essential components of PD. During PD teachers engaged in active learning practices like observing, receiving feedback, and analyzing student work whereas coherence ensured alignment with teacher knowledge, teacher beliefs, and student needs. To foster collaboration during sustained PD, teachers within the same grade or subject build a supportive professional community. Furthermore, the benefits of PD opportunities were often compounded when teachers engaged in self-reflection and goal setting based upon formative feedback (Desimone, 2009; Melton et al., 2019; Miller et al., 2019). The primary purpose of the study was to determine how PD opportunities specifically designed to support participants' knowledge for planning and implementing STEM with preschool-age children and incorporating research-based methods/approaches (e.g., self-reflection, goal setting), impacted EC educators' self-efficacy and perceptions of early STEM instruction. There were two main research questions:

- 1) What impact does a targeted professional development program have on early childhood educators' self-efficacy of STEM teaching?
- 2) What impact does a targeted professional development program have on early childhood educators' planning and implementation of STEM instruction?

Methods

Participants

This study used a sample of Head Start educators, all enrolled in the same online graduate-level courses and engaged in an ongoing, collaborative early STEM project at a midwestern university. The project provided a cohort model of instruction with four online graduate courses over a span of one year: two with a concentration on early STEM, one on improving instruction in early math, and one focused on deeper understanding of developmentally appropriate practices in early childhood education. The Primary Investigator (PI) for the study invited the Head Start educators by email to participate in the study. Initially, fourteen Head Start educators consented to participate, however one chose to withdraw prior to pre-survey completion.

The thirteen participants were white, English-speaking females, working in Head Start programs as preschool classroom teachers (54%) or managers/coaches supporting preschool classroom teachers (46%) in the same midwestern state. Most participants fell within the 26 to 35 year age range (54%), with 31% of the participants in the 36 to 45 age range. All participants held a bachelor's degree and for the majority (77%), the degree was in early childhood education (ECE). Those without a bachelor's degree in ECE had degrees in related fields (e.g., elementary education, social services). All participants (100%) were working in or supporting teachers working in preschool classroom settings. On average, participants had seven years of experience working directly with preschool-age children (e.g., ages 3-5) with a range of 3 to 17 years of experience. At the time of the post-survey, only twelve participants were retained. Table 1 provides a summary of participants' demographics.

Table 1*Participant Demographics*

Characteristics	Participants (<i>N</i> = 13)
Employment Role/Title	
Classroom Teacher	7
Management (non-coaching)	4
Coach	2
Age Range in Years	
19 – 25	1
26 – 35	7
36 – 45	4
46 – 55	1
Gender	
Female	13
Race	
White, non-Hispanic	13
Language Preference	
English	13
Highest Level of Education	
Master's Degree (Early Childhood)	1
Bachelor's Degree (Early Childhood)	9
Bachelor's Degree (Other)	3
Average Years of Experience	
Working with Young Children	
Ages Birth to Three	3
Ages Three to Five	7
Ages Birth to Five	7
Ages Five to Eight	2

Demographics

Demographic information collected related to the participants' age, gender, race, primary language, age range of children served, type of classroom (e.g., full year), employment (e.g., job role, work schedule), additional/outside employment (e.g., summer employment), experience working with young children, highest education level achieved, and licensure/certifications.

Measures

This study used two main sources of information to explore participants' behaviors and self-efficacies associated with planning and implementing STEM content for preschool-age children. A pre/post survey was completed to assist in answering research question one, gathering quantitative data related to participants' change in self-efficacy for teaching early STEM. The pre-survey, which was administered after participants consented and prior to beginning a graduate-level college course specific to the cohort, collected both demographic and self-efficacy data. Eleven months after the pre-survey and near the completion of the study, a post-survey collected self-efficacy data. The post-survey used the same self-efficacy survey questions previously asked in the pre-survey. STEM self-reflection logs were completed to assist in answering research question two, gathering quantitative and qualitative data for participants' planning and implementation of early STEM instruction. STEM self-reflection logs were used to collect perceptive data about how the participants implemented and/or promoted STEM learning activities in preschool classrooms.

EC Educator Self-Efficacy Scale (ECESES) for supporting preschoolers' STEM development

The ECESES-STEM was developed for the current study by examining two existing self-efficacy scales. The Coaching Efficacy Scale (Feltz et al., 1999), a 24-item scale, focused on coaching individual athletes and/or athletic teams, whereas the Science Teaching Efficacy Belief Instrument (Riggs & Enochs, 1990) used a 25-item scale to determine elementary teach-

er self-efficacy for teaching science. Both scales were considered in the development of the ECESES-STEM to assist with wording of questions and scale format. The ECESES-STEM included a total of 40-items, 10-items in each of the four STEM disciplines (i.e., science, technology, engineering, math). Wording was consistent across each of the four STEM disciplines, however each subset of ten focused on one STEM discipline. For example, item one for the Science discipline stated, "I believe I can effectively use observation/documentation to find out if a preschooler is in need of individualized support in science," whereas item one for the technology discipline replaces the word "science" to "technology". The scale was rated on a 5-point Likert scale asking participants to indicate the confidence with which they felt each statement to be true (1 = Not Confident to 5 = Extremely Confident). The stem for each item was "I believe I can..." (e.g., I believe I can effectively use observation/documentation to find out if a preschooler is in need of individualized support in science). Overall mean ratings were calculated for each of the 40 items. In addition, overall mean ratings were calculated for each of the four STEM disciplines. Mean ratings between 4 and 5 suggested participants had higher perceived confidence for planning and implementing content for preschool-age children. Mean ratings of 3 to 3.9 suggested moderate perceived confidence, and mean ratings of 1 to 2.9 suggested lower perceived confidence.

The ECESES-STEM has not been validated for use with EC educators; however, the PI conducted a pilot study of the ECESES-STEM with three-experienced EC educators not affiliated with this study prior to its use in the current study. The pilot group completed the scale via Qualtrics and provided written feedback via email to the PI regarding: ease of use, length of scale completion time, and general feedback on the wording and clarity of questions. The pilot group feedback was utilized to fine-tune the survey prior to implementation by establishing an anticipated completion time, and rewording instructions to increase clarity. A copy of the ECESES-STEM is available upon request.

STEM Self-reflection Logs

The STEM self-reflection logs used in this study were a modification of logs available from the Friday Institute for Educational Innovation (Friday Institute for Educational Innovation, 2012). The logs were modified to align with research question two and for use with preschool educators rather than elementary teachers. The logs were used to collect perceptive data about how the participants implemented and/or promoted preschool STEM learning activities over time. Six monthly self-reflection logs were emailed to the participants as linked Google forms to gather data about early STEM lesson applications in the preschool work setting and establish goals for future early STEM instruction. A link to the log was emailed to each participant on the 20th of the month, followed by one email reminder on the first day of the subsequent month. The self-reflection logs used five open-ended prompts (e.g. Something I tried this month to promote STEM learning through the use of indoor environment was...). The three subsequent prompts asked about early STEM learning through the outdoor environment, direct instruction, and family engagement. On the final question, participants were prompted to share their feelings and thoughts regarding the implementation and/or outcomes of early STEM instruction with preschool-age children. A copy of the STEM Self-Reflection Log is available upon request.

Procedures

Recruitment and informed consent

The PI for the current study emailed the potential participants, explained the study, and obtained informed consent. Once informed consent was obtained, participants were prompted to complete an online Qualtrics survey that included a collection of demographic information and self-efficacy for planning and implementing STEM content for preschool-age children (pre-survey).

ECESES-STEM survey

The demographic survey and self-efficacy scale were generated using Qualtrics (2021) software, and participants utilized their own computer and internet

connection to complete the survey and scales within the stated 2-week time period. The completed surveys provided information about participant demographics, as well as their self-efficacy data for planning and implementing STEM content for preschool-age children.

ECESES-STEM Survey Scoring

Individual mean ratings were calculated for the ECESES-STEM pre-survey and post-survey. Additionally, mean ratings from the pre and post surveys were calculated for each of the 40-items and the four STEM disciplines (i.e., science, technology, engineering, math).

STEM Self-reflection Logs Review

Each of the six individual participants' self-reflection logs were combined into one transcript, for a total of six transcripts (i.e., February, March, April, September, October and November). Using an inductive coding method, two independent observers completed a first cycle review of each transcript to establish emerging codes. After reviewing the self-reflection logs' transcripts, the two coders met to create a codebook. A total of two self-reflection logs' transcripts (30%) were randomly selected for a check of interrater agreement. The same two independent observers coded the randomly selected self-reflection logs' transcripts and were required to be 80% reliable (Salkind, 2006) across all previously identified codes. Interrater agreement scores below 80%, prompted mutual review of the code definitions and consensus for coding those transcripts. Individual codes had interrater agreements of 80% - 96%, except for three; teacher responsiveness (29%), hands-on exploration (55%), and teacher growth (56%). After establishing consensus of the codes and updating the codebook, the two observers completed a second and final independent review, with each observer coding half of the self-reflection logs' transcripts.

Analysis

To allow for a richer understanding of the participants' knowledge, skills, and self-efficacies for plan-

-ning and implementing developmentally appropriate STEM activities for preschool-age children, a multiple methods research design (Morse, 2003) was used. First, quantitative data from the self-efficacy scale pre and post ratings were collected and summarized. This data provided information about participants' perceived confidence for planning and implementing STEM content for preschool-age children (e.g., self-efficacy pre and post survey data).

Specifically, data was analyzed for the ECES-ES-STEM scale completed by the participants at two different times (pre and post) for this study. The results from the pre and post surveys represented participants' perceptions of their self-efficacy for planning and implementing STEM learning for preschool-age children. An overall mean rating was calculated for each pre and post survey. In addition, mean ratings were calculated for each of the 40-items across the four STEM disciplines.

A visual inspection of the mean scores was used to examine how Head Start preschool educators' self-efficacies differed from pre-survey to post-survey. The four STEM disciplines pre and post-survey means offered insight to the participants' self-efficacy levels for 1) identifying individual needs of preschool children, 2) recognizing age appropriate skill development, 3) evaluating skill development, 4) facilitating effective activities, 5) providing individualized supports, 6) providing independent learning opportunities through use of the indoor and outdoor learning environments, 7) promoting content through everyday situations and daily routines, 8) involving parents in the learning process, 9) answering young children's content questions, and 10) teaching STEM content as well as they do other content areas (e.g., language, literacy, creative arts). In addition, a t-test was used to compare the mean scores and to examine whether the change was statistically significant.

Next, quantitative data from the coded STEM Self-Reflection Logs' transcripts was collected and analyzed. The frequency of each code was determined by adding up the number of times each associated code was used over all six combined transcripts. The most frequently mentioned codes were identified from the data. In addition, qualitative data from the transcripts was analyzed through visual inspection, providing evidence for understanding and describing the 'participants' planning and implementation

of early STEM instruction over the 11-month time frame.

Results

Self-Efficacy for Supporting Preschool-Age Children's STEM Development

Mean ratings from the ECES-ES-STEM pre and post surveys were used to evaluate participants' self-efficacy for supporting preschool-age children's STEM development. The scale was rated on a 5-point Likert scale asking participants to indicate the confidence with which they felt each statement to be true (1 = Not Confident to 5 = Extremely Confident). Table 2 provides the mean ECES-ES-STEM pre and post survey scores categorized by the four STEM disciplines, along with the overall pre and post survey means. At both pre and post survey, participants reported higher confidence levels in the STEM disciplines pertaining to science and math in comparison to technology and engineering.

Pre-survey

On the ECES-ES-STEM pre-survey, mean scores ranged from 1.3 to 4.2. Participants reported the highest confidence level at for three criteria, all within math instruction ($M = 4.2$): *using observation/documentation to identify individual supports; facilitating activities to support development; and promoting skill development through everyday situations/daily routines*. The lowest levels reported in the pre-survey included confidence for *teaching one specific STEM discipline (of the four) at the same level of confidence as for non-STEM disciplines such as literacy*. The mean scores ranged from 1.3 (engineering) to 2.4 (math).

Post-survey

Post-survey mean scores ranged from 2.5 to 5.0. At the time of the post-survey, the highest confidence level ($M = 5.0$) was for facilitating activities to support development for math. As shown on the last post-survey item, lower perceived confidence levels still existed for teaching technology at the same confidence level as other subjects ($M = 2.6$) and teaching

Table 2										
Mean Ratings for 1 st and 2 nd Completion of the Early Childhood Educator Self-Efficacy Scale for Supporting Preschool-Age Children's STEM Development										
Scale		Mean Rating Pre-Survey					Mean Rating Post-Survey			
		S	T	E	M		S	T	E	M
ECESES-STEM		3.7	3.2	3.0	4.1		4.6	4.3	4.2	4.6
ECESES-STEM Overall Means		3.3					* 4.3			
Prompt: "I believe I can..."										
use observation/documentation to identify individual supports.		3.7	3.5	3.2	4.2		4.4	4.3	4.3	4.5
recognize age-appropriate development.		3.5	3.2	3.0	4.0		4.6	4.3	4.1	4.7
evaluate age-appropriate development.		3.5	3.2	2.9	4.1		4.5	4.2	4.3	4.5
facilitate activities to support development.		3.9	3.2	3.0	4.2		4.7	4.5	4.3	5.0
provide opportunities for those in need of additional support.		3.7	3.2	3.0	4.0		4.7	4.3	4.3	4.5
promote independent opportunities through learning environments.		3.8	3.3	3.2	3.9		4.6	4.3	4.4	4.6
promote skill development through everyday situations/daily routines.		3.8	3.2	3.2	4.2		4.7	4.3	4.3	4.6
involve parents in their child's skill development.		3.5	3.1	2.9	3.7		4.2	4.1	3.9	4.3
answer children's questions.		3.8	3.3	3.0	4.3		4.6	4.3	4.0	4.6
teach _____ as well as other subjects. (e.g., science, technology, engineering, math)		2.0	1.6	1.3	2.4		3.2	2.6	2.5	3.2
Note. The scale is measured on a 5-point Likert scale; EC = Early Childhood; ECESES-STEM = Early Childhood Educator Self-Efficacy Scale for Supporting Young Children's STEM Development; S = Science; T = Technology; E = Engineering; M = Math; * <i>p</i> < .0001.										

engineering as well as other subjects ($M = 2.5$). The lowest yet still moderate to higher confidence levels at post-survey were shown for involving parents in their child's engineering skill development ($M = 3.9$) and teaching science and math as well as other subjects ($M = 3.2$). See Table 3.

Confidence levels across all four disciplines increased from pre-survey to post-survey, with a statistically significant difference in the overall ECSES-STEM means ($M = 3.3$; $M = 4.3$). The results from the pre-survey ($M = 3.3$, $SD = 0.5$) and post-survey ($M = 4.3$, $SD = 0.5$) indicate that the participants' self-efficacies for early STEM changed, $t = 25.71$, $p < .0001$. See Table 3.

Implementation of STEM in preschool classrooms

The 13 participants were asked to self-reflect six times over the 11-month timeframe about their implementation and/or promotion of STEM activities in preschool classrooms. Data from the self-reflection logs revealed six common themes including: 1) Implementation of Early STEM Activities, 2) Child Responsiveness, 3) Teacher Growth, 4) Teacher Responsiveness, 5) Sharing with Colleagues, and 6) Hands-on Exploration. The frequency of each theme was determined by the number of times the participants mentioned each theme within the combined self-reflection logs' transcripts, as shown in Table 4. Qualitative data for each of the six themes follows in rank order of the frequently mentioned themes.

Table 3

Overall Mean for Pre-Survey and Post-Survey Scores on the ECSES-STEM ($N = 13$)

Survey	Mean	Standard Deviation	t-value
Pre-Survey	3.34	0.54	
Post-Survey	4.26	0.50	25.7093

Table 4

Themes: Number of Times Mentioned in Combined STEM Self-Reflection Logs Transcripts

Theme	Number of Times Mentioned
Implementation of Early STEM Activities	78
Child Responsiveness	75
Teacher Growth	67
Teacher Responsiveness	44
Sharing With Colleagues	42
Hands-On Exploration	35

Theme 1: Implementation of Early STEM Activities. Participants most frequently mentioned implementation of planned early STEM activities through direct teaching and/or use of the indoor and/or outdoor environments. This theme was mentioned by participants 78 times within the combined self-reflection logs transcripts.

Building and engineering activities. The participants commonly described the implementation of early STEM activities in which young children built and engineered structures. For instance, one EC educator shared that small groups of young children used provided materials to build structures stating, “Many of the children used the materials to build and engineer different structures based on their own developmental levels.” Other participants described how they implemented early STEM activities in which the young children engineered and built houses, towers, musical instruments, water pipes, and sprout houses to plant seeds.

Outdoor STEM activities. Accounts of early STEM implementation went beyond the classroom setting with many participants purposefully planning and providing outdoor STEM experiences. One EC educator described the use of “STEM boxes or bins” [a box, tub, bin, kit containing purposefully provided materials] so the young children could readily explore outdoors. Two examples of young children using an outdoor STEM box included using materials to experiment with how long it takes snow to melt and to see what kind of food ants prefer eating.

Additionally, participants implemented early STEM activities outdoors. One described, “...building ramps on the playground using different materials to zoom matchbox cars down.” Another participant connected early STEM to their study of physical science simple machines unit by encouraging the young children to find different machines around their playground. This outdoor exploration of simple machines led to the implementation of an indoor investigatory early STEM activity where young children learned more about how a teeter totter worked as a machine. “The children worked in small groups indoors to build teeter totters and find ways to make it [the teeter totter] balance using plastic counting bears” as weights.

Early STEM discipline activities. Many participants mentioned implementation of early STEM learning opportunities directly related to particular STEM disciplines such as science or math. Instances of implementing science activities were most frequently mentioned in participants’ February, March, and October self-reflection logs. For instance, one EC educator described taking young children on nature walks and having them use magnifying lenses to explore and describe their surroundings during their walk. Several participants described how nature walks led to discussions about life science topics collectively including leaves, bark, tree beans, pumpkins, and pinecones. Participants described implementing physical science activities such as light and shadows, sound, magnetism, density, and properties of matter. One EC educator described a physical science activity in which young children took rhythm sticks outdoors to try to find “instrumental objects” [objects that make sounds when moved or manipulated] and then compared the sounds the objects made. Another participant shared how they implemented water play with a sandbox creating a “mud kitchen” as a means of investigating the physical science concept of properties of matter (e.g., liquids, solids, and mixtures). A third EC educator shared how the students explored physical science with magnets.

Just last week we spent time identifying the kind of things the magnet would or would not stick [to] and coming up with the reason why that is. We also explored a little with the magnetism in the sense that the magnetic pull can go through things such as a piece of paper, book, and table to make the paper clip move around.

Implementation of math activities was most frequently mentioned in the participants’ self-reflection logs during the months of September, October, and November. Reported instances of implementation of early STEM activities highlighting math concepts included subitizing, graphing, using 10-frames to create numbers, and geometry/shape-related activities. Incorporating math talk and using activities from the Learning Trajectories website (Clements and Sarama, 2017/2019) were commonly mentioned. One EC educator described planning and implementing a large group activity in which they “drew two shapes and

the children identified and discussed their attributes, similarities, and differences.” Another EC educator described having young children create shapes with various materials, stating, “the children composed different-shaped bubble wands and tested different types of bubble solutions.” Yet another EC educator incorporated shapes into a unit about clothing.

Using stories to launch early STEM activities.

Several participants mentioned using young children’s stories to introduce or enrich early STEM experiences for large group activities or in conjunction with learning centers. Two participants described a project in which young children used different materials to build a house after reading the story, *The Three Little Pigs*. Another EC educator described using a different version of the traditional story,

We read the story, The Three Little Super Pigs. Afterwards, I asked the kids what they could build to keep the wolf in. First the kids drew their building plan and then they got to build it [their planned building].

Several participants mentioned reading children’s books aloud during large group times and then implementing related early STEM activities during small group time and/or center time. One EC educator shared,

One of my recent favorites involved reading the children’s book, After the Fall: How Humpty Dumpty Got Back Up Again (Santat, 2019) in a large group setting and then challenging my students to work in small groups to create a safer wall for Humpty Dumpty using Legos and other materials.

Another EC educator referenced, *Dreaming Up: A Celebration of Building* (Hale, 2012), stating, “Earlier this month we talked about towers and how we think they were built. The kids then explored with building up. It has taken off. Students loved it.” Yet another EC educator read the story, *10 Sparkly Snowflakes* (Tales, 2017) and had the young children go outdoors to collect snowflakes so they could look at them through magnifying glasses. This EC educator shared how the young children noticed and discussed, “the unique patterns of each snowflake before making their own snowflakes using various mediums.”

Theme 2: Child Responsiveness. The theme of

Child Responsiveness was mentioned by participants 75 times within the combined self-reflection logs transcripts. *Child responsiveness* conveyed the participants’ perceptions of how the young children responded to planned/implemented early STEM activities, learning environments, and/or materials provided. Descriptions included but were not limited to: (a) the children’s enjoyment; (b) finding multiple ways to solve problems or complete challenges; and (c) social interactions, discussions, and learning.

Children’s enjoyment. The words, “fun” and “enjoyed” frequently emerged in the participant’s self-reflection logs when describing young children’s responses to planned/implemented early STEM activities. Three examples follow, “Seeing how real snowflakes are all different was such a fun activity for all involved,” and “It was a lot of fun- students really loved it and learned a lot!” Another participant described creating a song,

This [musical STEM activity] was super FUN! We somehow created the pattern with floor sticks while playing a pattern. One of my friends [child] made the connection to a song, and belted out, We will... we will...rock you!

Instances of participants describing young children’s enjoyment follow, “The kids really enjoyed making their pond,” while another EC educator stated, “I did my final project from my STEM class [developed during one of the courses completed as part of the study], the kids really enjoyed all the extra things in the centers.” Other participants shared that the young children enjoyed subitizing math games, graphing activities, mathematical learning trajectories activities, exploring with funnels and sand to figure out why wet sand gets stuck, yet dry sand goes through, and predicting and testing items to see which sink or float. Several participants shared that the children enjoyed the early STEM activities, and the children wanted to do the activities again.

Children’s participation and engagement. Many of the participants described the young children’s active participation and engagement during early STEM activities. One stated, “Children were engaged, responded to the question she [educator] asked, and they were excited to predict what was going to hap-

-pen.” Another EC educator reported feeling “amazed” as she watched the young children so engaged in working through the problem. Yet another EC educator described the young children as being “engaged and wanting to learn more about trees” and being “engaged when they were actively exploring the room and making discoveries of what a magnet will stick to.” Two additional participants stated, “I love that they [children] got so engaged and they [children] were in so much control of their learning” and “I am in a 6-hour classroom with 25 students who have numerous disabilities, and all of the students absolutely love STEM time.”

Multiple ways to solve problems or complete challenges. Participants mentioned the young children wanting to solve problems or complete STEM challenges. One EC educator shared, “Some of them [children] even got excited when their towers fell because they were able to build it better.” Another EC educator stated, “the children really had to think about and discuss how they wanted to design and build the roof of their house in terms of size and shape [flat or inclined].”

Several participants described the young children’s use of imagination during open-ended STEM activities. For instance, an EC educator described, “the children had fun finding new ways to use the STEM materials through ongoing exposure and opportunities to use them.” Another EC educator described the young children using their imagination during play,

The students were pretending that the swings were rocket ships and they were on them and were flying to the moon. Then when they got inside, they started building ‘rocketships with Legos.

Yet another EC educator shared, “It was absolutely awesome to see what my preschoolers came up with and listen to them explain their thought process about why their wall was safer.”

Social interactions, discussions, and learning. Several participants’ self-reflection logs included descriptions of young children working together and interacting with one another. The young children were frequently described as working in small groups and talking to one another as they solved problems and

completed early STEM activities. Several participants cited instances of young children making suggestions about how to use the materials and/or building upon their peers’ ideas and designs. Additionally, participants mentioned that the young children asked and answered questions while learning from one another. One EC educator wrote, “It [the STEM activity] increased conversations about the topic and students asked questions we hadn’t even thought to talk about previously,” and another EC educator shared,

[One] little guy had never thought to build [the tower] against a wall so with the right questions and inquiries, it became his idea. The next thing the little guy knew, he had several friends with him trying to build a tower as high as they could against the wall.

Theme 3: Teacher Growth. Participants described Teacher Growth 67 times within the combined self-reflection logs transcripts. Reflections related to Teacher Growth related to: (a) increased self-efficacy; (b) collaboration; and (c) other benefits of the study in terms of professional development opportunities.

EC educator self-efficacy. Many participants shared positive or affirmative statements regarding their self-efficacy or confidence related to early STEM implementation across the six self-reflection logs. Many described personal growth and/or feeling more confident. For instance, one EC educator described STEM implementation as “feeling natural” in her classroom and others described STEM implementation as becoming easier with experience. . One EC stated, “In the past, it was always easy to overthink implementing science and math activities or even trying to implement technology and engineering.” Another EC educator shared, “I love how much easier it is getting to implement STEM into day-to-day activities! I see STEM teaching opportunities in places where I hadn’t thought of before.”

“One EC educator described STEM implementation as “feeling natural” in her classroom and others described STEM implementation as becoming easier with experience.”

Four different participants shared, “It’s still taking some adapting to spending more time on projects and lessons, but it is getting so much better!” “I love doing different STEM activities all day long and I have learned to implement it as part of my lesson that it has just become such an easy transition.” “I am feeling that what I have learned has made me a better teacher and supervisor because now I am able to teach my staff as well which make me proud,” and, “I need to slow down a little because I get so excited and I want to implement everything all at once - I constantly remind myself this is not the most effective way to promote STEM learning.”

Collaboration. Participants often stated feeling more confident using a team approach to early STEM instruction. One shared, “We’re learning together as a team to break lessons and topic down more and spread it out so we can really dive into it.” Another stated,

My team has been printing off many of the lesson ideas to have for future reference and have been working on implementing more STEM based lessons. We have also been adding more STEM materials to our classroom and exploring them along with the kids to kind of learn as we go.

Yet another shared,

This was a wonderful opportunity for Head Start Staff. The STEM team [study team] has provided us with so much knowledge, practical approaches, experiences along with a wealth of resources that we can make our programs STEM Rich!

Benefits of professional development opportunities related to the study. Many participants identified early STEM materials, resources, and practices/strategies shared within the college courses they completed as part of the study as being beneficial to their professional growth and development. Participants’ responses included, “I feel like I’m getting more and more resources with every class [course taken as part of the study]” and “I appreciate that we’ve gained so many ideas through these classes [courses provided as part of the study] to share with children.” Another stated,

I am really enjoying the textbook, specifically the STEM books. Since graduating college almost 10

years ago, a lot has changed! I think I understand STEM better as it being described more as an approach-all day everyday- rather than one solitary experience.

Participants also shared the benefits of the graduate-level college courses in terms of camaraderie provided as part of the overall study. The final December self-reflection logs contained the following participants’ comments, “I am absolutely loving all that I am learning, along with the collaboration with instructors and classmates - this has been incredibly valuable, and I am beyond grateful!” Another EC educator wrote,

As this is my last reflection log, I cannot begin to explain how invaluable our coursework, our professors, the people in our cohort has been to me. I feel so grateful that I will be able to provide more meaningful, engaging STEM lessons in my classroom, which will benefit my students for years to come.

Other participants described future collaboration, including this quote,

We are working to plan a family STEM night at our next parent meeting! We’re hoping to set up some fun and engaging STEM activities for parents to engage in with their preschoolers. I have so many ideas I have gleaned from our classes.

Theme 4: Teacher Responsiveness. Participants’ STEM self-reflection log transcripts also contained descriptions of and/or perceptions of how the EC educators responded before, during, or after adult-child interactions, activities, or using learning environments. This theme emerged 44 times within the combined self-reflection logs transcripts.

Many self-reflection logs entries conveyed a sense of teacher enjoyment about using early STEM activities with the young children. For instance, the following quotes were shared by various participants: “I am having a blast teaching the [STEM] lessons!”, “I have actually enjoyed bringing the math lessons [shoe graph and math game] into the classroom.”, “Students and staff enjoyed it and were really engaged!”, and “Teachers loved the activities because they were easy to follow and kept students engaged in activities.”

EC educators' responses and facilitation during early STEM activities. Participants shared instances of how they responded to or facilitated early STEM activities. One participant shared,

After viewing a video [in a college course related to the study] of a child who couldn't stop his tower from tipping and then moving to build it against a wall, I saw this same opportunity within the classroom and seized it once the little one became upset that he couldn't get Godzilla to the top.

Another EC educator shared that the young children initially thought they could only collect insects in the containers she provided for them to use during outdoor exploration. Once she noted this, she explained to the young children that the containers could be used to hold any item they wanted to bring back for closer observation in the classroom. Once she clarified this point, she shared that, "the containers have been in constant use." Another EC educator shared that the young children wanted to make different shapes, so she brought out more supplies for them to do so. Yet another EC educator described how she followed the child's lead and tried to engage the young children in different challenges using the materials in the "STEM boxes or bins she had created for one of the early STEM college courses she had completed as part of the study.

EC educators' goals and adjustments for future early STEM implementation. After implementing early STEM activities, several participants shared goals for doing the same early STEM activities again and/or modifying and adjusting the early STEM activity for future early STEM implementation. For instance, one EC educator shared, "I would like to spend more time doing intentional activities with the materials so that students have a better understanding of what the materials are and ideas for using them." Other participants mentioned wanting to change up materials throughout the year and using a variety of open-ended materials to enhance the young children's experience. One EC educator noted, "When there are more of those open-ended materials the young children seem to engage with them for a longer amount of time both during the day and over a duration of days." Another EC educator described incidentally implementing a early STEM activity using sand and funnels

and how she now planned to build upon this "happy discovery" in the future by "having the children try it with materials other than sand, such as water, snow, and ice." After seeing the young children engage in outdoor exploration, another EC educator described her plan to make exploratory STEM kits containing magnifying glasses, clipboards, paper, pencils, and bug catchers that go outdoors daily with the young children.

Theme 5: Sharing with Colleagues. The self-reflection logs' entries referenced how many of the participants shared or planned to share information or ideas for early STEM instruction with other educators, colleagues, and/or administrators via training opportunities and/or coaching. The theme emerged 42 times within the combined self-reflection logs transcripts.

Training opportunities. Several participants described how they provided or planned to provide STEM training for colleagues and/or team members. One participant shared, "I think it would be wonderful to introduce STEM and train staff on it when they return in August." Another participant described developing a short training for teaching staff in January, "I am excited to share what we have learned and how it can easily be included into our lesson plans." Yet another EC educator wrote, "I want to work with teaching staff to intentionally focus on challenging the students by posing the questions and problems and emphasizing Twenty-First Century Skills."

Coaching. Many participants described coaching as a means of providing suggestions for their colleagues and/or other EC educators. Suggestions that participants shared or planned to share with colleagues and staff included: using math language daily, using STEM during choice time, providing more time for early STEM projects, incorporating small group or team activities, and taking materials outside. One EC educator shared an instance in which she was observing in an EC classroom that was struggling with classroom management. "I suggested changing up the lesson plans and providing more hands-on, engaging activities, and I suggested open-ended materials where they [the children] can create their own things."

Other participants shared or planned to coach by sharing specific information and/or resources with colleagues and/or EC educators from the early STEM college courses they completed during the study. For instance, many participants indicated that when coaching colleagues or other EC educators, they planned to recommend the use of resources from Learning Trajectories website (Clements & Sarama, 2017/2019). Another stated, “In completing some of my STEM activities for our classes [college courses completed as part of the study], I have encouraged my co-teachers to do similar activities with their groups and they have (subitizing, graphing, science experiments).” Another participant wrote, “I have encouraged a few of my teaching staff to try and use my STEM kit [created during courses completed as part of the study] in their classroom.

Theme 6: Hands-on Exploration. The participants also described how the young children used hands-on materials for building, creating, or exploring in various learning environments. This theme emerged 35 times within the combined transcripts. Many participants reported early STEM activities in which the young children used hands-on materials to design, engineer, create, explore, and/or build. Participants mentioned using household and/or recyclable materials for early STEM activities including 3D foam pieces, felt, blocks, cardboard tubes, rocks, toothpicks, glue, markers, straws, wooden craft sticks, toothpicks, and a type of clay referred to as ‘model magic.’ Participants also cited young children using mathematical and scientific materials such as ten-frames, tweezers, magnifying lenses, petri dishes, balances, scales, and STEM boxes or bins for hands-on experiences.

Many participants described how the young children used hands-on materials and manipulatives to create structures or models. For instance, young children created shadows, shapes, houses, buildings, tee-totter totters, and snowflakes with the varied materials provided by the participants. Other participants described how the young children solved a particular problem or challenge using hands-on materials in the classroom or in an outdoor environment. For example, after reading a story about the Three Little Pigs, some participants described young children using materials to design a house that could withstand the wolf’s

“huffing and puffing.” Others described young children using hands-on materials to build sprout houses for planting seeds, designing catapults, creating shadow towers, making a volcano out of a pumpkin, crafting animal habitats, and fashioning musical instruments so they could have, “their very own little marching band.” Additionally, several participants described how the young children engaged in open-ended opportunities in which they used hands-on materials to explore and create with minimal constraints or directions from the participants.

Discussion and Implications

The multiple methods study examined Head Start preschool educators’ self-efficacy and instructional practices for supporting preschool-age children’s STEM learning during their participation in a targeted professional development program that consisted of four graduate-level courses. As shown by the results, each of the 40 ECESES-STEM confidence-level mean scores increased. At the time of the pre-survey, six of the 10 indicators were deemed to be at the lower level of perceived confidence whereas after the intervention, only two mean ratings fell below 3.0. Consistent with findings from Sarama, et al. (2018), the implementation of a cohort model for professional learning over time and connected to educators’ classrooms, increases the likelihood that change will occur. With an increased understanding of how to integrate STEM in early childhood classrooms, educators are more likely to involve young children in purposeful interactions with STEM materials, increasing opportunities for young children’s development of critical thinking skills (Englehart, 2016). Relatedly, with opportunities for formative feedback overtime and from the college instructors and peers, the participants’ confidence levels were positively influenced (Blonder & Vescio, 2022).

In addition to survey data, the combined transcripts from the self-reflection logs revealed six common themes (e.g., *Implementation of Early STEM Activities*, *Child Responsiveness*, *Teacher Growth*, *Teacher Responsiveness*, *Sharing with Colleagues*, and *Hands-on Exploration*) which contained perceptive data related to the participants’ confidence and in-

instructional STEM practices.

Three of the themes (i.e., *Teacher Growth*, *Teacher Responsiveness*, and *Sharing with Colleagues*) relate to participants' increased confidence. Several participants described personal growth in terms of increased preparedness and confidence throughout the study and professional development opportunity. Many mentioned greater early STEM understanding and/ or having more confidence after trying STEM activities with the preschool-age children. These findings align with what is known about self-efficacy and PD. Educators are more likely to gain confidence when they participate in ongoing and interconnected PD opportunities designed to increase content and pedagogical knowledge (Desimone, 2009; McClure et al., 2017). This study incorporated Sarama et al. (2018) recommendations for effective PD opportunities as it was ongoing (i.e., four courses taken over 11 months), connected to personal teaching practice and/ or instructional setting (i.e., preschool educators, instructional coaches, and program directors), and tailored to the EC educators' needs (i.e., instructor and peer feedback, e-meeting times). Consistent with a study conducted by Chen et al. (2021), many participants in this study reported higher levels of STEM self-efficacy after participating in early STEM-related activities and PD.

Furthermore, the self-reflection logs' transcripts frequently suggested an increase in participants' confidence via *Teacher Responsiveness*. In this study, Teacher Responsiveness included opportunities to apply what was learned, self-reflect and set professional goals, all of which are known to be impacted by one's self-confidence (Bandura, 1993; Gerde et al., 2018). The participants frequently shared instances of teacher responsiveness after applying their early STEM knowledge to their own instructional setting. Their self-reflection logs often conveyed personal enjoyment when watching young children partake in early STEM activities, suggesting a positive effect. Many of the participants mentioned their eagerness to plan for and implement additional early STEM activities. The findings confirm Zee and Koomen's (2016) study showing that educators with positive affective attitudes are more likely to implement and develop innovative pedagogical beliefs.

Relatedly, the theme of *Sharing with Colleagues*

suggests educators must have confidence in order to willingly exchange instructional strategies and/ or ideas with other educators. Several of the participants disclosed either a future goal for sharing or having shared their early STEM knowledge and/ or activities with colleagues. The EC educators in this study participated in structured PD in which they had ongoing opportunities to engage as educational leaders. For example, they facilitated early STEM PD activities and provided a range of supports to their colleagues with frequent opportunities to rehearse, analyze, reflect on instructional practices, and set goals (Sarama et al., 2018, p.4). The results of this study parallel previous studies (Chen et al., 2021; Desimone, 2009; McClure et al., 2017) related to ongoing PD opportunities as an effective means of increasing self-efficacy and promoting early STEM instruction.

The remaining themes of *Implementation of Early STEM Activities*, *Hands-on Exploration*, and *Child Responsiveness* pertain to the participants' instructional practices. The prevalence of the Implementation of Early STEM Activities theme indicates ongoing implementation throughout the study. As advocated by Lange et al. (2019) and Sarama et al. (2018), the participants frequently described whole and/ or small group early STEM implementation in which young children simultaneously incorporated STEM disciplines to investigate and/ or solve a phenomenon-based, real-world problem. As recommended by Lange (2019), the self-reflection logs transcripts contained descriptions of participants incorporating early STEM experiences in which young children used multi-modal senses to observe and explore, discover patterns, and learn through trial-and-error. Many participants provided play-based indoor and/ or outdoor learning experiences to immerse young children in the scientific process. Research supports the role of "play" as fundamental to effective STEM instruction (Stipek, 2017).

The participants' implementation of early STEM included specific references to math, science, engineering, and technology. All four NGSS (2013) Disciplinary Core Ideas (e.g., Life Science, Earth Science, Physical Science, and Engineering, Technology, and Systems) were represented in the participants' account of early STEM implementation. The participants described using exploratory science

experiences in which young children asked questions, made predictions, observed, explored, collected, and discussed the data collected through hands-on, inquiry-based investigations. Bredekamp (2019) supports these experiences since they allow young children to grow their knowledge and skills related to life science, physical science, earth science, and engineering.

STEM technology refers to materials, resources, or tools that young children can use to solve a problem or to complete a design task (Lange et al., 2019). The participants provided accounts of young children using technologies, including hands-on materials (e.g., household items or tools) to explore scientific phenomena or complete engineering designs. As supported by Bredekamp (2019), blocks, math manipulatives, and games were also frequently used for STEM implementation.

“The participants provided accounts of young children using technologies, including hands-on materials (e.g., household items or tools) to explore scientific phenomena or complete engineering designs. ”

The self-reflection logs’ transcripts also contained evidence of teaching specific mathematical process skills including *reasoning and problem solving, communicating, and composing and decomposing* (National Research Council, 2009). These interrelated skills have the potential to collectively enrich young children’s understanding of STEM concepts, helping young children develop the character traits of curiosity, problem-solving, and perseverance (Lange et al., 2019).

Additionally, many participants described young children’s responses to planned/ implemented early STEM activities in terms of fun and enjoyment. The findings align with a study by Atma et al. (2021) stating when students enjoy and are motivated to learn, they have a positive attitude. Similarly, Cudney and Ezzell (2017) stated that motivation fostered a desire to learn and encouraged students to produce mean-

ingful work. The results of the current study indicate that the young children enjoyed early STEM activities and wanted to do them again, suggesting a desire for continued learning.

Relatedly, many participants described the young children’s active participation and engagement during early STEM activities. Reeve et al. (2004) described *engagement* as a student’s emotional and active involvement during a learning activity. Active learning engages students and is therefore considered to be a teaching technique that supports learning (Atma et al., 2021). The participants’ self-reflection logs’ transcripts provide evidence to support the National Association for the Education of Young Children and National Council of Teachers of Mathematics’ (NAEYC & NCTM, 2010) joint position statement affirms that young children can engage in the science and engineering practices (i.e., making predictions, carrying out experiments, and collecting data). Furthermore, the National Research Council (2001) stated that in addition to asking questions, young children should have the capacity and propensity to observe, explore, discover, and make sense of the world around them.

One way that young children in this study were reported to make sense of the world around them during early STEM activities was through social interactions. Accounts of groups or pairs of preschool-age children working and interacting with one another as they engaged in learning from one another while participating in early STEM activities substantiates what is known about social learning (Vygotsky, 1986). In addition, the young children being reported as actively participating in early STEM activities, the participants also described how young children persisted and often found multiple ways to solve problems or complete challenges. This is supported by Sarama et al. (2018) and Lange et al. (2019) who found that STEM experiences allow young children to gain STEM knowledge while simultaneously developing character traits that may build foundational background knowledge and interest in STEM.

Limitations and Future Studies

While the findings are encouraging, it must be acknowledged that the small sample size used for

this study limits generalization of the findings. In addition, the study yielded inconsistencies with the return rate for the six self-reflection logs.

Future research focusing on EC educators' abilities and use of strategies for promoting early STEM instruction in both indoor and outdoor learning environments, particularly during times of inclement weather may help in preparing teachers to effectively and efficiently plan and implement early STEM instruction. In addition, focusing on the dyadic relationship between coach and coachee and their self-efficacy levels before and after shared professional development opportunities, may assist the field in further defining the value of the coaching model and potential benefits for alignment of coaching and PD experiences.

While it is important to remember the ever-increasing STEM workforce demands, it is equally if not more important to consider how STEM knowledge, skills and self-efficacy may impact career choices and/or readiness of young children, our future workforce. Workforce demands often lead to higher compensation and benefits. Ensuring EC educators, particularly those providing care and education to Head Start children, often at higher risk of school failure is important not only to fill the increased STEM workforce demands, but to provide pathways toward financial stability.

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Choosing and Disusing Educational Technology: Examining Parents' Decision Making about Math and Literacy Apps for Their Young Children

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ABSTRACT

Each year, more educational apps are designed for young children and some research suggests that well designed apps can have positive effects on children's literacy and math skills. However, many commercially available apps are poorly designed. This highlights the importance of understanding how parents decide which educational apps they make available for their child and also why they may disuse them. Sixty-five Canadian parents (58 mothers) completed a survey of their child's literacy and math knowledge and their own decisions about literacy and math apps. Parents' naturally self-generated features for app selection yielded similarities e.g., (ease of use, age appropriateness) and differences (e.g., advertisements, games) to rubrics typically generated by researchers. Highly endorsed features were similar across app types. App quality and potential for independent use were key reasons for disuse. Parental knowledge of foundational literacy and math concepts such as phonological awareness and cardinality was low, which could pose a challenge for their assessments of apps.

KEYWORDS

Apps, parents, children, math, literacy, education, home learning environment

Educational apps are popular with parents of young children (Broekman et al., 2018; Ochoa & Reich, 2020) and research regarding high-quality apps indicates use can improve children's literacy (Arnold et al., 2021; Chuang & Jamiat, 2023) and math skills (Griffith et al., 2019; Outhwaite et al., 2023). A high-quality app should have accurate and developmentally appropriate content, as well as scaffolding features, such as levelling and feedback provided for both correct and incorrect answers (Cai et al., 2022, Cayton-Hodges et al., 2015; Outhwaite et al., 2023). Given that commercially available educational apps vary substantially in quality (Dubé et al., 2019), research has attempted to understand how parents evaluate educational apps, including how parents evaluate app store descriptions

(Montazami et al., 2022; Pearson et al., 2023), as well as the apps themselves (Urquhart et al., 2023; Urquhart et al., 2024). One limitation in these research studies is that parents may evaluate apps one way in an experimental setting, especially when prescribed rubrics are used, and another way in their homes. Indeed, it is currently unknown if parents naturally engage in any sort of systematic app evaluation at all. The present research examines parental app evaluation within the naturally occurring Home Learning Environment (HLE). Given that math and literacy are both important for a child's development (Skwarchuk et al., 2014), the study also examines whether parents evaluate math and literacy apps differently.

The HLE includes how parents teach their child, attitudes about teaching (Lehrl et al., 2021), and what tools they use (e.g., toys and educational apps). A rich and diverse HLE has been shown to improve academic outcomes for both math and literacy (Griffith & Arnold, 2019; Lehrl et al., 2021; Rodriguez & Tamis-LeMonda, 2011; Swkarchuk et al., 2014); however, in the traditional HLE, there is greater emphasis on fostering literacy over numeracy skills (Manolitsis et al., 2013; Skwarchuk et al., 2014). It is currently unknown whether the emphasis on literacy over math extends to educational app selection. Shared enjoyment between parent and child engaging in activities can be an important piece of the HLE for both math (e.g., Eason & Ramani, 2018) and literacy (Preece & Levy, 2018). Shared engagement is generally lower for digital activities than print activities (e.g., Ewin et al., 2020; Lee & Wood, 2020), however, co-use between parent and child during technology-based activities seems to support learning outcomes (Griffith & Arnold, 2018).

Similar to toy selection, parents typically decide which educational apps (if any) to bring into their home, and also which to remove (Miller et al., 2017; Richards et al., 2020). Parents' attitudes and competencies about teaching literacy and math may influence their app selection and deletion/disuse decisions (Keating et al., 2022). For example, parental math teaching confidence has been shown to affect math app evaluations (e.g., quality) and decisions (e.g., downloading apps) (Urquhart et al., 2023). In general, parental confidence regarding teaching their child literacy and math is quite high, but these high perceptions may not always reflect

actual knowledge or skill (Sonnenshein et al., 2020). In addition, differences occur across domains with higher confidence in their ability to teach literacy over math (Skwarchuk 2009). This difference might also influence educational app decisions, resulting in literacy apps being evaluated differently than math apps. Since many children have high levels of screen time (McArthur et al., 2022), it is crucial to understand how parents decide to both choose and disuse math and literacy apps for their children.

The present study investigates parental adoption and deletion/disuse decisions regarding educational apps within the HLE. The key research questions include: (RQ1) How do parents naturally choose educational apps? (1a) Are these similar to research generated criteria, (1b) Do these criteria differ for literacy versus math apps? (RQ2) Why do parents decide to disuse educational apps, if they do and are there similarities for literacy and math apps?

Method

Study Design

This study employed a survey design including both multiple choice/Likert-type scale questions and open-ended response questions. This design allowed for predetermined research questions to be tested (e.g., parents' endorsement of specific app characteristics), as well as parents' own ideas to be recorded.

Participants

The sample size was determined by the number of anticipated predictors in a linear regression (three) and aiming for twenty participants per predictor. With a final sample size of 65 and criterion set at 0.05, power for a regression with three predictors was 0.72. There were three additional participants who completed only the consent form and did not continue with the study.

Sixty-five Canadian parents (58 mothers, 6 fathers, 1 unspecified, Mage = 36.55 years, SD = 4.32) of children two- to six-years-old participated. Most participants were White (n = 42), followed by South Asian (n = 7), Southeast Asian (n = 6), two each of Middle Eastern, Latin American, Black,

and one each of Indigenous and West Asian ethnicity. Overall, participants were highly educated with 41 parents having completed an undergraduate degree, followed by completion of a graduate degree ($n = 12$), partial completion of an undergraduate degree ($n = 4$), partial completion of a graduate degree ($n = 3$), and completion of high school ($n = 2$). Most participants spoke English as their first language ($n = 47$). Of those with a different first language ($n = 18$), 61.11% reported themselves as “completely fluent” in English, 33.33% as “almost fluent”, and 5.56% as “somewhat fluent”. All parents indicated that they spoke English to their child at home (67.7% indicated always, 16.7% almost always, 12.3% sometimes, and 3.1% occasionally).

Participants had between one and three children ($M = 1.32$, $SD = .50$). Those who had more than one child were asked to identify one child that they would use as a referent during the survey. The mean age of referent children was 4.11 years old ($SD = 1.47$). Forty (61.5%) of the target children were male and 25 (38.5%) were female.

Recruitment primarily occurred through online sources (e.g., Facebook parenting groups and Instagram) as well as through bulletin boards in community centres, libraries, and grocery stores. When a potential participant expressed interest in the study, they emailed or messaged the researcher, who then scheduled a time to complete the study. To ensure that all participants were real people (not bots), participants were required to meet the researcher on Zoom to complete the study. The research was reviewed and approved by a university research ethics board. All participants were treated in accordance with APA/CPA ethical guidelines.

Procedure

The study was conducted using video conferencing software. During the call, parents were provided with a link to one online survey that assessed demographic information (including age, gender, ethnicity, and languages spoken in the home) and measures related to math, literacy and technology (see below). The researcher was available to troubleshoot technical difficulties and to clarify questions if needed.

Attitudes Towards Home Learning

A 10-item scale was created for this study to measure parents’ attitudes towards their child learning at home. The scale consisted of 5 items for math and 5 mirror items for literacy. Parents rated items such as “It’s a parent’s job to start teaching their child [to read/ math] before they start school” from 1 (strongly disagree) to 5 (strongly agree). The scale had acceptable reliability, $\alpha = 0.76$.

Math Measures

Parents rated their child’s math abilities using a 10-item scale created for this study. These items represented early numeracy skills consistent with recommendations from the National Association for the Education of Young Children & National Council of Teachers of Mathematics (2010), for example “Match numbers and quantities”. Parents indicated their child’s ability as 1 (my child cannot do that), 2 (my child can sometimes do that), 3 (my child can always do that), or 0 (I’m not sure if my child can do that). This scale had excellent internal reliability, $\alpha = 0.94$.

Parent self-reported math behaviours were assessed with the 15-item Home Numeracy Practices scale (Skwarchuk et al., 2014) where parents rated the frequency with which they do various math activities with their child from 1 (never) to 4 (daily); for example, “I help my child weigh, measure, and compare quantities”. This scale had good internal reliability, $\alpha = 0.81$.

Parental confidence teaching math to their young children was assessed with one item, “How confident are you in your ability to teach early math skills to your child?” rated from 1 (not at all confident) to 5 (extremely confident).

Literacy Measures

Parental-report of child’s literacy abilities were assessed using a ten-item scale based on a literacy taxonomy (Grant et al., 2012). The items represented early literacy skills including alphabets and phonological awareness; for example, “identify letter sounds”. Parents were rated their child’s ability as 1 (my child cannot do that), 2 (my child can sometimes do that), 3 (my child can always do that), or 0 (I’m not sure if my child can do that). This scale had excellent internal reliability, $\alpha = 0.91$.

Self-reported literacy behaviours were assessed with the 12-item Home Literacy Practices scale created for this study. Parents rated the frequency with which they do various literacy activities with their child from 1 (never) to 4 (daily); for example, “reading aloud to your child and having them repeat back to you (e.g., echo reading).” This scale had good internal reliability, $\alpha = 0.87$. Parental confidence teaching literacy to do their young children was assessed with one item, “How confident are you in your ability to teach early reading skills to your child?” rated from 1 (not at all confident) to 5 (extremely confident).

Technology Measures

The following questions were asked for both math and literacy apps. Parents were asked if they had ever downloaded an app for their child. Those who said no were not presented with the subsequent questions about apps. Those who said yes were presented with the following questions.

Participants were asked to indicate (Yes/No) whether they had ever downloaded each of a math app and a literacy app (with questions allowing for a general educational app that contained math or literacy content).

To assess the features that parents look for in apps, participants were asked to generate “what are the top two things that you would look for in a [literacy / math] app?” Each question had two open-ended response possibilities. Participants were then presented with a matrix of 16 researcher-generated features (see Table 1) and were asked to indicate if they have used this feature for math apps, literacy apps, neither, and “I have not used this criterion before but I would now”.

To assess the sources of information, parents use when selecting apps, they were asked to rate to what extent they use seven sources of information (e.g., recommendations from teachers; see Figure 3 for the complete list) from 1 (strongly disagree) to 5 (strongly agree). They were also asked if they explore apps before giving it to their child, rated from 1 (always) to 5 (never).

Co-use of apps was defined as “I engage with the technology with my child” and was assessed by estimating the percentage of time that parents co-use technology with their child, rated on a sliding scale from 0% to 100% of the time.

To assess deletion/disuse of educational apps once they have been downloaded, participants were asked, “Have you ever downloaded a [math / literacy] app that you later decided to not use with your child?” with answer options of yes and no. Those who indicated yes were then presented with an open-ended text box to answer, “Tell us what made you make the decision to not use the [math / literacy] app that you had downloaded?”.

Results

All data was analyzed using SPSS Version 27. Missing responses within a set of questions were replaced by the mean if there were one or two missing items in a set of questions. Results from the survey data (as described in the Materials section) permitted examination of the two key research questions. RQ1 was assessed through an analysis of parent-generated features (descriptive statistics, thematic analysis) and researcher-generated features (descriptive statistics and one-way ANOVA to compare endorsement by subject). In addition, sources of information and co-use levels were assessed using descriptive statistics and t-tests to compare by subject (literacy versus math). Finally, contributions of the home learning environment including parent confidence and ratings of their child’s math and literacy skills were examined using regression analyses (binary logistic regression and linear regression respectively), with attitudes about home learning compared across subject areas (i.e., t tests). RQ2 was assessed using descriptive statistics and thematic analysis of qualitative data.

RQ1: How Do Parents Choose Literacy and Math Apps?

The majority of participants indicated that they had downloaded an educational app before: 86% for literacy and 80% for math apps.

Parent-generated App Features

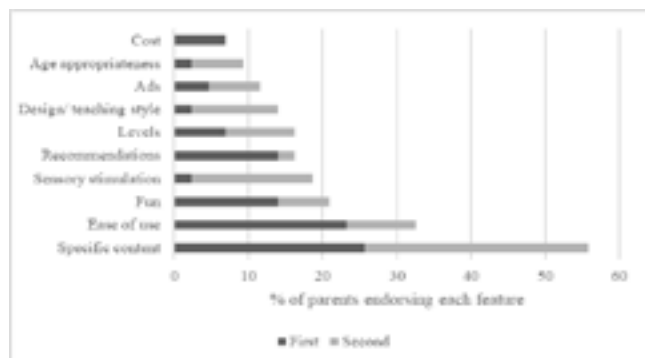
To determine criteria that parents naturally think about when selecting apps, parents were asked to generate two features that they look for when choosing an app for their child. Open coding of all responses was conducted to extract themes

(Boyatzis, 1998). Two coders independently read through all responses before generating themes and theme labels in an iterative manner. Then both coders collaboratively compared their themes and labels before reaching 100% agreement amongst themselves about classification of parent-generated responses. Ten themes were identified: ease of use, ads, fun, specific content, recommendations, levels, age appropriate, sensory, cost, and design/teaching style. Responses within each theme tended to be similar (e.g., six parents simply wrote the word “free”, which was coded into the cost theme) with the exception of the ‘specific content’ theme. The variety of ‘specific content’ responses reflected features about individual apps including comments about the animations (e.g., “five little ducks”) and general approach (e.g., “phonics approach” and “helps to learn counting”).

Figures 1 and 2 show the percentage of parents who endorsed each of these features for literacy and math apps, respectively. In total, for both literacy and math respectively, specific content (55.81%; 52.50%), ease of use (32.56%; 27.5%) and fun (20.93%; 42.5%) were the three most frequently identified features by parents. However, the overall order of endorsement of features was not the same across domains. For example, ‘fun’ was identified as second most important for math and third most important for literacy, and vice versa for ‘ease of use’. Order differences for some features was more varied. For example, sensory was the fourth out of ten most important for literacy and the eight out of ten most important for math. The least endorsed feature for literacy apps was cost (7%) whereas the least endorsed feature for math apps was ads (5%).

FIGURE 1

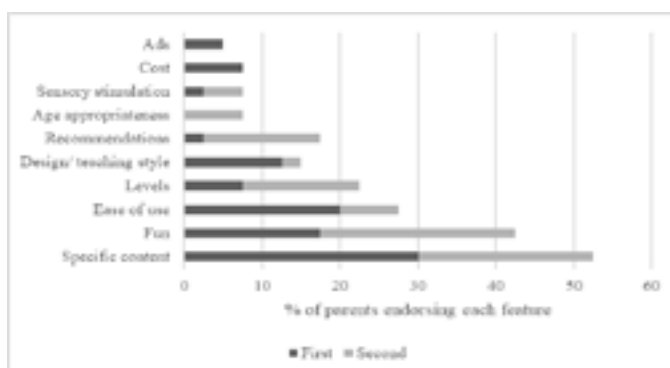
Percentage summary of parent-generated literacy app features as a function of overall prevalence and number of times each feature appeared as the first or second item listed in the open-ended questions.



quently analyzed as a function of placement (i.e., feature listed first versus second; see Figures 1 and 2). Although cost was only listed by 5% and 7% of parents across literacy and math respectively, when it was mentioned, it was listed first in 100% of these instances for both the literacy and the math responses. When age appropriateness was mentioned, it appeared as the second feature listed for both literacy and math. Other features showed differences in first and second endorsement by domain. For example, recommendations were endorsed first for literacy 86% of the time, and second for math also 86% of the time.

FIGURE 2

Percentage summary of parent-generated math app features as a function of overall prevalence and number of times each feature appeared as the first or second item listed in the open-ended questions



Researcher-generated App Features

After parents generated their own selection features, they were presented with 15 researcher-generated features and were asked to indicate which of the features they have used previously to select an app. The options included whether the feature was used for neither app domain, literacy only, math only, both domains, and not presently but I would use this in the future. Parents could indicate more than one category, for example, neither and also I would use this in the future. See Table 1 for a summary of the 15 features and the percentage of parents who endorsed each for literacy and math apps.

Table 1*Percentage of parents endorsing researcher-generated reasons for literacy and app selection*

Feature	% of Parents Endorsing				
	Both Literacy and Math	Neither	Literacy Only	Math Only	Would use in Future
How easy the app is to use/ navigate.	82	0	8	0	8
The quality of the educational content in the app.	80	2	6	2	6
How fun or engaging the app is.	76	2	8	4	6
Whether my child can use the app independently (without my help).	72	12	4	0	10
Cost of the app.	70	14	2	2	4
The quality of the audio (e.g., music, talking, etc.).	66	6	0	6	12
If the app has difficulty levels.	56	18	4	6	14
The quality of the instructions in the app.	54	14	6	4	20
The type of feedback given for incorrect answers.	44	22	2	4	26
The type of feedback given for correct answers.	44	20	2	4	28
If the app automatically moves my child across levels.	40	14	10	2	24
Familiar characters that my child already likes.	36	34	0	8	18
New characters that I think my child will like.	36	32	0	10	20
The quality of the visuals (e.g., colours, easy fonts, etc.).	32	22	4	20	12
Whether the audio and visual features can be cus- tomized to accommodate sensory needs.	14	48	14	0	20

Note: Parents could use more than one category, for example, neither and also I would use this in the future thus percentages may exceed 100 percent.

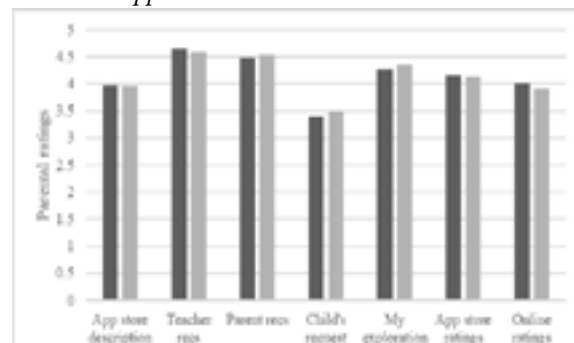
The most endorsed research-generated features were ease of use (82% for both and another 8% for literacy only), quality of the educational content (80% for both and an additional 6% for literacy only and 2% for math only), and fun (76% for both and an additional 8% for literacy only and 4% for math only). The three least endorsed features were customization (48% have not used), familiar characters (34% have not used), and new characters (32% have not used). The features that were most likely to be considered in the future were the type of feedback given for correct answers (28%), the type of feedback given for incorrect answers (26%), and if the app's levels are automatic (24%).

A one-way ANOVA showed that there was a significant difference in the number of people endorsing each of the option types (neither, literacy only, math only, both, 'future') across the 15 features, $F(4, 70) = 41.01$, $p < 0.001$, with a strong effect size, $\eta^2 = 0.70$. Bonferroni post-hoc analysis revealed that the differences were primarily driven by the 'both' option. Specifically, more people endorsed both than neither, $t = 8.22$, $p < .001$; both than math only, $t = 10.90$, $p < .001$; both than literacy only, $t = 11.05$, $p < .001$; and both than future, $t = 8.80$, $p < .001$.

Sources of Information

Parents' ratings for the seven possible sources of information about both literacy and math apps approached ceiling for all but child's request; see Figure 3.

FIGURE 3
Sources of information that influence decisions to download apps



Visual inspection suggests that the means for literacy and numeracy apps were similar. To test whether differences between the types of apps occurred, two t-tests were conducted, one for the child's request category and one for online ratings as these categories reflected the largest mean difference in use of a source of information between the literacy and math apps. No significant differences were found for either of these two exemplars, $t_{literacy}(.59) = -1.22$, $p = 0.229$ and $t_{math}(0.65) = 1.09$, $p = 0.280$, further indicating that none of these categories differed by domain.

Participants were also asked if they explore an app before giving it to their child (rated from 1 = always to 5 = never). Self-reported pre-exploration was high for both literacy ($M = 2.13$, $SD = 1.03$) and math ($M = 2.08$, $SD = 0.93$), and did not significantly differ by subject, $t(0.32) = -1.00$, $p = 0.324$.

Co-Use of Apps

Overall, parents indicated that they engaged in co-use of apps approximately a third of the time for both literacy (35.61%, $SD = 25.38\%$) and math apps (31.93%, $SD = 26.07\%$). A comparison was made between parents who did and did not indicate that they disused an app after having downloaded it. To determine whether co-use differed among parents who had or had not disused an app a t-test was conducted for each app domain. No significant differences were found. For literacy apps, co-use in the app-disuse group was $M = 37.4\%$ ($SD = 27.4\%$) of the time, whereas co-use in the continued use group was $M = 33.9\%$ ($SD = 23.7\%$); $t(41) = 0.45$, $p = 0.653$, $d = 0.14$. For math apps co-use in the app-disuse group was $M = 36.9\%$ ($SD = 29.2\%$) of the time, whereas co-use in the continued use group was $M = 27.2\%$ ($SD = 22.4\%$); $t(40) = 1.23$, $p = 0.226$, $d = 0.38$.

Apps as Part of the Home Learning Environment (HLE)

Downloading Apps

Two binary logistic regressions were used, one for math and one for literacy, to test if parents' self-reported behaviour (i.e., supporting HLE), confi-

-dence teaching the subject, and their child's subject abilities predicted whether they download each type of educational app. None of the variables predicted literacy app downloads ($B = 0.47$, $p = 0.567$ for HLE, $B = -0.80$, $p = 0.056$ for literacy teaching confidence, and $B = -0.39$, $p = 0.569$), though literacy teaching confidence approached significance. Similarly, none of the variables predicted math app downloads ($B = 2.12$, $p = 0.070$ for HLE, $B = -0.21$, $p = 0.714$ for child's math knowledge, and $B = -0.67$, $p = 0.146$ for math teaching confidence).

Parent-reported Child's Math Knowledge

Parents were asked to rate if their child could do ten early numeracy skills, targeting concepts such as one-to-one correspondence and cardinality. Overall, the mean rating was relatively high ($M = 2.30$, $SD = .75$, max. score = 3). Across the 10 concepts, 59.7% of parents indicated their child could always do these skills, 18.3% indicated their child could sometimes do the skills, and 14.08% indicated their child could never do the skills. The least common response was I'm not sure if my child could do that which was endorsed by 7.71% of parents. Further examination of the unsure category indicates that 10 parents indicated uncertainty for one of the ten concepts, five parents for two of the concepts, one parent for three concepts, and two parents for each of four and ten concepts.

This means two parents indicated that they were unsure if their child could do any of the items or knowledge sets. See Table 4 for the breakdown of parent-reported child's knowledge across specific knowledge sets. The most common knowledge set that parents did not know if their child could do was "know that the last number they count represents the total number in the set," which represents cardinality ($n = 14$ parents indicated they were not sure if their child could do this). The next most common knowledge set that parents were not sure about was "recognize numbers on dice," representing subitizing ($n = 9$), followed by "generate the correct number of items to match a number," representing cardinality ($n = 6$). Self-reported confidence teaching math to their child was reported as moderate ($M = 3.88$, $SD = 1.10$, with 5 representing "very confident").

Measures of self-reported math app co-use,

pre-exploration of math apps, and child's sex significantly predicted parent-reported child's math knowledge, $F(3, 36) = 3.31$, $p = .032$, with a large effect size $f = .44$. This effect was specifically driven by pre-exploration of math apps, $t = 3.11$, $p = .004$. Co-use was not a significant predictor of child's math knowledge, $t = .64$, $p = .528$ and neither was child's sex, $t = .01$, $p = .992$.

Parent-reported Child's Literacy Knowledge

Parents were asked to rate if their child could do 12 early literacy skills, taken from the literacy taxonomy (Grant et al., 2012). The overall rating parents gave their children across the 12 literacy skills was relatively high ($M = 2.17$, $SD = .73$, maximum score = 3). Across the 12 features, on average, 50.78% of parents indicated their child could always do these skills, 23.33% said their child could sometimes do the skills, and 19.01% said their child could never do the skills. The least common response was I'm not sure if my child could do that which was endorsed by a mean of 6.93% of parents across the ten items. Further examination of the unsure category indicates that five parents indicated uncertainty for two of the 12 concepts, four parents for one of the concepts, three parents for three concepts, two parents for five concepts, and one parent each for 6 and 11 concepts. See Table 4 for a detailed breakdown of parents' ratings of their children's literacy knowledge. The most item that parents did not know if their child could do was "count or clap syllables," representing phonological awareness ($n = 12$ parents indicated they were not sure if their child could do this). The next most common item that parents were not sure about was "tell if two words start with the same sound," representing phonological awareness ($n = 9$), followed by "recognize rhyming words," representing phonological awareness ($n = 6$). Self-reported confidence teaching literacy to their child was reported as moderate ($M = 4.02$, $SD = 1.10$, with 5 representing "very confident").

Digital related measures of self-reported literacy app co-use and pre-exploration of literacy apps almost significantly predicted parent-reported child's literacy knowledge, $R^2 = 0.16$, $F(2, 35) = 3.19$, $p = 0.054$. This effect was specifically driven by pre-exploration of literacy apps, $t = 2.52$, p

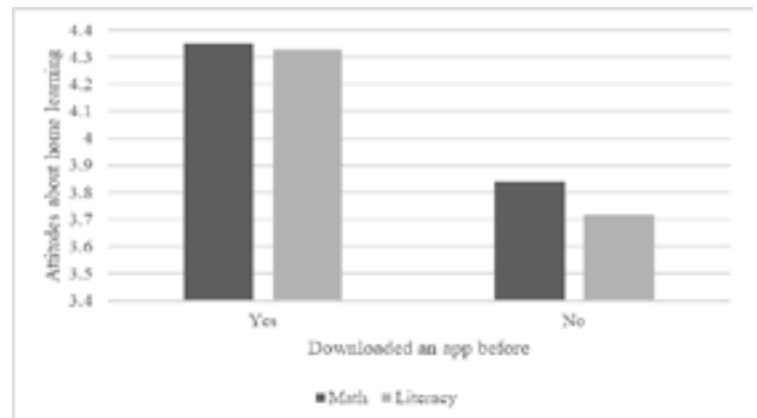
= 0.016. Co-use was not a significant predictor of child's literacy knowledge, $t = 0.05$, $p = 0.964$.

Attitudes About Home Learning

Overall, parents reported high levels of agreement with the ten item attitudes scale which assessed their attitudes towards teaching both literacy and math to their child at home ($M = 4.21$ out of 5, $SD = 0.58$). The level of endorsement of home learning differed between parents who had and had not downloaded educational apps before, see Figure 4. Specifically, independent samples t-tests showed that parents who had downloaded a math app before had more positive attitudes about home learning, $t(10.87) = 2.30$, $p = 0.042$. This was also true for parents who had downloaded a literacy app before, $t(6.46) = 2.60$, $p = 0.038$.

FIGURE 4

Self-reported attitudes about home learning compared between people who had and had not downloaded an educational app for their child before



Note. Responses on the attitudes scale could range from 1 to 5.

Table 2

Number of parents who indicated 'cannot', 'some-times', 'always', and 'don't know' when rating their child's numeracy skills, as a function of knowledge set

Question text	Knowledge set	Cannot	Some-times	Always	Don't Know
Generate the correct number of items to match a number.	Cardinality	9	12	37	6
Know that the last number they count represents the total number in the set.	Cardinality	6	16	28	14
Name numbers.	Identifying numbers	8	8	46	2
Identify which set has a larger or smaller amount in it.	Magnitude comparison	8	16	36	4
Match numbers and quantities.	Magnitude comparison	9	14	36	5
Count a set of items by assigning one number per item (e.g., 1, 2, 3...)	One-to-one correspondence	2	8	50	4
Count items in an organized way without skipping or duplicating items.	One-to-one correspondence	9	22	30	3
Know the counting sequence from 1-10	Stable order	4	3	55	2
Recognize numbers on dice.	Subitizing	14	6	35	9
Print numbers.	Writing numerals	21	12	29	2

Table 3

Number of parents who indicated 'cannot', 'sometimes', 'always', and 'don't know' when rating their child's literacy skills, as a function of knowledge set

Question text	Knowledge set	Cannot	Sometimes	Always	Don't Know
Name alphabet letters.	alphabetics	6	8	47	1
Identify letter sounds.	alphabetics	8	14	35	4
Match upper- and lower-case letters.	alphabetics	15	11	32	5
Print letters.	alphabetics	21	9	31	2
Point to words in print.	fluency	12	19	27	4
Print their first name.	memorization	19	4	39	1
Identify words/ signs (e.g., STOP, McDonald's).	memorization	8	18	36	1
Recognize/ read their name.	memorization	10	7	43	3
Count or clap syllables.	phonological awareness	14	21	16	12
Recognize rhyming words.	phonological awareness	10	21	26	6
Generate rhyming words.	phonological awareness	16	19	23	5
Tell if two words start with the same sound.	phonological awareness	7	19	28	9

RQ2: Deletion/Disuse of Apps

Of the parents that had downloaded each type of app before, 44.9% (literacy) and 42.9% (math) of parents reported having decided to no longer use the app with their child. Qualitative analysis following the same open-coding procedure as was used for the parent-generated features and again 100% agreement was observed between the two raters. Seven themes emerged: cost, ads, level of challenge, requiring assistance, lack of interest, other engaging sources, and productivity (see Table 4 for themes, examples, and endorsement). Prevalence of these themes were similar for both math and literacy apps, with some apparent differences (e.g., ‘other engaging sources’).

Table 4

Summary of themes for disuse of math and literacy apps

Theme	Example response	% of parents endorsing	
		Literacy	Math
Lack of interest	“The children weren’t interested in it”	45.45	42.86
Level of challenge	“Not challenging enough” - either too easy or too hard	40.91	38.10
Cost	“A number of in app purchases required”	22.73	28.57
Requires assistance	“Required my assistance to use”		
TABLE 9 Literacy Skills Mean, Standard Deviation, and Pearson Correlation for AEPS-3 Ready Set (Teachers) and AEPS-3 FACS (Parents)			
Ads	“Too many ads”	13.64	9.52
Other engaging sources	“Found a better app that my child prefers”	9.09	23.81
Productivity	“No productivity in app”	9.09	4.76

Note. The percentages reported in this table are out of the total who indicated they had disused a literacy and/or math app before (i.e., out of 22 and 21 participants).

In general, the order of endorsement of each reason was the same across domains (e.g., ‘lack of interest’ was the most cited and ‘productivity’ was the least cited reason for both literacy and math). No reason was endorsed for more than half of the participants who had disused apps.

Summary of Findings

Overall, with respect to the question “How do parents naturally choose educational apps?” (RQ1), both similarities and differences were found in parent-generated app features compared to researcher-generated app features, but no differences were found between literacy and math apps. Ease of use and fun were in the top three app features in both the parent and researcher generated lists. In contrast, parents’ self-generated features included specific content whereas educational quality served as a third feature from the researcher-generated features. RQ2 examined why parents decide to disuse educational apps, if they do and whether there are similarities in disuse for literacy and math apps. Consistent reasons were identified for disuse of math and literacy apps, which included some features generated and endorsed for RQ1, such as the top reason of lack of interest (similar to engaging or fun in the features list).

Discussion

The present study investigated how parents of young children choose educational literacy and math apps and criteria that might cause them to stop using an app in each of these domains. Most parents had downloaded an educational app before engaging in this study, with slightly more (86%) having downloaded a literacy app than a math app (80%) consistent with previous research that reports an emphasis on literacy over math in early childhood (Skwarchuk et al., 2014). Parents with more positive attitudes about teaching their child at home were more likely to have downloaded an educational app, indicating that parents consider educational apps to be a tool within the home learning environment. Features parents used to decide whether to download an app overlapped with features typically generated by researchers

in the extant literature, however some differences were observed. Pre-exploration of both literacy and math apps significantly predicted greater literacy and perceived math knowledge (respectively), supporting the idea that carefully selected apps can be part of a diverse and rich home learning environment.

How Parents Choose Apps

Both the parent-generated and the researcher-generated features for app selection included ease of use, fun, age appropriateness, levels, cost, and sensory stimulation. Parents, however, also indicated concerns about ads and noted they looked for specific features, such as “songs” and “games”. In addition, a small number of parents highlighted features such as “teaching philosophy” (coded as the Design / Teaching Style theme), however, this feature was vague and did not specify what aspect of teaching philosophy was important. Features such as “teaching philosophy” may be consistent with what parents see in app store descriptions, however, these descriptions are not necessarily accurate or useful (Pearson et al., 2023). Given that parents only were asked to identify two features, and some indicated features not appearing on traditional research generated lists, it would be important to follow up on parent-generated criteria to gain a richer and more complete understanding of parental criteria. Future focus group studies may allow for expansion of these unique criteria as well as other criteria beyond the two parents listed for the present study.

Generally, the desired features parents generated for literacy and math apps were similar, however, there were some notable differences in the order of endorsement. “Fun” was generated by 42.5% of parents for math versus 20.93% for literacy apps. Fun may be a more important consideration when looking at math apps as previous research indicates that many math apps rely on practice drills, similar to a worksheet (Outhwaite et al., 2023) which does not fully utilize the engaging multimedia potential that apps could offer. In addition, sensory stimulation was generated by 18.5% of parents regarding literacy apps and only 7.5% for math apps. It is possible that literacy apps have more varied sensory features than math apps, for example reading

aloud, and making sounds to match text content. Alternatively, parents may consider literacy more important than math (Skwarchuk et al., 2014) and this may bias their evaluations of literacy versus math apps. Further investigation of parents' perceptions about the purpose and design of math and literacy apps may be an important future direction.

Of the researcher-generated features, the most endorsed feature was ease of use / navigation, followed by educational content, fun, and child can use it independently. This aligns with previous findings that parents endorse "educational" value but also value apps that allow their child to engage independently which may allow parents an opportunity to engage in other activities (Urquhart et al., 2023). Although independent use may be an important consideration, outcomes for the sources of information parents use support that educational opportunities rather than child entertainment are a priority. Among the sources the only source of information that had an average slightly below the "agree" range was child's request. If parents were simply looking to entertain their child, child's request would likely be a higher priority.

Although parents endorse the educational potential of apps, parents may not be clear regarding instructionally important supports within apps. Fourteen parents said they had not considered feedback but they would look for this feature in future. This suggests that parents may need direct exposure and explanation of these features as in the present study. It may be important to provide explicit information through websites, app descriptions or other sources to identify critical educational/instructional features.

Parents' evaluations of educational value may also rest on their understanding of key foundational skills and their child's abilities. For example, parents were unsure of fundamental skills, such as phonological awareness and cardinality the type of skills that should be targeted in a well-designed early literacy or math app (Cayton-Hodges et al., 2015). Parents may require support in recognizing developmentally appropriate math and literacy content, a feature that may be needed in app evaluations and descriptions. The results of this study cannot identify if these parents did not know what the skills mentioned were or if they knew what the skills were but were unsure if their own child could

do them. Future research could investigate parent knowledge of foundational math and literacy skills to uncover what the specific gaps may be.

Less than half of participants indicated they stopped using an educational app, which could mean most are successful at choosing high quality apps in the first place, or it could mean they do not notice when an app they have downloaded is poor quality or is not achieving desired outcomes. Parents acknowledged poor quality (e.g., "level of challenge", "ads") as important for considerations leading to disuse and that the app cannot be used independently (e.g., "requires my assistance"). It might be expected that parents who co-use educational apps with their children would be more likely to notice an app is of poor quality or failing to achieve its purpose. However, co-use levels did not differ between parents who had or had not disused an app. This nonsignificant outcome may, however, reflect the generally low co-use across the sample. More effort may be needed to inform parents of co-use as an important informal instructional support (Griffith et al., 2021).

Overall, findings suggest that parents are motivated to find educational apps for their children, they use various sources of information and consider multiple features when choosing apps. App decisions were relatively similar for math and literacy. However, gaps in parental knowledge about foundational math and literacy skills may influence their app decisions. This study adds to the literature about educational apps as a tool in the home learning environment, including specifically comparing parents' attitudes and evaluations of literacy versus math apps, as well as considering both use and disuse of apps. Understanding how parents think about educational apps can lead to the creation of tailored resources to support their decisions, with the goal of promoting student learning.

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Practice Makes Progress in Mathematics: A Research to Practice Summary

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ABSTRACT

This research-to-practice article supplements the research article Practice Makes Progress: Leveraging Practice-Based Teacher Education in Mathematics Pedagogy Courses for Primary Grade Learners published in the journal *The Dialog*. This article presents suggestions based on a research study that provided a research-based framework, Inclusive and Equity-based Mathematics Teaching (IEBMT), and examined how future teachers (referred to as teacher candidates) effectively planned for and taught mathematics activities in kindergarten classrooms. This work is relevant to early childhood education professionals since research supports benefits in using inclusive and equity-based practices when teaching mathematics.

KEYWORDS

Early childhood education, elementary education, mathematics education, practice-based teacher education, problem solving

Classrooms today include a more diverse group of students than ever before, which includes children from varied linguistic, socioeconomic and cultural backgrounds (Domingo-Martos et al., 2002). It is critical that programs that prepare and support future and current early childhood educators adequately help individuals teach classrooms of young children that are increasingly diverse. Additionally, the number of individuals in early childhood education programs who demonstrate learning differences continues to increase (Schaeffer, 2023), requiring early childhood education professionals to have background knowledge and experiences supporting learners who have learning differences.

Further, in an era where student learning and achievement data continues to be a focal point, student achievement data continues to show discrepancies between students based on their cultural and linguistic backgrounds across all grade levels (Domingo-Martos et al., 2022; Musu-Gillette et al., 2017).

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Early childhood educators need support and adequate resources to effectively teach all learners regardless of students’ linguistic and cultural backgrounds.

Inclusive and Equity-Based Mathematics Teaching: What is It?

The ideas included in inclusive and equity-based mathematics teaching (IEBMT) come from research on teaching mathematics to learners from diverse backgrounds as well as children who demonstrate learning differences. IEBMT has two main pillars or parts: 1) Access to grade-level aligned, research-based experiences and 2) Opportunities for the exploration of problems embedded in meaningful contexts. Table 1 describes aspects of IEBMT.

What We Know about Educator Preparation Programs

Experts who conduct research and influence

policy have made recommendations for course work for teacher candidates to align with the work that they do in schools for clinical experiences (Putman & Polly, 2021; Zeichner, 2021). Early childhood TCs who hope to work with primary grade learners need ample experiences working with and learning about children in clinical practice settings in classrooms (Matengu et al., 2020; Polly, 2021).

Practice-Based Teacher Education

Practice-based teacher education (PBTE) is a process used to describe four phases to prepare TCs to learn about and enact research-based pedagogies (Grossman et al., 2009). Table 2 describes the four phases of PBTE: Learn, Practice, Enact, and Reflect (McDonald et al., 2013). In a nutshell, TCs learn about a research-based pedagogy, plan to use that pedagogy and practice using it, then they go and use the pedagogy with children, and finally reflect on their experiences (Colonnese & Polly, 2022).

Table 1

Aspects of Inclusive, Equity-Based Mathematics Teaching

Pillar	Aspect	Description
Access to grade-level aligned, research-based experiences	Alignment to grade level content	Learners should engage in activities aligned to current grade-level Standards (Gutiérrez, 2009; NCTM, 2014; Unbound Ed, 2021). Connect concepts prior to grade-level Standards to grade-level concepts (Tomlinson, 2017)
	Access to research-based experiences	Learners will engage in activities that are aligned to research-based teaching practices proven to increase student learning and achievement (Ci-oè-Peña, 2017; Gutiérrez, 2012).
Opportunities for the exploration of problems embedded in meaningful contexts	Exploring problems	When appropriate, learners will explore problems and select the strategies that they will use to solve problems (Buchheister et al., 2019; Sinha & Kapur, 2021). Gutiérrez (2009) describes this as Power.
	Meaningful mathematics contexts	Learners engage in activities that are contextualized in real-life situations that are meaningful to learners and build upon their cultural and academic assets (Buchheister et al., 2019; Domingo-Martos et al., 2022).

Table 2

Phases of Practice-based Teacher Education

Phase	Description
Learn	Learn research-based pedagogies by participating as learners in an example lesson, watching videos, and/or other experiences.
Prepare	Prepare to enact the research-based pedagogies with young learners. This may include selecting activities, writing lesson plans, and rehearsing/practicing teaching with peers (aka other TCs) and receiving feedback on their rehearsal.
Enact	Enact research-based pedagogies with students in a school setting. This experience may include the collection of artifacts from the enactment such as student work samples, audio recordings, video recordings, or observation notes from an observer.
Reflect	Reflect on the enactment based on TCs’ experiences, student data, or recordings of the enactment.

As a result of the need to prepare future educators to use aspects of IEBMT practices with children, this study examined how two different courses used PBTE to influence TCs use of IEBMT practices.

Description of the Research Study

The study included TCs from an in-person course offered during a spring semester (Course A) and an online course offered in a summer semester (Course B). All TCs were placed in a kindergarten setting (Course A) or had spent time in kindergarten in the past year (Course B).

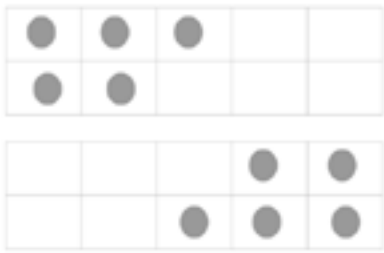
Description of Mathematics Activities

All TCs had to plan and teach a number sense activity (aka a number talk) and a 3-lesson unit about addition and subtraction word problems.

Number Sense Activity

TCs in both the in-person and the online course experienced number sense activities as learners during class. Here is an example. The author, who was the course instructor, displayed Figure 1 and then asked TCs, “What do you notice in this picture?”

FIGURE 1
Screen shot of image from number sense activity



TCs usually state ideas such as:

- “I see dots in each row.”
- “I see 5 on the top and 5 on the bottom and I know that 5 plus 5 is 10.”
- “I see that the bottom dots can be moved up to fill the empty boxes so that all 10 boxes on top are full to make a total of 10.”
- “I went from left to right and counted by 2s. I landed on 10 which is the total.”

In the course meeting after the activity, TCs spent time talking about their experiences as learners and the benefit of these activities. Part of the discussion focused on the specific questions that the instructor (the author) asked during the activity with a focus on how those questions elicited students’ thinking about the mathematical concepts

embedded within the activity. In a future class meeting in both courses TCs had planned their own number talk, practiced teaching it to classmates, and received feedback from their classmates and the course instructor. TCs then went and did the activity with a small group of children and reflected on their experience.

Problem Solving Lessons

During both courses the instructor provided examples of ways to support primary grades students while solving word problems. For example, consider the word problem: There are 4 dogs in the park. Then 3 more dogs show up. These scaffolds that were shown to TCs included asking questions about the problem to guide students through the problem-solving process and providing them with a number path and hands-on counters to help students who need help keeping track of the numbers in the problems (Figure 2).

The instructor walked through the process with TCs in the following way:

- Instructor: I want us to think about this situation. There are 4 dogs in the park. Then 3 more dogs show up.
- Instructor: How many dogs are in the park?
- TCs: There are 4.
- Instructor: How can we use our counters to show that?
- TCs cover the numbers 1, 2, 3 and 4 on the number path.
- Instructor: What is the action in our problem?
- TC: 3 more dogs showed up.
- Instructor: Use your counters to show the 3 dogs that showed up.

- TCs put counters that are a different color on the numbers 5, 6, and 7.
- Instructor: The question we are going to answer is “how many dogs are now in the park? What is the answer?
- TC: The answer is 7.
- Instructor: How do you know?
- TC: I have 4 counters and 3 counters. That is a total of 7.

TCs then spent time during a class meeting creating word problems to use in each of their three lessons. The template that was given to students required five word problems per lesson. TCs were required to create an opening word problem and then four follow up word problems. TCs were asked to create two of the four follow-up problems to be easier than the opening problem, meaning the numbers were smaller OR there would be more guidance from the TC while teaching young learners. Additionally, two of the follow-up problems were expected to be more challenging than the opening problem with larger numbers and possibly focusing on the use of pictures instead of hands-on manipulatives and less teacher guidance. After students created word problems, they had a class session where they practiced teaching one of their word problems using the process that was detailed above. Similar to the number sense activities, peers provided feedback.

Findings

The findings focused on two areas: 1) TCs provided access to grade-level aligned research-based experiences and 2) TCs providing opportunities for young children to explore problems embedded in

FIGURE 2
Picture of Number Path and Counters



meaningful contexts.

In the first area, TCs effectively planned for and ask questions during the number talk that gradually increased in difficulty- from asking students to share their strategy towards more high-level questions where TCs asked young children to explain why they chose specific strategies. Examples of these questions are: “How is this strategy of finding the total number similar to the strategy we saw earlier?” and “How do you know that your thinking is correct?” TCs also effectively planned for and taught activities where learners used manipulatives and visuals. All TCs were aligned with the desired pedagogies by using manipulatives such as counters or cubes along with Number Paths (Figure 2). While TCs demonstrated some degree of fidelity to the desired pedagogies by planning for and using manipulatives such as counters and cubes in their Practice activity. TCs, though, reported a lot of uncertainty across both courses on how to help students transition from manipulatives to pictures.

In the second area, TCs effectively wrote and taught word problems that were embedded in contexts that were meaningful and relevant to young learners. These problems were about topics that young learners could relate to, such as Latin American food and cultural events for students whose family was from Latin America. However, there were mixed findings on TCs during their teaching. TCs were supposed to pose word problems and guide young children's mathematics work by asking questions; however, a few of the TCs directly taught children with step-by-step instructions that children just mimicked and copied.

Tips and Suggestions Based on This Study

This study found that the practice-based teacher education (PBTE) activities such as Learning, Preparing, Enacting, and Reflecting helped support teacher candidates (TCs) enactment of Inclusive and Equity-Based Mathematics Teaching (IEBMT) with kindergarten learners. Specifically, TCs were able to plan mathematics activities that were relevant to learners and appropriately aligned to their grade level and TCs. Here are some takeaways:

- Practice does make progress. TCs did number talk activities and problem-solving activities as learners, planned their own activities, and

then did practice teaching before using them with children. This practice helped TCs become more comfortable with the activities and how to teach them.

- Focusing on questioning. TCs demonstrated, in a lot of instances, their skills in asking questions about children's math ideas as well as follow-up questions that included more how or why questions about children's use of strategies (see Colonnese et al., 2022).
- Guiding versus directing children. While the approach of practice-based teacher education helped TCs, some TCs reverted back to directing students' process of solving word problems when they sensed that children were struggling instead of guiding them. A lot of practice and discussion may be needed with TCs related to supporting children's problem solving when they are striving to figure out what to do with a word problem.

“Practice does make progress. TCs did number talk activities and problem-solving activities as learners, planned their own activities, and then did practice teaching before using them with children.”

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Empowering Families for STEM Success: How Parental Involvement Shapes Early Childhood Education

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ABSTRACT

As STEM (science, technology, engineering, and mathematics) education becomes a cornerstone of modern curricula, early childhood educators play a critical role in laying its foundation. However, the classroom is only part of the equation. Research shows that families particularly parents with STEM-related knowledge, experiences, and values can profoundly influence children's early interest and success in STEM fields. This article highlights recent findings on STEM-specific parental social capital, summarizes key insights, and offers practical strategies for educators to engage families in meaningful STEM experiences.

KEYWORDS

STEM, teaching practices, preschool children, parent involvement

S TEM-Specific Parental Social Capital

STEM-specific parental social capital refers to the knowledge, resources, and cultural attitudes related to STEM that parents bring into their children's lives. This includes formal education in STEM, careers in related fields, or even informal interests and hobbies involving problem-solving, technology, or scientific thinking. These resources help shape children's learning environments, mindsets, and aspirations—often in subtle but powerful ways.

Key Research Insights for Early Childhood Education

Parental STEM Background Matters

Children whose parents have backgrounds in STEM are more likely to develop confidence in these subjects. They may engage in exploratory play, ask more questions, and receive positive reinforcement when tackling

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STEM-related tasks. For early educators, this highlights the importance of understanding the STEM capital families already possess and finding ways to extend it within the learning environment.

Early Exposure Is Critical

STEM habits of mind—such as inquiry, observation, and logical reasoning—develop early. Children who experience STEM-rich environments at home are more prepared to engage in classroom STEM activities. Integrating STEM into daily routines from a young age helps solidify foundational skills and fosters lifelong curiosity.

Barriers to STEM Engagement Are Real

Many families face barriers to participating in STEM activities, including limited time, lack of confidence, or unfamiliarity with STEM concepts. Culturally and linguistically diverse families may also encounter challenges in accessing resources or feeling welcome in school-based programs.

Family-Based STEM Programs Make a Difference

Programs that invite families to participate in STEM activities together such as science nights, take-home kits, or hands-on workshops significantly boost parental confidence and children's engagement. These shared experiences reinforce learning, normalize STEM conversations at home, and help parents see themselves as capable STEM supporters.

Suggestions for Early Childhood Educators

Parents with STEM resources and expertise play a vital role in shaping their children's learning. At a macro level, federal, state, and philanthropic initiatives can strengthen STEM capacity among educators, students, and families particularly those in underserved communities. These efforts should include parent training on engaging children in STEM and professional development for teachers. Classrooms and curricula must also evolve to support more open-ended, inquiry-driven STEM learning. As research shows, well-resourced schools lead to better student outcomes (Darling-Hammond, 2004).

Parents interviewed in recent studies empha-

sized the importance of giving children time to explore, wonder, and problem-solve independently, suggesting a need to revise curricula to allow for student-centered, exploratory learning. Likewise, parents need flexible time to engage in STEM activities at home. Schools can support this by promoting practices that align both home and classroom STEM experiences.

STEM engagement is influenced by a child's broader environment, including the people, programs, and extracurricular opportunities they encounter. This exosystem plays a significant role, as children benefit indirectly from well-prepared teachers, community partnerships, and university-led initiatives. Higher education institutions can bridge the gap by connecting teachers and families with tools, mentorship, and learning opportunities—ensuring equitable access for all families.

Parents also reported using various STEM tools and resources with their children, underscoring the need for access to practical, user-friendly information. Local universities, libraries, and community STEM events can serve as rich sources of support. Encouraging the formation of parent networks and involving STEM professionals as mentors and role models can further enhance learning.

Teacher collaboration is equally important. Platforms that allow educators, administrators, and community partners to share lesson plans and best practices help ensure all students' STEM needs are met. Developing accessible, home-friendly STEM curricula allows children to demonstrate understanding through hands-on engagement, with tools that parents can confidently use (Glass et al., 2013).

Parents without formal STEM backgrounds may hesitate to explore activities at home, assuming they require expensive materials. However, STEM engagement can thrive when confidence is nurtured, even when experiments don't go as planned. While online resources exist, families often need help locating and using them effectively.

The microsystem direct interactions between children and their environments also shapes STEM learning. The expectations and messages parents share significantly influence children's STEM trajectories (Mara & Toni, 2020). In mathematics, parent expectations are among the strongest predictors of achievement (Wang & Yang, 2019). Aligning efforts across all systems home, school, and community ensures children receive consistent, encouraging STEM messages.

Policy and Program Considerations

- To scale and sustain these efforts, early childhood education systems should:
- Integrate family engagement into STEM curriculum frameworks.
- Provide training for educators on culturally responsive practices.
- Fund initiatives that support home-school connections in STEM.
- Develop metrics that assess the role of STEM in student learning across home and school contexts

Conclusion

STEM success starts early—and it starts at home. When families are invited to be active partners in their children’s STEM education, the benefits ripple outward: children gain confidence, families feel empowered, and educators build stronger learning communities. By recognizing and supporting the vital role families play, early childhood educators can ensure that every child has the opportunity to grow into a curious, capable STEM learner.

Resources for Further Exploration

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Research-to-Practice Summary What do we know? Reflecting on changes in knowledge of mathematical development in pre- and in-service early childhood teachers

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ABSTRACT

This study examines whether students in early childhood teacher education programs gained more knowledge of early math development in 2017-2018 when compared to 2008. I compare data from each period on pre- and in-service teachers' knowledge of mathematical development as measured by the Knowledge of Mathematical Development Survey (KMDS). I found that the KMDS mean scores of students in each of the education groups (beginning versus seniors versus math course) differed within each collection year. In a statistical comparison between the two collection periods, there was no significant difference between the mean scores from 2008 and 2017-2018 for the beginning group. However, there was a significant difference between 2008 and 2017-2018 in mean scores in the seniors and math course groups. Overall, all mean KMDS scores were lower in 2017-2018 when compared to 2008.

KEYWORDS

Early mathematics, early childhood education, preservice, in-service, teachers

How much the world has changed over the last few decades. The phenomenal progress in science, technology, engineering, and mathematics (STEM) is unprecedented. We now live in a world where there are gene-editing cures for inherited diseases (Yang et al., 2024), computing power that continually increases in speed and capacity (Markoff, 2016, 2023), and solar panels that are integrated into building materials (Vijayan et al., 2023). Mathematics has been at the core of all of these advancements.

The use of mathematics is also an essential part of everyday life outside of these professions. Financial knowledge is differentially distributed in the United States resulting in socioeconomic disparities. Those individuals with more knowledge are more likely to apply for and acquire loans with lower interest rates,

manage credit card debt efficiently, obtain financially effective insurance, and save for retirement (Lusardi & Mitchell, 2023). The foundation of these skills is numeracy (Lee & Nam, 2023).

Mathematical development and skills, similar to many other learning domains, builds upon prior knowledge. Research in early mathematical development supports the idea that even infants possess rudimentary mathematical abilities (Visibelli et al., 2024). This knowledge continues to build through the years prior to formal schooling. However, this knowledge is also highly dependent on environmental influences (Gashaj et al., 2023; Silver & Libertus, 2022).

In 2007, Duncan and colleagues published a meta-analysis of influences of preschool-level skills on academic success at 3rd and 5th grade. This and other prior and concurrent studies (Baroody, 2004; Foster, 2010; Grimm et al., 2010; Hooper et al., 2010; Pagani et al., 2010) illustrated the considerable influence of early math knowledge on later academic skills. In the last decade more research has been conducted to determine the influences of early mathematical skills (Duncan & Magnuson, 2011; Geary et al., 2013; Jordan et al., 2009; Kwok et al., 2021). These studies and more continue to support the theory that early and sustained high quality support for mathematical development is a vital part of curriculum. Relatedly, in 2007 new legislation was passed requiring, by 2013, at least 50% of Head Start teachers to possess a bachelor's degree in early childhood education (Improving Head Start for School Readiness Act). The implication was that this education would better ensure that teachers were prepared to support children's intellectual and physical development, including their "understanding of early math" (Section 19, p. 121).

In 2023, the percentage of the U.S. population enrolled in state-funded preschools reached an all-time high of 35% of four-year-olds and seven percent of three-year-olds (Friedman-Krauss et al., 2024). If we broaden the lens to include all non-parental care, almost 70% of families with young children utilize some external early education and care resource, including Head Start (National Academies of Sciences, Engineering and Medicine, 2018, p. 57). These statistics, combined with the knowledge that mathematical development is greatly de-

pendent on environmental influences, highlight the need for these early education and care settings to provide supports for mathematical development.

In fact, studies have shown that early childhood programs that provide a rich mathematics curriculum can result in increases in math, language and literacy skills in young children (Gormley et al., 2018; Joo et al., 2020; Mattera et al., 2021; Sarama et al., 2012; Wang et al., 2016). Black and Latino students may benefit from these programs even more than their peers (National Academies of Sciences, Engineering, and Medicine, 2023). However, many early childhood programs do not provide a rich environment (p. 67).

Many state early learning standards have undergone revisions in the decade under review (Gable & Fozi, 2023; p. 1844), seeking to improve children's early education experiences. However, supporting mathematical development in centers and preschool classrooms requires that teachers are prepared to provide that support. Research evidence prior to and post 2008 indicate that teachers may not be provided with the education and experiences that result in the ability to extend support in their classrooms (Bachman et al., 2018; Cerezci, 2021; Ginsburg et al., 1999; Klibanoff et al., 2006; Sarama et al., 2004). Relatedly, instructors in teacher education programs may not be prepared themselves to provide this essential instruction (Copeman Pettig, et al., 2018; Ginsburg et al., 2006; Wright et al., 2021).

Given this research on the importance of early mathematical development, the influences of its supports in the environment, the preparedness of early childhood teachers to provide that support, and the ability of college and university professors in teacher preparation programs to provide related pedagogical instruction, it is of interest to know whether pre- and in-service early childhood teachers were better prepared to support children in their classrooms in 2017-2018 when compared to 2008. Specifically, do these teachers have more knowledge of mathematical development than those from the previous decade?

Purpose of the Study

Drawing from a dataset gathered in 2008 (Platas, 2008) and data gathered in 2017-2018, I sought

to ascertain whether pre- and in-service teachers' levels of knowledge of mathematical development in young children had changed over the decade. Given that many teacher preparation programs were drastically altered during COVID in 2020-2021 (VanLone et al., 2022; especially with a lack of in-person instruction and student internships), the timing of the research provides a window in which teacher preparation programs were conducted as business-as-usual.

Summary of Research Methods

The participants were recruited through a stratified purposeful sampling method in 2008 (N= 346) and 2017-2018 (N = 338) from community colleges and universities in three states in the western and eastern United States. Three categories of pre- and in-service students in early childhood education teacher preparation programs were created from the pool of participants: beginning (first- and second-year students enrolled in child development entry courses at community colleges and four-year universities), seniors (seniors with no math course), and math course (graduate master's and undergraduate upper division students who had completed a 3-semester unit math development course). Students who did not fit one of these categories were excluded from the analyses.

Participants completed a short demographics survey and the Knowledge of Mathematical Development Survey (KMDS; Platas, 2008; 2014), a 20-item survey on young children's mathematical development. The KMDS was developed in 2007; instrument validation and reliability were supported through several pilots and a validation study (Platas, 2014). It has since been used in several studies (Cox, 2011, Kim, 2013; Lange, Nayfield, et al., 2022). The demographics survey included questions on ethnicity, age, education and teaching experience.

Findings

An analysis of variance (ANOVA) test showed that there were statistically significant differences in 2008 between all KMDS mean scores of the three categories (beginning, seniors, and math course) of pre- and in-service teachers (11.18, 12.81, and

15.30, respectively). In 2017-2018 there were statistically significant differences only between the mean scores of the beginning group (10.58) and seniors group (11.63) when compared to the math course group mean (13.54). This meant that there was no statistically significant difference in 2017-2018 between the beginning and seniors groups.

When comparing 2008 and 2017-2018, there was no statistically significant difference between the beginning group means (11.18 and 10.58, respectively). There was a significant difference between the seniors group means (12.81 and 11.63, respectively; $p = .02$). There was a larger significant difference between the math course group means from each of the years (15.30 and 13.54, respectively; $p < 0.001$). Note that in all comparisons from 2008 and 2017-2018, mean scores from 2008 were significantly higher.

Because the math course groups were drawn from undergraduate, graduate, and mixed undergraduate/graduate courses whereas the beginning and senior groups were drawn from only undergraduate programs, it was important to ascertain whether there was a difference that resulted from enrollment in graduate-level programs (e.g., perhaps the graduate programs were more exclusive in enrollment than the undergraduate programs, resulting in selection bias). However, in a comparison of mean KMDS scores across all eight math courses, there were only significant differences between math course A (graduate course) and courses G and H (undergraduate courses). The remaining 25 comparisons between math courses (undergraduate, graduate, and mixed) showed no differences. In conclusion, results showed that education level did not significantly affect the mean scores across these math courses.

A univariate analysis showed that two or more years of classroom experiences significantly increased mean KMDS scores for only those participants in the math course groups (an increase of 1.02/20 possible points). KMDS scores of the beginning and senior participant groups did not significantly increase with two or more years of classroom experience.

Implications for Practice

In 2008, it was quite difficult to find math

courses in preschool teacher preparation programs. However, the courses I was able to survey were of quite good quality, with all instructors having published research on early math development and teaching. On the contrary, in 2017-2018, it was much easier to find courses to survey. However, of the instructors in 2017-2018, only one had published on math development (the only overlapping math instructor from 2008).

Given the increasing importance of math development in early childhood research and new standards, it could be expected that early childhood teacher preparation program students in the decade following 2008 would graduate better equipped to support mathematical development in centers and classrooms. But the analyses did not support that hypothesis. We know that teachers and teacher educators want what is best for young children. So where is the breakdown?

In Copeman Pettig and colleagues' (2018) study across eight states, teacher educators reported being ill-prepared themselves to teach math in their curriculum. Yet, according to the research, feel compelled to teach it anyway. It appears that the desire is there, but the knowledge is not.

There are resources that could make inroads in remedying this mismatch in desire and knowledge. Head Start itself has rich resources at least going back to 2010. High Five Mathematize (National Head Start Family Literacy Center for the Office of Head Start, 2010) was an early extensive training guide for teachers and those who support them (instructors, mentors, directors). The Head Start Performance Standards are being updated, but the Interactive Head Start Early Learning Outcomes Framework: Age Birth to Five (Office of Head Start, 2015) still contains valuable resources on mathematical development and how to support it.

A multi-university network, the Development and Research in Early Mathematics Education (DREME; n.d.) has free resources specifically for teacher educators. Modules include information on supporting counting, spatial relations, operations, patterns and algebra, and measurement and data in early childhood classrooms. The modules contain short and practical research background readings, descriptions of development, activities for the classroom, and ideas for assessment.

The National Association for the Education

of Young Children (NAEYC; n.d.) publishes both teacher- and educator-friendly articles and books on early math. Many of their publications provide information on mathematical understanding and practical applications for center and preschool classrooms (Turrou et al., 2021).

States also have been legislating support for their early learning math standards (Education Commission of the States, n.d.). These include professional development, coaching resources, teacher preparation program standards, and more.

Finally, as we know, public policies can promote or challenge efforts in the classroom. Policies that come to mind that promote more effective and sustainable math development in the preschool classroom and beyond are better instilling coherence, alignment, and coordination in teacher education programs, school districts, and state standards. Early childhood and elementary teacher education programs can coordinate their instruction so that teachers graduate understanding the full scope of development from birth through elementary and how to support such practices in the classroom (Lange, Robertson, et al., 2022).

“Early childhood and elementary teacher education programs can coordinate their instruction so that teachers graduate understanding the full scope of development from birth through elementary and how to support such practices in the classroom”

School districts and their early childhood partners, whether within or outside the district, can share knowledge about children's progress and teaching pedagogy (Stein & Coburn, 2023). Head Start has examples of this (Cook & Coley, 2019). States can examine their early childhood standards and elementary standards (usually based on the Common Core State Standards; National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) to better ensure that both content and pedagogy are aligned (Whitaker et al., 2022)

Perhaps I am optimistic, but I am hopeful that we will see improvements in all of the preceding policy areas, and that they will result in richer mathematical environments and experiences for our young children. I believe interest and ability are there at all levels, from children to teachers to teacher educators.

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Early Childhood Educator Self-Efficacy for Implementing Early Stem childhood teachers

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ABSTRACT

Research substantiates that providing high-quality STEM activities at an early age is important for young children to become college and career ready (Moore et al, 2016). However, not all educators are as knowledgeable and/or confident in supporting STEM instruction. Research suggests individuals with strong self-efficacy tend to commit to goals that challenge their current capabilities (Bandura, 1993). Therefore, educators may be more inclined to implement STEM lessons if they feel knowledgeable and confident. The study used a multiple methods design including surveys, and self-reflection logs to explore how intentionally designed professional development impacted early childhood educators' self-efficacy in planning and implementing early STEM activities for preschool-age children. The findings found a significant increase from pre-survey to post-survey in early childhood educators' self-efficacies for supporting preschool-age children's STEM activities.

KEYWORDS

Early STEM, self-efficacy, Head Start, STEM instruction, professional development, early childhood educator preparation, preschool

Science and engineering careers are predicted to grow nearly 10% in the United States by 2029 (Bureau of Labor Statistics, 2020). To address the United States' workforce needs, many professional organizations (e.g., National Association for the Education of Young Children (NAEYC), National Council of Teaching Mathematics (NCTM), National Science Teachers Association (NSTA)) through standards, frameworks, guidelines, and position statements advocate for the inclusion of STEM curriculum during the early years (i.e., birth to age five) while young minds are most malleable and capable of developing lifelong thinking skills (Sarama et al, 2018). Purposefully designed STEM activities can help young children develop the character traits of curiosity, problem-solving, and perseverance (Lange et al., 2019). Therefore, young children can and should be engaged in intentionally

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designed and developmentally appropriate early STEM activities as a means of developing interests and a foundational background in STEM (Lange et al., 2019; NAEYC, 2001).

Effective early STEM activities should simultaneously incorporate many or all four STEM disciplines (i.e., science, math, technology, and engineering) using a “play”-based format (Stipek, 2017) to investigate and/or solve phenomenon-based, real-world problem (Lange et al., 2019; Sarama et al., 2018). Phenomenon-based problems are observable facts or events occurring in young children’s everyday life or world. Common phenomenon-based events for preschool-age children may include understanding changes in the weather or seasons, why stars shine in the sky or make patterns, how cold it needs to be for water to freeze, why soda pop makes a bubbly sound, or what plants need to grow (Penuel & Bell, 2016). In addition, early childhood (EC) educators should design STEM activities that encourage young children to: (a) wonder; (b) use multi-modal senses to observe and explore; (c) notice and discover patterns; and (d) learn through trial-and-error (Lange, 2019). These types of experiences increase opportunities for children to take the lead, have more ownership in the learning process, and actively engage in learning.

When EC educators plan early STEM activities such as designing the strongest bridge, tallest tower, or a habitat for a particular animal, children act as engineers, designing and testing possible solutions or prototypes. Based on the results or lack of results, EC educators should encourage children to adjust and/or improve their plan or prototype through trial-and-error (Lange et al., 2019). However, many EC educators report having low self-efficacy related to their ability to design and facilitate early STEM learning due to past experiences and current attitudes and are thus, less inclined to provide STEM opportunities for young children (Gerde et al., 2018). How educators feel, think, and motivate themselves on the job can be influenced by their self-efficacy beliefs (Bandura, 1993). Therefore, educators may be more inclined to implement STEM lessons if they feel knowledgeable and confident for planning and implementing early STEM activities. Providing professional development (PD) designed to develop EC educators’ knowledge and/or confidence to support STEM learning may increase the

likelihood of early STEM implementation.

Current Study

The purpose of this study was to determine how professional development (PD) designed to support participants’ knowledge for planning and implementing early STEM with preschool-age children impacted EC educators’ self-efficacy. There were two main research questions:

1. What impact does a targeted professional development have on early childhood educators’ self-efficacy of early STEM instruction?
2. What impact does a targeted professional development have on early childhood educators’ planning and implementation of STEM instruction?

Participants of the study were, thirteen white, English-speaking females, working in Head Start programs as preschool classroom teachers (54%) or managers/coaches supporting preschool classroom teachers (46%) in the same midwestern state. Most participants fell within the 26 –to-35- year age range (54%), with 31% of the participants in the 36-to-45-year age range. All participants held a bachelor’s degree and for the majority (77%), the degree was in early childhood education (ECE). Those without a bachelor’s degree in ECE had degrees in related fields (e.g., elementary education, social services). On average, participants had seven years of experience working directly with preschool-age children (e.g., ages 3-5) with a range of 3 to 17 years of experience. The participants were enrolled in the same online graduate-level STEM courses and engaged in an ongoing, collaborative STEM project at a midwestern university. The project provided a cohort model of instruction with online graduate courses over a span of one year: two with early STEM concentration, one math, and one specific to deeper understanding of developmentally appropriate practices in ECE.

A multiple methods research design involving two sources of information (e.g. a pre- and post-survey and ten monthly self-reflection logs) was used to gather information about participants’ behaviors and self-efficacies associated with plan-

-ning and implementing early STEM instruction for preschool-age children.

Key Findings

EC educator confidence levels across all four disciplines (i.e., science, technology, engineering, math) increased from pre-survey to post-survey, with a statistically significant difference in the overall survey means ($M = 3.3$; $M = 4.3$). The results from the pre-survey ($M = 3.3$, $SD = 0.5$) and post-survey ($M = 4.3$, $SD = 0.5$) indicate that the participants' self-efficacies for early STEM changed, $t = 25.71$, $p < 0.0001$.

Data from the EC educator self-reflection logs revealed six common themes including: 1) Implementation of Early STEM Activities, 2) Child Responsiveness, 3) Educator Growth, 4) Educator Responsiveness, 5) Sharing with Colleagues, and 6) Hands-on Exploration. The themes are summarized in order of frequency mentioned by the participating EC educators.

Theme 1: Implementation of Early STEM Activities

Participants most frequently described planning and implementing early STEM activities in which young children engineered structures. Examples included children building or creating houses, towers, musical instruments, a sandbox "mud kitchen", water pipes, and sprout houses to plant seeds. They also described using STEM boxes or bins [kits containing purposefully provided materials] to conduct outdoor explorations. For instance, having the children create different-shaped bubble wands with various materials and testing different types of bubble solutions, figuring out how long it took snow to melt, what kind of food ants preferred eating, and building ramps on the playground using different materials to "...zoom matchbox cars down."

Theme 2: Child Responsiveness

Participants often shared perceptions of how children responded to planned/implemented early STEM activities, learning environments, and/or materials. The participants' self-reflection logs frequently included the words, "fun" and "enjoyed"

when describing children's responses to planned/implemented early STEM activities. Enjoyment was noted as a motivating factor that led to the preschool-age children asking if they could do the STEM activities again. Some participants mentioned the preschool-age children wanted to complete the STEM challenge more than once, using their imagination to try to improve upon previous attempts. For instance, "Some of them [children] even got excited when their towers fell because they were able to build it better." The participants' reflection logs also described children engaging in STEM activities by working together and interacting with one another. Preschoolers used the materials provided, building upon their peers' ideas and designs as well as asking and answering questions while learning from one another.

Theme 3: Educator Growth

Many participants' self-reflection logs contained statements reflecting teacher growth or increased self-efficacy for planning and/or implementing early STEM activities. For instance, one shared, "I love how much easier it is getting to implement STEM into day-to-day activities! I see STEM teaching opportunities in places where I hadn't thought of before." Other participants shared that although planning STEM activities takes time, they perceived that it was becoming easier and more attainable with practice. Participants frequently reflected on gains in confidence. One shared, "I am feeling that what I have learned has made me a better teacher and supervisor because now I am able to teach my staff as well which makes me proud."

"I love how much easier it is getting to implement STEM into day-to-day activities! I see STEM teaching opportunities in places where I hadn't thought of before."

Theme 4: Educator Responsiveness

According to participants' self-reflection logs, not

only did the children enjoy the early STEM activities, but many of the EC educators (participants) reported enjoying them as well. For instance, participants stated: “I am having a blast teaching the [STEM] lessons!” and “Teachers loved the activities because they were easy to follow and kept students engaged in activities.” After implementing STEM activities and seeing the children’s responsiveness, several shared goals for doing the same STEM activities again but with improvements or adaptations. Many described wanting to modify and adjust the STEM activity for future STEM implementation. For instance, using a “variety of open-ended materials” was mentioned to enhance young children’s engagement.

Theme 5: Sharing with Colleagues

Participants described planning to share or sharing information or ideas for early STEM instruction with other educators, colleagues, and/or administrators. Several participants described providing early STEM training for colleagues and/or team members. Connectedly, coaching was frequently mentioned as a means of sharing what they learned about early STEM instruction with colleagues and/or other EC educators. Several participants had already coached or planned to coach by sharing specific information and/or resources with colleagues and/or EC educators from the STEM college courses they completed during the study. One participant wrote, “I have encouraged a few of my teaching staff to try and use my STEM kit [created during courses completed as part of the study] in their classroom.”

Theme 6: Hands-on Exploration

When self-reflecting upon early STEM implementation, participants often described how preschool-age children used hands-on materials and manipulatives (i.e., foam pieces, felt, blocks, cardboard tubes, rocks, glue, markers, straws, wooden craft sticks, and clay) to build or create structures or models. Several participants’ self-reflection logs included descriptions of children creating shadows, shapes, houses, buildings, teeter totters, and snowflakes with varied materials. Other participants described how the children solved a particu-

lar problem or challenge using hands-on materials. For instance, after reading a story about the Three Little Pigs, a participant described children using materials to design a house that could withstand the wolf’s “huffing and puffing.” Others described children using hands-on materials to build sprout houses for planting seeds, designing catapults, creating shadow towers, making a volcano out of a pumpkin, crafting animal habitats, and fashioning musical instruments so they could have, “their very own little marching band.” Additionally, some participants described preschool-age children engaging in open-ended opportunities in which they used hands-on materials to explore and create with minimal constraints or directions.

Barriers and/or Challenges to Early STEM Instruction

In addition to the six themes, participants’ self-reflection logs revealed perceived barriers and/or challenges related to implementing early STEM activities for preschool-age children. Some participants mentioned being busy or having other job-related priorities as barriers for implementing early STEM activities. Participants mentioned duties such as completing child assessments and/or preparing for supervisory visits. Others noted the time of the year (e.g., early or late in the school year) as being a challenge, which may be due to teacher home visits and/or parent teacher conferences. Time constraints were also mentioned due to staff shortages. Another barrier that was noted pertained to weather conditions being “too cold,” “rainy,” or “hot.”

Implications

There are several implications of this study that educational leaders, institutes of higher learning, and educators can consider, particularly when designing PD opportunities designed for EC educators’ self-efficacies and instructional practices for supporting STEM learning. Suggestions based upon previous research and/ or the results of our study follow.

Increasing EC Educators’ Self-efficacy for Early STEM Learning

- Create a community of learners by implementing a cohort PD model (e.g., groups of educators receiving similar experiences). EC educators are more willing to share and exchange instructional strategies and/or ideas with others when they are confident and feel 'safe' doing so. The cohort model is designed to increase confidence by providing structure, various levels of support, and opportunities for EC educators to collaborate and receive formative feedback in a low-stake format.
- Tailor PD opportunities to EC educators' needs (e.g., time requirements, geographical location, workload, resources, funding, and time of year). Provide multiple meeting times as well as face-to-face or virtual options for cohort meetings and/or one-on-one coaching.
- Design purposeful, ongoing, and interconnected PD opportunities connected to personal teaching practice and/or instructional settings (i.e., preschool educators, instructional coaches, and program directors) to increase content and pedagogical knowledge (Desimone, 2009; McClure et al., 2017).
- Encourage EC educators to engage in ongoing self-evaluation and goal setting through use of reflection logs, videos, discussions with colleagues, and other like methods.
- Empower EC educators to engage as educational leaders through opportunities to facilitate early STEM PD activities for their teaching teams/colleagues including opportunities to rehearse, analyze, reflect on instructional practices, and set goals (Sarama et al., 2018).

Increasing EC Educators' Planning and Implementation of Early STEM Learning

- Align PD with EC educators' educational settings, allowing for purposefully planning and implementation of early STEM,

meeting the specific needs of the young children they serve.

- Identify and address potential barriers and challenges to EC educators' early STEM implementation (e.g., workload, resources, and busy times of the year).
- For outdoor early STEM implementation, consider solutions and resources for challenges related to predictable weather conditions (e.g., heat, cold, wind, rain, snow).
- Support EC educators' planning and implementation of early STEM activities in which young children simultaneously incorporate many of the STEM disciplines (e.g., Science, Technology, Engineering, and Mathematics).
- Support EC educators' planning and implementation of early STEM activities in which young children investigate and/or solve phenomenon-based, real-world problems (Sarama et al., 2018).

Conclusion

It is essential that EC educators consider how STEM knowledge, skills and experiences may impact school readiness and future career choices of young children. In addition, EC educators should self-reflect on their own knowledge, skills, and dispositions for supporting early STEM, setting short-term and long-term PD goals toward increased self-efficacy. EC educators, particularly those providing care and education to Head Start children, often at higher risk of school failure, need to be well prepared and supported in providing developmentally appropriate and purposefully designed early STEM activities. Preparing the future STEM workforce is not only important for meeting the increased STEM workforce demands, but it can provide pathways toward financial stability through higher compensation and benefits often associated with STEM careers.

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Educational Apps for Young Children: Insights from Parents

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ABSTRACT

Many parents are interested in using educational apps to supplement their children's literacy and math development at home. Research shows that well designed apps can be a tool to support children's learning, however parents might struggle to find well designed apps due to the large number that exist and their overall poor quality. The present study investigated how parents choose educational apps, including their attitudes towards teaching their children, the sources of information they use, and the features they look for in math and literacy apps. Results indicate that parents are motivated to find educational apps but may not be certain about some important instructional features that would make an educational app effective. Practical suggestions based on the findings are provided. Understanding obstacles parents face as well as how they select instructional tools is important in order to identify ways to support parents in finding high quality educational apps that have the potential to supplement education at home.

KEYWORDS

Educational apps, math, literacy, children, parents

C an children learn from educational apps?

As touchscreen devices become an increasingly prevalent part of many young children's lives, there has been an increase in the number of software applications (apps) advertised as 'educational' tools to support young children's learning of foundational skills such as math and literacy. Existing research suggests that children can learn from high quality educational apps. For example, greater math learning gains for four- to five-year olds who spent some instructional time playing with a math app than for the children who completed more traditional paper-based math activities are found (Outhwaite et al., 2023). Another study found similar results for literacy skills in four- to five-year-old children who

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used a literacy app compared to a non-literacy app (Arnold et al., 2021). In addition, when parents or care-providers engage in app use with their children, known as co-use, learning outcomes can be improved (Griffith & Arnold, 2018).

Importantly, these positive results for apps as learning tools reflect research studies where the instructional quality of the apps was carefully controlled. Unfortunately, app stores do not have regulations about what qualifies as an 'educational' app, and research has found that many commercially available apps are of poor quality (Dubé et al., 2019). This means that parents/care-providers are faced with an overwhelming array of apps to choose from but no formal system to discriminate well-designed, instructionally relevant apps from those of poor quality.

What makes a 'good' educational app?

There are some features that are supported by the science of learning that make an app effective. First, the content of an app should be developmentally appropriate. For example, literacy apps for young children should include foundational literacy skills, such as phonological awareness related to letter-sound correspondence and playing with words and sounds such as rhyming or creating word families (e.g., b – bat, m- mat). Math apps for young children should include early counting principles, such as one-to-one correspondence which refers to the knowledge that each item must be counted once and only once, stable order (knowing that the counting sequence is always the same: 1, 2, 3, 4, 5... and so on), and cardinality which refers to knowing that the last number counted represents the total number in the set.

Good apps support children by scaffolding (Vygotsky, 1978) their learning. Scaffolding refers to supports that an adult – or an app – provides to help the child go beyond their current abilities. In apps, this can include features such as difficulty levels, particularly those that respond to the child's performance on activities/tasks by automatically moving up or down to better meet the child's needs. Feedback is also important. Most apps provide feedback for correct answers but many do not provide feedback for incorrect answers (beyond a 'wrong'

sound), which can leave the child guessing how to fix their mistakes (Meyer et al., 2021).

How do parents choose educational apps?

There is some evidence that parents have challenges identifying the best apps, with some of these challenges attributed to inconsistencies or limitations in information on app store descriptions (Montazami et al., 2022). There is also evidence that the criteria parents use to evaluate math apps is different than the criteria used by researchers/experts (Urquhart et al., 2024). However, it is not currently known how parents specifically find and select educational apps. The present study addressed this gap by examining how parents choose educational apps targeting early literacy and math skills.

Method

How did we test this?

Our study included a 30-minute survey which was completed over Zoom. The survey included questions about:

- Math and Literacy: parents' ability to teach foundational math and literacy skills to their child, confidence teaching math and literacy, and self-reported number of math and literacy activities engaged with their child (e.g., baking, using a timer and reading, using magnetic letters).
- Valued app features: parents described features they look for in apps (open-ended questions) as well as identified features from a curated list.
- Sources of information parents use: recommendations from teachers, ratings on websites (e.g., Common Sense Media), rated from strongly disagree to strongly agree.
- Parent-Child co-use of math and literacy apps, estimated from 0 to 100% of the time.
- Disuse of apps: has the parent ever chosen not to let their child use an app they had downloaded and an open-ended question about why they had made this decision.

Who completed our study?

In total, 65 parents of children two- to six-years-old completed the study. The average age of participants was 36.55 years and 89% were mothers while 11% were fathers. In terms of ethnicity, 65% identified as White, 11% South Asian, 11% Southeast Asian, and the remaining 13% included Middle Eastern, Latin American, Black, Indigenous, and West Asian. As to highest level of education completed, 71% completed an undergraduate degree, 19% completed a graduate degree, and 10% completed high school.

Results

Overall 80% of parents said they had downloaded a math app and 86% had downloaded a literacy app. When parents were asked to spontaneously report the top features they look for in an app, the content (e.g., counting, songs), fun, and ease of use appeared for both math and literacy apps. When provided with a list of possible features, parents chose ease of use, quality of educational content, and fun for both math and literacy apps. Parents estimated that on average, they co-used math apps with their child 31.93%, and 35.61% of the time for literacy apps, though responses were highly variable in both cases.

What sources of information did parents use to choose apps?

The sources of information used were the same for selecting math and literacy apps. The six sources endorsed from most to least included:

- Recommendations from teachers
- Recommendations from parents
- Parents' own exploration of the app
- Online ratings
- App store description
- Child's request

Parents also reported often exploring apps before giving it to their child.

Did parental knowledge of and attitudes towards foundational math and literacy concepts influence their app decisions?

Overall, parents were the least certain about

the cardinality principle of counting for math (e.g., generating the correct number of items to match a number) and phonological awareness skills (e.g., clapping syllables in words) for literacy. There was no clear pattern for how parental knowledge affected app choices. Parents who had downloaded an educational app before (either math or literacy) had more positive attitudes towards teaching their child foundational concepts at home than parents who had not downloaded an educational app before. Parents who said they explored apps before giving them to their child reported their child's math and literacy knowledge as higher than parents who said they had not explored apps before giving them to their child.

How often did parents disuse apps and why?

Less than half of parents (44.9% for literacy, 42.9% for math) had disused an educational app before. Of those who had, the top three reasons for both literacy and math app disuse were lack of interest, lack of challenge, and cost.

Interpretations

What do our findings tell us about how parents think about educational apps?

Since the majority of our participants had downloaded both a math and literacy app before, it appears that this is an instructional aid parents are interested in using. In addition, the finding that parents who had downloaded educational apps before rated their attitudes about teaching their child foundational skills as more important than parents who had not downloaded an educational app before further suggests that parents do consider educational apps to be a tool to teach their children. Parents also indicated that of all the sources of information they might consider when choosing apps, a teacher's opinion was the most important and their child's opinion was the least important. This suggests that parents are looking for apps that can support their children's education and that teachers are a valued source for determining what apps to try.

What do parents value in educational apps?

The features parents said they looked for in apps were similar for math and literacy apps, with the functionality of the app (ease of use) and fun as two of the three most important features. This might reflect the previously mentioned overall poor quality of apps available for download – perhaps parents have to look for these basic features because many apps do not meet these criteria. When choosing from a list of features, the quality of the educational content in the app made top three, however, specific features that would make it high quality (e.g., levels and feedback) were not highly endorsed. This suggests that although parents might be looking for educational content, they may not know instructional features that could better support learning for their child.

Recommendations

Three key recommendations from the present study include the role of teachers for guiding parents, and parental exploration and co-use of apps. Specifically, teachers may consider providing app suggestions since they have training in how children learn math and literacy, and parents indicate that they highly value teachers' suggestions. Also, it may be important to encourage parents to explore apps first to identify apps that will or will not work for their child. In addition, co-using the app with their child is known to promote learning (Griffith & Arnold, 2019) and can lead to the parents identifying features in apps more readily. Many of the reasons for disuse mentioned by our participants are things that could be identified by exploring the app and/or co-using the app with their child. These recommendations can support parents to find apps that are developmentally appropriate and engaging for their child.

Scaffolding Skills

Our findings also suggest that parents may need assistance in identifying instructionally relevant design features in apps. Specifically, parents should be encouraged to seek out apps that have levels of difficulty built into the app design. This could include

levels that the user can select themselves, or that the app automatically adjusts based on the child's performance. Automatic levels are often preferable.

Parents should also be encouraged to look for feedback in apps. High quality feedback for incorrect responses will allow users to work toward an answer by providing increasing levels of guidance. Medium quality feedback for incorrect responses will include explanations. Poor quality feedback for incorrect responses will simply be a 'wrong' sound.

Math Skills

The specific skills should be tailored to the child; however, there are foundational math skills specifically the counting principles to look for:

One-to-one correspondence: activities that enforce the idea that each item is counted once and only once.

- Stable order: activities that enforce the idea that the counting sequence is always the same (1, 2, 3, 4, 5... and so on).
- Cardinality: activities that enforce the idea that IF the first two concepts are applied, the last number counted represents the total number in the set.
- Activities that support this skill could include a scale with different quantities on each side, finding the total number, and voiceovers that reinforce the emphasis on the last number.

Literacy Skills

Phonological awareness is an important predictor of reading. Activities that target phonological awareness might include:

- Discriminating between sounds, particularly sounds letters represent.
- Identifying syllables in words.
- Manipulating the sounds in words, such as changing the starting, middle, or ending sound (e.g., bat mat map mop).
- Rhyming activities.

Conclusion

As more educational apps are developed each year, and parents face pressures to educate their

children without being explicitly trained to choose between available educational tools, it is important for researchers to continue to find ways to support this process. Our results highlight parents' motivations to find educational apps and aspects where they can use extra support to do so effectively.

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