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Research

STEM Integrated Curriculums in Early Childhood Education: An Exploration of Teachers' Pedagogical Beliefs and Practices

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Young children are perfectly adapted to learning STEM concepts. A growing body of research indicates that experiences with science, Technology, Engineering, and Mathematics (STEM) are critical in preparing young children to think critically and creatively and solve problems. These are valuable skills young children need to succeed in school, work, and life. This raising awareness of STEM education needs has pushed for STEM integration in early childhood (EC) settings while giving limited attention to the teaching of STEM in the EC field and targeted STEM professional development programs. This qualitative study aimed to explore the EC teachers' pedagogical beliefs and practices about STEM-integrated curriculums and STEM teaching in pre-K settings after attending a series of STEM integration teacher professional development programs in an eastern state in the United States. Five EC teachers participated in in-person interviews after attending a series of professional development sessions designed to help teachers develop both content knowledge and pedagogical knowledge related to the STEM curriculum. A qualitative inductive approach was used for the data analysis. The analysis of data collected from interviews with EC teachers revealed that they were positively impacted by the STEM-integrated professional development, resources, and materials available to implement the STEM units. According to the teachers' beliefs, children were also positively impacted by their teacher's professional learning and high confidence in teaching STEM-related topics and activities. A discussion of the findings and implications for future research and practice is presented. Recommendations are also discussed for how teachers can effectively teach integrated STEM education.

STEM; STEM integration; STEM curriculum; Early childhood; Pre-k, Professional development

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INTRODUCTION

As the studies on science, technology, engineering, and mathematics (STEM) in early childhood (EC) education overwhelmingly focus on child learning outcomes, factors such as early childhood teachers' belief about STEM integration as well as their professional preparation to fully embrace STEM in their classroom are yet waiting to be investigated and understood (Martín-Páez et al., 2019). Integrated STEM education is **an effort to combine science, technology, engineering, and mathematics into one class that is based on connections between the subjects and real-world problems**. However, in general, integrated STEM education can involve multiple classes and teachers do not have to always involve all four disciplines of STEM (Hapgood et al., 2020). Research shows that introducing STEM into the class curriculum before the age of eight can have a significant impact on children's academic success and support learning later in life, in STEM and other areas, such as developing reading and language skills (Chen et al., 2021; MacDonald et al., 2020; Ryu et al., 2019). Young learners can understand relatively advanced concepts and enjoy learning experiences that explore such concepts. It is argued that STEM education should start in early childhood since concepts at the heart of STEM, including curiosity, creativity, collaboration, and critical thinking, are in demand (Hapgood et al., 2020).

Research also consistently shows that an earlier introduction to STEM education provides interdisciplinary development across numerous subjects, including literacy. When STEM is introduced early to young minds, they are given the opportunity to communicate and explain complex reasoning, an essential skill in language development. This complementary effect is seen across various interdisciplinary studies (Chen et al., 2021; Margot & Kettler, 2019). STEM helps young minds exercise skills and functions that influence their learning, such as problem-solving, critical thinking, conceptual learning, and verbal communication skills. The stronger these skills are at a young age, the easier the mind can absorb, categorize, and utilize information in later studies and across various subjects (Campbell et al., 2006). Moreover, research reveals that incorporating STEM into natural communication environments can support improvement in social communication by building on how children learn and explore the world while supporting the exploration of STEM concepts by promoting questioning and problem-solving (Moore et al., 2020). Although children show natural curiosity about their world and a remarkable capacity for independent learning, they need adult assistance to support, guide and build on their interests to ensure adequate early STEM experiences (Martín-Páez et al., 2019). At present, it seems that inadequate attention is being paid to the teaching of STEM in EC education. Less than five percent of instructional time in formal EC education settings is devoted to STEM learning. This may partly be due to EC education providers being inadequately prepared for STEM teaching, including few EC teachers who have taken the full complement of STEM courses in life sciences, natural sciences, and mathematics as part of their formal education and may need formal training in these fields as part of their professional development (PD) (Wan et al., 2021). According to NAE and NRC (2014), STEM literate means (1) awareness of the roles of science, technology, engineering, and mathematics in modern society; (2) familiarity with at least some of the fundamental concepts from each area; and (3) a basic level of application fluency (e.g., the ability to critically evaluate the science or engineering content in a news report, conduct basic troubleshooting of common technologies, and perform basic mathematical operations relevant to daily life) (p. 34). It is argued that STEM literacy is not a strength of many EC teacher preparation programs and more needs to be done to make sure that EC teachers leave the preparatory programs with enough knowledge, skills, and expertise to implement STEM units with quality and confidence in their classrooms as teachers are the essential agent in establishing a STEM-integrated early childhood curriculum (Wan et al., 2021).

STEM-Integration: What Research Shows

As a growing field of study, STEM integration in EC education has started taking its fair share in the research literature. Brenneman et al. (2019) designed a professional development (PD) model to empower preschool educators to provide rich, high-quality STEM learning experiences, particularly working in schools serving children from culturally and linguistically diverse backgrounds. The authors reported that their model was relevant, effective, culturally appropriate, and flexible enough to be implemented within any curricula and with a variety of materials for teachers and children. Their model resulted in considerable academic and developmental gains for the serving students and relevant PD for the participating teachers. In another study by Ryu et al. (2019), an integrated- STEM education methods course was developed for preservice teachers in STEM disciplines. The authors reported that while the students successfully developed STEM integration lessons and taught them, they faced challenges attributable to current school practices, limited interdisciplinary understandings, and a lack of role models. Bagiati and Evangelou (2015) examined a preschool teacher's experience implementing an early engineering curriculum. The findings revealed that different factors either discouraged or facilitated the implementation of the early engineering curriculum in early childhood education classrooms. Deterring factors were teachers' hesitation in trying specific instructional methods, lack of time to invest in engineering activities, and developmental differences among children. On the other hand, the facilitating factors included constructive feedback post-implementation of the curriculum, the teacher's confidence gained through her years of experience, and collaboration with parents. The authors also reported that the teacher's motivation, willingness to try new ideas, and critical reflection on their practice boosted the positive outcomes of their study.

Teachers need sustained science-specific training to make STEM education a success. Atiles et al. (2013) examined whether PD in science education would enhance EC teachers' content knowledge and self-efficacy in teaching science. The study results revealed that ongoing PD significantly improved teachers' knowledge of science concepts and their self-efficacy toward teaching science. The researchers in this study stressed the importance of modeling and hands-on training toward science activities incorporated into the PD of early childhood teachers. As PD would also need to include other aspects of STEM besides science. Technology, engineering, and mathematics would need to be incorporated as well. Guzey et al. (2016) designed and delivered a year-long teacher PD program to address the need to support science teachers in teaching science while focusing on more and deeper connections among STEM subjects. The findings revealed that the teachers developed STEM integration curricular units that address the characteristics of the STEM integration framework and STEM-ICA, which are supported by the literature and new reform documents.

Teachers' Belief

In the teaching profession, teachers' early memories of schooling, type of PD, and interactions with different stakeholders (e.g., school administration, family, community members, media, etc.) play a significant role in shaping their beliefs (Chen et al., 2021). Kagan defines teachers' beliefs as "tacit, often unconsciously held assumptions about students, classrooms, and the academic material to be taught" (Kagan, 1992, p. 65). Fang (1996) argues that "teachers' theoretical knowledge and beliefs" (p. 49) influence their curriculum design decisions and, consequently, the instructional methods they utilize, as well as the quality and depth of the interactions they have with their students in class. Furthermore, Teachers' theoretical knowledge and beliefs could impact the value a teacher places on teaching certain subject matters or different instructional methods. Chen et al. (2014) report that early childhood teachers' beliefs about what is more important in young children's education influence their decision regarding what to prioritize in the classroom. The authors further argue that misinterpretation of child-centered Developmentally Appropriate Practice (DAP) causes practitioners to think that content areas such as math are inappropriate to prioritize in early childhood education. This notion is an example of how teachers' beliefs often function as mechanisms to either confirm or refute new professional knowledge and skills that demand a change in their existing teaching practice. Park et al. (2016) studied early childhood teachers' beliefs about their readiness to teach STEM concepts. The researchers specifically examined the relationship between their practical experience in class and their perception of teaching STEM in early childhood. Participants were also prompted to list the challenges they might encounter with incorporating STEM into their curriculum and instruction. Lack of time to plan, lack of resources, inadequate PD and administrative support, lack of knowledge about STEM topics, lack of parent participation, and lack of collaboration with other teachers were among the challenges they mentioned. This study's results implicate that more PD is needed to transform teachers' perceptions about the importance of STEM in early childhood education. Such PD must equip teachers with comprehensive content knowledge, pedagogical strategies, and skills to plan and instruct STEM-integrated curricula in their classrooms.

Purpose of the Study

Unfortunately, research shows that many teachers, particularly EC teachers, not only lack confidence in teaching STEM subjects but are also ill-prepared in content and pedagogy to effectively engage young children in developmentally appropriate STEM learning (Aldemir & Kermani, 2017; Simoncini & Lasen, 2018). For EC programs to include quality STEM education, it is important to understand teachers' beliefs and perceptions about STEM-related PD. As a critical factor in young children's development, teachers hold prior views and experiences that will influence their STEM instruction (Brenneman et al., 2019). The view of EC teachers presented in this paper helps us explore some pedagogical beliefs about a newly recognized phenomenon: science, technology, engineering, and math (STEM) integration in the early childhood education curriculum following a series of PD sessions. The review of research literature also revealed that there is limited research looking at early childhood teachers' pedagogical beliefs regarding STEM integrated curriculum. Thus, this study aimed to explore the EC teachers' pedagogical beliefs and practices about STEM integrated curriculums and teaching STEM in pre-K settings after attending a series of STEM integration teacher professional development programs. The following research question guided this study:

RQ: How did the EC teachers perceive the impact of STEM-integrated PDs on their pedagogical beliefs and practices about STEM integrated curriculums and STEM teaching in pre-K settings?

STEM Integrated Curriculum Professional Development Project

The lead teachers in this study received a series of PD sessions designed to help teachers develop both content knowledge and pedagogical knowledge related to the STEM curriculum. The same PD series were also extended to all five teacher assistants from those classrooms. However, they could not participate fully due to other tasks and responsibilities at school (e.g., driving the bus, helping with afterschool duties, etc.). Each teacher participated in three formal PD sessions over the course of the study. The study was completed in 10 weeks (March through mid-May). PD sessions were continuous (90 minutes each) and facilitated by two researchers and a former kindergarten teacher with expertise in science and engineering. The content of each PD session targeted the STEM curriculum topics pre-selected by the teachers themselves: living and non-living, ocean animals, human body, weather and water, and motion. All the topics were explored via project-based learning activities. In each session, the participants discussed, brainstormed on teaching strategies and activities, and investigated and practiced the process as they would in the classroom with a group of young children. Moreover, two researchers served as mentors and support for engaging teachers in conversations about their practice and helping plan and implement units/projects when needed.

METHOD

Research Approach

Based on the nature and number of the participants, a qualitative research approach was used to gain a rich description of the participants' experiences and perspectives (Hatch, 2002). According to Merriam (2009), qualitative researchers are "interested in understanding how people interpret their experiences, how they construct their world, and what meaning they attribute to their experiences" (p.5). A phenomenological design was chosen to understand the participants' perceptions. Phenomenological design in qualitative research focuses on lived experiences of participants about a phenomenon and includes the study of "phenomena," including appearances of things or things as they appear in people's experiences along with relevant conditions of experiences (Creswell, 2013). In this study, we considered the EC teachers' lived experiences throughout the STEM-integrated PDs as the phenomenon.

Participants and Settings

Participants included five teachers, three from a public Pre-K Center and two Pre-K teachers from a Head Start program in a small town in an eastern State in the US. All five teachers were female (Four White and one African American), ranging in age from 29 to 40. As lead teachers in their classroom, they were responsible for planning and implementing the curriculum and assessing their students. All five teachers were licensed in Birth-Kindergarten, and two of them also enrolled in a graduate program. The teachers' experience at the Pre-K level ranged from three to ten years as lead teachers. All five teachers volunteered to participate in this study and were willing to share their project work and documentation as part of this research. Please see Table 1 for a summary of the participants' demographics.

Table 1

Participants' Demographic

	Age	Gender	Work Experience (years)	Ethnicity	Educational Degree	Program Setting
Teacher#1	34	Female	6	White	B. A	Public Pre-K
Teacher#2	30	Female	3	White	B. A	Head Start
Teacher#3	29	Female	5	White	B. A	Public Pre-K
Teacher#4	33	Female	5	White	B. A	Public Pre-K
Teacher#5	40	Female	10	African American	B. A	Head Start

Data Collection

Once University Institutional Review Board (IRB) approval was granted, early childhood teachers at two public schools (public Pre-K and Head Start) were approached and invited to participate in the study. Formal invitation letters were sent to all lead teachers at the public Pre-K and Head Start programs. Head Start/Early Head Start (HS/EHS) is a federal program in the U.S. that promotes children's school readiness from birth to age five from low-income families by enhancing their cognitive, social, and emotional development. To qualify, families must have an annual household income (before taxes) below the specific amounts established by the federal agencies (U.S. Department of Health and Human Services, 2020). Three public Pre-K and two Head Start teachers expressed interest and volunteered to participate in the study. Upon receiving teachers' interest in participation, the researchers met with the participants in person, reviewed the study procedures, and addressed all the questions about participation. Permission to participate in the study was obtained through verbal and written consent of the participating teachers. The data was collected through in-person interviews lasting 90-120 minutes each (Please see Table 2 for interview questions). The interviews were scheduled one week after the STEM integration PD completion. All interviews were done in person and conducted by one of the researchers who was not involved in the PD sessions as a mentor or support and had minimal contact and familiarity with the participants.

Table 2

Interview Questions

1. Please describe your experience of participating in this project.
2. What were some of the highlights of implementing STEM in your class? What was the greatest success that you can share?
3. When implementing STEM, what was the response among students?
4. What changes did you notice in children's overall learning? Can you give some specific examples of these changes?
5. How did the project (PD) help with the learning of content in STEM for you or your students?
6. How did this project reinforce or change your attitudes toward math, science, engineering, or technology?
7. How has it reinforced or changed your practice in teaching STEM?
8. Did this project make you want to try other experiences/projects/opportunities with STEM? Why or why not?
9. How do you see yourself (or your colleagues) implementing the STEM model in the following years?
10. What have been some of the challenges to implementing STEM?

The interviews were digitally audio-recorded, while the researcher took notes as a backup for content analysis. Specific prompts related to the interview questions were provided when necessary. Multiple strategies were implemented to establish member checks (Creswell, 2021). First, at the end of each interview, the interviewer summarized the major points EC teachers made to ensure she understood the major points raised and to seek clarification if needed. The interviewer also frequently rephrased EC teachers' comments throughout the process to ensure the data were accurate. Second, EC teachers were offered a copy of the interview transcript for review, although no EC teacher chose to do so. These strategies ensured that the data accurately reflected EC teachers' perceptions.

Data Analysis

The organization of the data and systematic analysis were carried out in line with the procedures delineated by Braun and Clarke (2006) and following the quality indicators of qualitative studies proposed by Brantlinger et al. (2005). An inductive approach was used for the data analysis. First, interviews were transcribed, and an analysis of the descriptive content by reading and rereading the data was performed. Any initial ideas taken from the text were also noted during this first step. Second, the interview's representative topics were categorized based on the developed units of meaning (Willig, 2013). Third, specific topic categories were defined around each of the broad categories. Finally, each topic that had emerged was defined, and the most representative verbatim statements were selected for each. Credibility procedures, such as peer review, were used to ensure that the coding of the topics was consistent. The initial set of codes from the interviews was created by one researcher, who then met with a second researcher to discuss the initial coding frame. The researchers met regularly throughout the coding process to discuss emerging codes and reach a final consensus. Subsequently, each researcher coded two sets of the same interview responses independently to check for coder agreement. The two researchers showed good agreement (78%) in their coding of the same interview responses. For the inconsistencies in the codes, the researcher reached a consensus. Written field notes were also used to examine the trustworthiness of the data throughout the study (Creswell, 2009).

Ethical Considerations

Data collection initiated after securing the Institutional Review Board (protocol number#H1213-099). All participipinats signed an infomed consent form before interviews. Names corresponding to audio recordings were kept confidential. Participants could withdraw from the study at any time with no penalty. Pseudonyms were used to protect participants' identity. All data including the recordings and notes, were stored in a locked cabinet. Any computer containing participants' data were password protected. Apart from the researchers, no other persons had access to the data. All data were de-identified and identified data (e.g., voice recordings) will be destroyed three years after final data collection.

RESULTS

Five themes emerged from the analysis of the interview data. The following section explains each piece exemplified with quotations from the participants.

Teacher Learning and Understanding of STEM Curriculum

The STEM curriculum professional development (PD) was designed to allow teachers to become familiar and comfortable with both content and pedagogy surrounding the STEM curriculum. All five teachers were provided STEM-related resources (STEM materials, laptops, iPad, digital cameras, etc.) that they could utilize in their classrooms. Furthermore, the research team supported teachers' curriculum plans with desired materials (informational books, body parts props, PVC pipes, loose parts, learning Apps to supplement the contents, etc.). In their interview, all five teachers reported how their pedagogical practice was impacted by such PD. According to the participants, the PD helped them widen their knowledge and skills in STEM subjects. EC teachers mentioned that the STEM curriculum PD helped them be better teachers because the more they learned, the more they could help children learn in their classes. It was a mutual benefiting process in which they felt empowered to develop themselves professionally and better serve their children and their families. According to one of the participants:

> Prior to the STEM curriculum, the way I looked at things, I was sometimes thinking inside of the box, and it was repetition. You know you come in; you have your morning meeting, and you go to centers. This type of learning occurred all day. Now, it doesn't have to be a small group setting, and it doesn't have to be a center… it can be… learning can occur anywhere, at any time. And sometimes it does have to be planned, and sometimes it's just by chance. So, it's, that's what I gained out of the STEM project.

EC teachers also talked about how the PDs in STEM integration excited them and made them more confident to explore ideas and concepts instead of being overly bossed with the end product. Participants believed that they have been much more intentional in their teaching of STEM, and they could cover the topics and concepts much more in-depth rather than just "zipping through" just for the sake of coverage. They believed that after the PDs, they had great experiences exploring STEM with the children in the class. One of the participants stated:

> Over the years, deep down, I knew of the importance of science for children. I guess I was practicing the "tourist curriculum" without knowing it. Still, for some odd reasons, perhaps my lack of confidence and/or lack of resources, I stayed away from offering authentic science activities. Or, if I did, they were simple activities like fall leaves or superficially studying the plants by naming/labeling their parts. Since the STEM integration curriculum, I am more aware of children's interests, responses, and likes.

The EC teachers also mentioned that STEM curriculum PD made them much more aware of how they were teaching the concepts. It made them much more aware of the questions they ask the children and how they recognize what children are learning. They also expressed appreciation for feeling more focused and purposeful in what we were doing after the STEM curriculum PD. One of the EC teachers shared:

> Like, I was aware I needed to start thinking more about science things and how can we use technology, so like we are videotaping and going to YouTube a lot more. Looking things up on google, showing pre-K kids, you know, we want to find out about trees, so what type of question could we type into the computer? Is this the answer we are looking for, and if not, well, how could we ask our question differently? Stuff that I might not have thought to do with preschoolers before, at least not to that extent!

Overall, the EC teachers shared that they gained a deeper understanding of STEM from a holistic perspective, whereas, before the PDs, all focused more on the science part of the curriculum and skipped the math aspect. All teachers (as explained above) realized that they had often stayed within the boundaries of the common practice employed in their programs regarding curriculum planning. According to the EC teachers, STEM PD sessions encouraged them to try different pedagogical practices, such as intentional teaching or trying different modalities to search for new information.

Increased Confidence in Teaching STEM

As part of the PD, the participants were provided with hands-on learning experiences focused on pedagogical and STEM content knowledge. As mentioned earlier, our goal was to provide the teachers with some of the same STEM-integrated experiences their students will have in the classroom. During the interviews, the EC teachers mentioned that this focus on pedagogical and STEM content knowledge helped boost teachers' confidence in both planning and implementing the STEM-integrated curriculum. Furthermore, EC teachers showed more commitment to STEM as they gained more comfort in handling STEM-related activities and materials. All teachers believed they gained some confidence in STEM, which helped them with planning and implementation. Three of the EC teachers expressed implementing the STEM curriculum in their classrooms with a high level of knowledge, comfort, and pedagogical skills in STEM, whereas two of the teachers shared that they still need more practice to feel confident enough with STEM implementation. One of the EC teachers explained how she learned about STEM as indicated below:

> When we were approached for the STEM project, I bought a book about STEM from teachers' aid--that way, I had a better understanding before actually implementing ideas or lessons into the classroom, and then with our PD days, the booklet and the resources that you brought us it was easy to research different lessons to implement in the classroom.

Similarly, another EC teacher explained how the STEM project helped her shift her focus from getting the correct answers to using the proper process when planning and implementing STEM-integrated lessons.

> The thing about science is that there is no right or wrong answer. When I am planning, I like to be right! But with this project [STEM], I learned that whatever happens, happens! The end is going to be whatever it is. We just learn what happens when we get there and, that's the attitude of a lot of kids too—try it, we didn't get the result we wanted, what can we do to get there? I really enjoyed this process….Now I am more hands-on.

EC teachers expressed that after the STEM curriculum PDs, they were taking a more project-based approach where children could get out to explore by themselves. The STEM PDs provided the EC teachers with a different perspective on their roles as teachers, where they learned to offer more opportunities to children to come up with their own blueprint. This required the EC teachers to step back and give children only the beginning of the tasks and let them figure out the middle and end, something they had not been doing before. The EC teachers also explained children's excitement about the STEM curriculum and new ways of practicing STEM concepts and believed that these strategies have been able to energize their pedagogical practices. According to one of the EC teachers:

> I got really excited when I saw how excited they [children] were, and I was like, yes, this is awesome; it's working! That way, it was easier because then I got into the groove of how they are learning and how they are picking this up. On the other hand, it's harder because then you have to keep up with them. You have to be ready and anticipate what they are going to go with, and you have to be able to be flexible in some ways, but some things we just couldn't do.

Two of the teachers shared that shifting their practices and being prepared to the extent required was somewhat difficult at first. However, they also acknowledged all the benefits and were confident they would continue those practices into next year. As one of the teachers mentioned: "It's like a good habit that I've started to form. It's been so beneficial that we will keep doing what we've been doing these last couple of months".

Need for STEM-Related Materials and Resources

As part of this study, each classroom received a collection of STEM-related materials and resources for children as well as teachers and helped the teachers be more effective in their practice and implementation of the STEM curriculum. During the interviews, all teachers revealed that the provision of STEM-related materials and resources motivated both their learning and teaching practice. All EC teachers believed that an integrated STEM curriculum requires appropriate and stimulating materials and resources for teachers as well as children to investigate, problem-solve, design, and test and retest hypotheses. If schools do not have sufficient funds to afford appropriate materials and consumable supplies, it might hinder teachers from effectively engaging their students with STEM-related activities. One of the EC teachers shared:

> I can encourage this STEM curriculum, but having the tools to support that, like having the iPad and the internet, the laptops, and digital cameras for them to document their own stuff, makes it more exciting. So, I think they felt like they [children] had more independence and control over what they were learning.

The EC teachers also expressed their appreciation for the materials and resources they received as part of STEM PDs and believed that those resources improved their classrooms and made their classes less chaotic as children had something to play with. It also helped the teachers feel more hands-on and prepared with the activities they wanted to do with children in the class, as they did not need to figure out the availability of materials and resources to plan an activity. According to one of the teachers:

> The more you guys brought in, the less chaotic my class got. Instead of what activity I would come up with today, it was let's go here, let's build this. Children would initiate what they wanted to do, which made a big difference for them and the children.

Another teacher also commented:

> Instead of [TA] and I think of what activity to do--we had to improvise a lot before this project--making a lot of teacher-made activities! At the beginning of the school year, we sent out a list of materials we needed to the parents, but we did not get anything. Thanks to this project, our children received some interesting materials.

As brought up by the EC teachers, having the right materials not only was a benefit, but also, during the STEM PDs they realized how they could turn even the simplest thing into a math, science, engineering, or technology activity. They acknowledged that sometimes teachers forget that children do not necessarily need fancy stuff to learn and get excited about STEM. According to them, having the right preparation, curriculum, resources, and questions to ask the children will intrigue their curiosity. One of the EC teachers explained her experiences as below:

> The extra materials were definitely a plus for the kids, especially the digital cameras. Children loved taking pictures of things we were studying. For example, when we were exploring the topic of living and nonliving, children took photos of different objects in class or on the playground to later label [them] as living or nonliving. For this particular activity, we put the images into a PowerPoint Presentation. During one of our circle times, I played it, and each child would explain their photo and why they thought it was living or nonliving. The children were so proud of their pics, which allowed for a great conversation and many questions to explore further. I loved it when the children would say, "Ms.[teacher], we should explore this [topic or question] more. We can google it to find out…They were excited and pretty much part of the learning process.

Children's Learning

A common theme found in teachers' interviews was the extent and quality of learning that occurred among children. Overwhelmingly, teachers explained that the STEM curriculum offered their students numerous opportunities to be active, engaged, and take the initiative in their own learning. The EC teachers saw a significant association between their content, pedagogical knowledge, and children's learning. They believed the higher the teachers' competence in pedagogical and STEM content knowledge, the greater the students' level of engagement and conversations surrounding the STEM units and activities. As one of the teachers said:

> I think there was a lot of learning going on in the classroom. They [children] were active; they were engaged; they didn't want for it to end. So, it was really nice that this classroom was picked. And these children got to experience it, you know it helped me as a teacher grow, and it helped the children grow as well. Thus, overall, it was GREAT!

The EC teachers also talked about the impact of STEM on children becoming much better thinkers and questioners and paying more attention to how things were working or why they were the way they were, rather than just this is what it is. EC teachers believed that STEM encouraged children to want to know more information, and they asked more questions and tried to find ways to solve those problems. One of the teachers shared:

> I think, not thinking about their scores and what they were tested on, children were much better thinkers. They started asking good questions and then taking those answers and applying them to new experiences. Children started asking more questions. Wanting to work more independently, kind of explore on their own…. The kids wanted to learn!

According to the EC teachers, one of the greatest successes of STEM PDs was the impact they had on the children and the experiences they were able to have. Some teachers shared that even the most impulsive and squirmiest children in their classes were asking good questions and retaining the answers. The teachers could clearly see the content was getting through to them, and they were learning, and I could see it quickly and immediately because they were asking these questions.

> One little boy asked what the word research was because we were doing some research. So, I explained it to him, and the next time we were on the carpet, I asked how could we figure this out, and another kid goes, "we could do some research"! So, it's staying with them, and I think they were learning how to think and figure things out. I think that was the biggest success-even more than what they were learning about the topics.

Some EC teachers also expressed that partnering up with these STEM PDs made their students think outside the box. Before they did any major project, children had learned how to develop their own blueprint, for how they would build it. They also liked the technology part of the PDs as it kept children engaged. I do not know if they played with those types of tools at home. However, they really liked them. Children would help each other with the games if they did not know how to play them. The teachers believed that instead of the teachers having to model and tell the children what they needed to do, children were able to take ownership of their learning. One of the teachers explained her experiences as below:

> When making a bridge, children at each table worked together and created their blueprint, how many pieces of wood we needed to reach from this part to that part, and what we needed to glue them together. It was a lot of discussion, hands-on, them figuring out vs. us telling them what to do. Here everyone's bridge was different even though we used the same concept. Every bridge was different because they were allowed to show their individuality.

According to the teachers, the STEM integrated curriculum has enabled all children with different abilities to benefit from the content and activities. For the ones at the higher end of learning, it reinforced skills that they already knew, but, more importantly, taught them how to work with and teach their peers needing help. The children at the lower end of the scale made improvements in areas they wouldn't have otherwise without implementing this project. This, according to the teachers, transformed their approach to teaching. Teachers believed the depth given to each lesson helped children learn the material at a deeper level and stay engaged with the materials for a more extended time. One teacher shared:

> Seeing all the children engaged with the materials and content was nice! This year, I had a very active group of children, so I was constantly putting out new materials/activities to keep them "busy and occupied." Instead of focusing on pre-planned themes and introducing fast-paced lessons/activities, I introduced fewer activities with much richer content. Following children's interests, I offered the activities in various modalities so that all children could participate and learn in their own way.

Teachers also shared that the hands-on component and the novelty of the materials [iPads, digital cameras, props, loose parts, etc.] not only helped with learning content but also with some behavioral challenges. To these teachers, the quality and variety of the materials and activities helped children to be more independent, creative, and less confrontational. They showed interest in the activities and had better self-control. This also gave teachers more opportunities to interact with children and facilitate their learning. Children were totally in charge and would share their learning with confidence. Teachers also observed that even those children who would seldom participate in in-group conversation were contributing with much enthusiasm. EC teachers found watching children engage deeply and creatively with the target topics and content exciting and motivating. As one teacher stated:

> So, it was less time spent on managing children's behavior and more time on learning together—Totally a win-win situation! For example, when studying the unit on water, we researched the topic by learning about the water cycle and its importance to living things. Children brainstormed ideas, asked interesting questions, and offered strategies to examine water further. We looked at pictures,

read informational books, asked our local library for other picture books on water, and watched short video clips on the types of water in the ocean, lake, river, marsh, swamp, etc.

Integration Challenges

In their interview, although all EC teachers unequivocally marveled about the benefits of the STEM project, they also shared several challenges in implementing it. As part of the study, teachers were asked to complete reflective journals; collaborate with other teachers to plan if possible; facilitate children's technology use; and document children's learning. However, teachers explained that it was hard to keep up with all these whiles at the same time addressing the goals and assessments required by the state and their school curriculum/curricula. Teachers from Public Pre-K used a combination of curricula, Opening the World of Learning (OWL), Number Worlds, and CIRCLE, whereas teachers from the Head Start program used the Creative Curriculum. Some of the teachers also mentioned that they had children with Individualized Education Programs (IEPs) and some with the high end as far as learning abilities which made it more challenging to get their attention and get them to want to work in a group.

According to one of the teachers:

> It was hard to fully commit to it because of the other things going on. I think it was the time of the year too! The end of the year was hard because students are getting ready to move on and other things going on with testing and parent conferences, wrapping up everything, and planning for the end of the year celebration…

Some teachers also brought up challenges with the technology piece. They shared that the technology piece was attractive to many of the children in the class, but the frequent daily glitches made it challenging to work with it, and they thought that having a technology person available to help with the issues would have been a great help. One of the teachers brought up:

> It was very helpful when someone came to help with the computers because the kids really liked the computers/ iPads. However, we had some mornings that the games on the computers would freeze, and we had to restart it, and the kids had to wait…. They didn't like that. So, it was nice to have someone to help with that.

The teachers also talked about the challenge of whole-class documentation. To these teachers, it was not easy to keep up with the documentation and the school requirements. Sometimes they had to prioritize, and unfortunately, one had to be put aside, and if they did not get to it on the same day, it was hard to pick up where it was left off. As one of the teachers shared:

> The challenge was the documentation piece because sometimes you would be so involved in an activity and you were thinking, Okay, I gotta stop because I have to document this with pictures or, ya know, I gotta write my notes down.

Some teachers talked about having difficulty finding time to collaborate with their colleagues and share STEM ideas in a true sense. They believed such collaboration was necessary to share, brainstorm and improve one another's work. According to one of the EC teachers:

> We often had various meetings scheduled in the afternoon, so there was not much time left during the school day to really collaborate. Although we are given daily "planning time/prep time," most of the time, they are used for meetings or other tasks than actual planning and/or collaborating. It was wonderful when and if we got to collaborate and plan together! However, those were few and far between. You know…our TAs are asked to drive the bus on some days, or help with the afterschool duties, so we did not even get the chance to reflect and discuss the day's teaching/learning with our own TA.

DISCUSSION

The purpose of this study was to explore the impact of a STEM-integrated professional development program on EC teachers' pedagogical practices and beliefs about teaching STEM curriculum in pre-K settings. The data collected from interviews with early childhood teachers revealed that all EC teachers were positively impacted by the STEM-integrated PD, resources, and the materials available to implement the STEM units. Consequently, children were positively impacted by their teacher's professional learning and high confidence in teaching STEM-related topics and activities. Excerpts and explanations provided by the teachers above are all supported by previous work done by other researchers showing a direct association between the instructional approach of the teacher and children's learning, indicating that children are more likely to learn from teachers with higher levels of instructional competency (e.g., Hamre et al., 2014; Mashburn et al., 2008; Oades-Sese & Li, 2011).

In addition, the findings of this study support that EC teachers' beliefs about what and how young children learn could critically impact children's acquisition of various emergent knowledge and skills in preschool years reported in research by Çiftçi & Topçu (2022) and Margot & Kettler (2019). Opportunities to improve teaching practices (e.g., teacher research), ongoing professional development support (e.g., integrating STEM), administrative policies that provide a democratic and liberated work environment for teachers, and most importantly, teachers' positive self-efficacy to take on challenges would help early childhood teachers constantly reflect back on their beliefs and make more conscious decisions regarding pedagogical issues (Chen et al., 2021). Research support that teachers who are enthusiastic and knowledgeable about STEM concepts play a vital role in enhancing children's learning (Chen et al., 2021; MacDonald et al., 2020). However, many EC educators are apprehensive about incorporating content areas such as math and science, leading to poor student learning outcomes in those areas. Many teachers are reluctant to teach STEM concepts based on opposing views or misconceptions about the subject (C. Campbell et al., 2018; MacDonald et al., 2020). The findings of the present study suggest that frequent high-quality professional development is necessary for both inservice and preservice teachers. In addition to content knowledge, teachers need to understand and apply pedagogical elements such as gauging student understanding and building on students' knowledge to introduce them to new concepts by carefully planning developmentally appropriate learning goals and objectives.

Empowering young children in STEM also requires the empowerment of the educators who are teaching them. The current need for more STEM curriculum integration is not due to a lack of enthusiasm of the children, parents, or teachers in most cases, but perhaps due to a variety of obstacles that educators might face outside of the programming and resources (Margot & Kettler, 2019). Based on the findings of this study, we include our reflections on factors affecting teachers' pedagogical beliefs about integrating STEM in their classrooms and future directions that need to be taken to make STEM integration in EC curriculums more successful.

Professional Development

Many EC teachers expressed their eagerness to add STEM integrated curriculum to their classroom. However, some teachers also acknowledged the confidence level, preparedness, and support they need to teach STEM topics successfully. Not only can this influence the effectiveness of a new curriculum, but these feelings and assumptions can also be transferred to the children. Growing confident and critical thinkers of young students require having confident STEM mentors to guide them. By providing thorough training, resources, and support, educators can be empowered to lead the classroom with curiosity, excitement, and enthusiasm and pass on these feelings around STEM to their students. Particularly in early childhood education, providing teachers with **hands-on, authentic, and experiential learning experiences** (a very effective learning model for early STEM development) helps them empathize with their students - mirroring their own curious and joyful approach to STEM (Brenneman et al., 2019). Such PDs can also empower educators by sharing STEM content knowledge, developing STEM practices, and building confidence to provide more meaningful STEM experiences for children. Research supports that EC teachers who have STEM teaching experience and relevant PDs reported interests in STEM or participated in STEM-related activities, show higher levels of STEM self-efficacy in terms of cognitive concept, affective attitude, and equipped skill (Chen et al., 2021; MacDonald et al., 2020). Targeted STEM-related PDs also help teachers become inspiring STEM mentors who promote positive attitudes, confidence, and natural curiosity in their classrooms. As a mentor, a teacher can also monitor and balance the right amount of challenges for their students to keep these skills active without overwhelming or discouraging them (Ryu et al., 2019). As mentioned by the EC teachers in this study, they often face their own time and responsibility restrictions that limit their investments in new teaching methods and professional development. By providing the resources for teachers to learn, train on new ideas, and cultivate their own inspiration and enthusiasm, teachers can continue to share that enthusiasm with their students and focus their energy on the classroom.

Building a Web of STEM Learning Resources and Support

During the interviews, the EC teachers shared their perspectives regarding the importance of receiving support to fully implement a STEM-integrated curriculum. Teachers need an ecosystem of enabling resources to implement STEM-integrated curricula successfully. Beyond supplies and materials, activating a network of museums, libraries, and community organizations can contribute to a web-effect of STEM learning and continue to build connections in young children through experiential learning. Many museums and libraries partner with non-profit organizations to bring learning labs and special STEM events to their facilities. Collaborating with community partners and organizations can help build a multi-dimensional infrastructure of experiences for young learners outside of the classroom (Alan et al., 2019). Educators also benefit from having open and receptive communication with school administration to keep the curriculum and its implementation fresh and effective (compelling instead of effective?). Creating an accessible system for teachers to share curriculum ideas with colleagues and administration creates a collaborative environment to continue to grow and succeed with the curriculum. It should also be acknowledged that each school system faces its own unique challenges (DeJarnette, 2018). An integrated STEM curriculum requires appropriate and stimulating materials/resources for teachers as well as children to investigate, problem-solve, design, and test and retest hypotheses. Schools with little to no funds to afford appropriate materials and/or consumable supplies may hinder early childhood teachers from effectively engaging their students with STEM-related activities. Some students have limited technology or internet access at home, and some schools face limited curriculum budgets to incorporate the STEM learning programs they would like for their students. Finding organizations, grants, and opportunities that can assist teachers could be the difference in closing the STEM gap for the next generation (Li et al., 2020).

LIMITATIONS AND RECOMONDATIONS

Some limitations must be considered when evaluating the findings from the current study. The first potential limitation relates to the convenience sampling method used in this study. The participants were volunteers from the STEM curriculum PD project; thus, the participants' characteristics in this study might not represent the general teachers' population. The respondents were drawn from a state-wide population. Considering the small number of participants and the inherent bias in convenience sampling, the sample is unlikely to represent the population being studied, which undermines our ability to generalize from our sample to the population being studied. In regard to another limitation, although the gender and ethnicity of participants are representative of EC teachers' workforce in the field, the lack of representation of other gender and ethnical groups (males and others) in this study should be noted. Future studies should examine or replicate this study with more participants and different sampling methods. More research, including the EC workforce's perceptions, needs, and perspectives in terms of quality STEM integrated curriculum, would add valuable insight into the potential directions that leadership development should take in the field. Future research also needs to examine other existing EC programs that incorporate STEM integrated curriculums and PDs better understand how they prepare the EC teachers to take on STEM teaching and what direction needs to be taken to make those kinds of preparation programs more effective and available.

CONCLUSION

Engaging in early STEM learning activities can lead to positive academic and developmental outcomes for young children by building on how children learn and explore the world. Empowering young children in STEM requires the empowerment of the educators who are teaching them which highlights the current need for more STEM curriculum integration. In addition to starting STEM concepts early, being consistent, providing proper training and professional development support for educators, and enabling a network of STEM resources for educators, programs and children, this kind of structured curriculum can provide the framework for children to gain a solid foundation in STEM fluency and empower their educators to be inspiring STEM mentors.

REFERENCES

Alan, B., Zeng, F. K., & Keçeci, G. (2019). Using STEM applications for supporting integrated teaching knowledge of pre-service science teachers. *Journal of Baltic Science Education*, *18*(2), 158–170. Retrieved from https://eric.ed.gov/?id=EJ1310484

Aldemir, J., & Kermani, H. (2017). Integrated STEM curriculum: Improving educational outcomes for Head Start children. *Early Child Development and Care*, *187*(11), 1694–1706. https://doi.org/10.1080/03004430.2016.1185102

Atiles, J. T., Jones, J. L., & Anderson, J. A. (2013). More than a read-aloud: Preparing and inspiring early childhood teachers to develop our future scientists. *Teacher Education and Practice*, *26*(2), 285–299. Retrieved from https://eric.ed.gov/?id=EJ1044780

Bagiati, A., & Evangelou, D. (2015). Engineering curriculum in the preschool classroom: The teacher's experience. *European Early Childhood Education Research Journal*, *23*(1), 112–128. https://doi.org/10.1080/1350293X.2014.991099

Brantlinger, E., Jimenez, R., Klingner, J., Pugach, M., & Richardson, V. (2005). Qualitative studies in special education. *Exceptional Children*, *71*(2), 195–207. https://doi.org/10.1177/001440290507100205

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Brenneman, K., Lange, A., & Nayfeld, I. (2019). Integrating STEM into preschool education; Designing a professional development model in diverse settings. *Early Childhood Education Journal*, *47*(1), 15–28. https://doi.org/10.1007/s10643-018-0912-

Campbell, C., Speldewinde, C., Howitt, C., & MacDonald, A. (2018). STEM practice in the early years. *Creative Education*, *09*(01), 11. https://doi.org/10.4236/ce.2018.91002

Campbell, P. H., Milbourne, S., Dugan, L. M., & Wilcox, M. J. (2006). A Review of evidence on practices for teaching young children to use assistive technology devices. *Topics in Early Childhood Special Education*, *26*(1), 3–13. https://doi.org/10.1177/02711214060260010101

Chen, Y.-L., Huang, L.-F., & Wu, P.-C. (2021). Preservice preschool teachers' self-efficacy in and need for STEM education professional development: STEM pedagogical belief as a mediator. *Early Childhood Education Journal*, *49*(2), 137–147. https://doi.org/10.1007/s10643-020-01055-3

Çiftçi, A., & Topçu, M. S. (2022). Pre-service early childhood teachers' challenges and solutions to planning and implementing STEM education–based activities. *Canadian Journal of Science, Mathematics and Technology Education*, *22*(2), 422–443. https://doi.org/10.1007/s42330-022-00206-5

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches*. Thousand Oaks, CA: Sage

DeJarnette, N. K. (2018). Implementing STEAM in the early childhood classroom. *European Journal of STEM Education*, *3*(3). Retrieved from https://eric.ed.gov/?id=EJ1190735

Guzey, S., Moore, T., & Harwell, M. (2016). Building up STEM: An analysis of teacher-developed engineering design-based STEM integration curricular materials. *Journal of Pre-College Engineering Education Research (J-PEER)*, *6*(1). Retrieved from https://doi.org/10.7771/2157-9288.1129

Hamre, B., Hatfield, B., Pianta, R., & Jamil, F. (2014). Evidence for general and domain-specific elements of teacher-child interactions: associations with preschool children's development, *Child Development*, 85, pp. 1257–1274. https:// doi: 10.1111/cdev.12184

Hapgood, S., Czerniak, C. M., Brenneman, K., Clements, D. H., Duschl, R. A., Fleer, M., Greenfield, D., Hadani, H., Romance, N., Sarama, J., Schwarz, C., & VanMeeteren, B. (2020). The importance of early STEM education. In *Handbook of Research on STEM Education*. Routledge

Hatch, J. A. (2002). *Doing qualitative resaerch in educational settings*. Albany: State University of New York Press

Li, Y., Wang, K., Xiao, Y., & Froyd, J. E. (2020). Research and trends in STEM education: A systematic review of journal publications. *International Journal of STEM Education*, *7*(1), 11. https://doi.org/10.1186/s40594-020-00207-6

MacDonald, A., Huser, C., Sikder, S., & Danaia, L. (2020). Effective early childhood STEM education: Findings from the little scientists evaluation. *Early Childhood Education Journal*, *48*(3), 353–363. https://doi.org/10.1007/s10643-019-01004-9

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education*, *6*(1), 2. https://doi.org/10.1186/s40594-018-0151-2

Martín-Páez, T., Aguilera, D., Perales-Palacios, F. J., & Vílchez-González, J. M. (2019). What are we talking about when we talk about STEM education? A review of literature. *Science Education*, *103*(4), 799–822. https://doi.org/10.1002/sce.21522

Mashburn, A., J., Pianta, R., C., Hamre, B., K., Downer, J.,T., Barbarin, O., A., Bryant, D., Burchinal, M., Early, D., M. & Howes, C. (2008). Measures of classroom quality in prekindergarten and children's development of academic language and social skills, Child Development, 79, pp. 732–749. https://doi.org/10.1111/j.1467-8624.2008.01154

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation (2nd ed.)*. San Francisco,CA: Jossey-Bass

Moore, T. J., Johnston, A. C., & Glancy, A. W. (2020). STEM integration: A synthesis of conceptual frameworks and definitions. In *Handbook of Research on STEM Education*. Routledge

NAE and NRC. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. https://doi.org/10.17226/18612

Oades-Sese, G. V. & Li, Y. (2011) Attachment relationships as predictors of language skills for at-risk bilingual pre-school children. *Psychology in the Schools*, 48, pp. 707–722. https://doi.org/10.1002/pits.20597

Ryu, M., Mentzer, N., & Knobloch, N. (2019). Preservice teachers' experiences of STEM integration: Challenges and implications for integrated STEM teacher preparation. *International Journal of Technology and Design Education*, *29*(3), 493–512. https://doi.org/10.1007/s10798-018-9440-9

Simoncini, K., & Lasen, M. (2018). Ideas about STEM among Australian early childhood professionals: How important is STEM in early childhood education? *International Journal of Early Childhood*, *50*(3), 353–369. https://doi.org/10.1007/s13158-018-0229-5

U.S. Department of Health and Human Services, Administration of Children and Families, Office of Head Start. (2020). *A National Overview of Grantee CLASS® Scores in 2018*. ECLKC.Retrieved from https://eclkc.ohs.acf.hhs.gov/data-ongoing-monitoring/article/national-overview-grantee-class-scores-2018

Wan, Z. H., Jiang, Y., & Zhan, Y. (2021). STEM Education in early childhood: A review of empirical studies. *Early Education and Development*, *32*(7), 940–962. https://doi.org/10.1080/10409289.2020.1814986

Willig, C. (2013). *Introducing qualitative research in psychology*. McGraw-Hill.

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