

# Thai Preschool Teachers' Experiences Implementing STEM-Based Education: Values, Challenges, and Success Factors\*

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## Abstract

STEM education plays a vital role in 21st-century learning. However, studies on Thai preschool teachers' experiences in implementing STEM-based learning remain limited. This qualitative case study aimed to investigate the experiences of preschool teachers participating in STEM learning initiatives organized by the Institute for the Promotion of Teaching Science and Technology (IPST). The primary participants were ten preschool teachers purposively selected to capture diversity in school affiliation, region, and teaching experience. Secondary participants included three school administrators and three parents of preschool children, who provided contextual and supporting perspectives. Data were collected through in-depth individual interviews, a focus group interview with teacher participants, interviews with secondary participants, and document analysis. Data were analyzed using qualitative content analysis and coding. The findings revealed three key themes: (1) the value of STEM-based learning, encompassing benefits for children, teachers, and schools; (2) challenges in implementation, including children's readiness, teacher abilities, resource allocation, and workload; and (3) success factors, including key characteristics of preschool STEM teachers, as well as cooperation and support both within and outside the school. The context-bound findings suggest the need for sustained teacher development, school support, and family-community collaboration.

**Keywords:** STEM education, science, preschool teachers, professional development

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## **Introduction**

The world is undergoing rapid changes in various aspects, including politics, economy, society, lifestyle, and technology. The World Economic Forum (2022) emphasizes that in the era of Education 4.0, young people must develop essential skills for living and working in the future. These include innovative and creative thinking, technological proficiency, global citizenship, interpersonal skills, and 21st-century skills. Such skills can be nurtured through problem-based learning and collaborative experiences. Fundamental skill development should begin early to enable children to think critically, creatively, and analytically, as well as to work collaboratively (Battelle for Kids, 2019). These capabilities are vital for adaptability, problem-solving, and overcoming challenges in the future.

In Thailand, STEM education has been recognized as a key strategy within the National Education Plan B.E. 2560–2579 (2017–2036). Since 2013, the Ministry of Education has promoted STEM implementation through collaboration between the Institute for the Promotion of Teaching Science and Technology (IPST) and the Office of the Basic Education Commission (OBEC), including research, curriculum development, learning materials, and STEM-based instructional activities disseminated to schools (Office of the Education Council, 2017, 2018, 2020). However, efforts to establish a strong foundation for STEM-related learning experiences in early childhood education have been ongoing since 2006, led by the IPST, a public agency under the Ministry of Education (Promkatkeaw et al., 2022).

Between fiscal years 2020–2022, IPST implemented a project to develop learning resources and instructional processes for early childhood education. The project created integrated STEM activity sets in science, mathematics, and technology to help young children build knowledge, develop skills, and apply learning to design products or solutions to real-life problems through engineering design processes (EDP) and inquiry-based learning (The Institute for the Promotion of Teaching Science and Technology [IPST], 2014, 2022).

The development process included drafting, pilot testing, evaluation, and revision before dissemination to preschool teachers and educators as guidelines for organizing learning experiences. The pilot was conducted in 40 classrooms across diverse educational settings, including the Office of the Basic Education Commission (OBEC), the Office of the Private Education Commission (OPEC), the Department of Local Administration (DLA), the

Ministry of Higher Education, Science, Research, and Innovation (MHESI), and the Border Patrol Police Bureau (BPPB). These schools represented diverse contexts, including opportunity expansion schools, municipal schools, and large schools.

Although STEM education has been increasingly promoted in Thai early childhood education, limited research has examined preschool teachers' experiences of implementing STEM-based learning in authentic classrooms across diverse school contexts. Teachers involved in the IPST project can provide insights into how STEM-based learning was implemented, perceived, and supported in practice.

This study therefore aimed to explore the experiences of preschool teachers who participated in the IPST project, focusing on their implementation of STEM-based learning experiences. The grand tour question was: *What happened during your participation in the IPST project to implement STEM-based learning experiences?* Three sub-questions were posed:

1. What were preschool teachers' experiences with STEM implementation?
2. What were preschool teachers' perspectives on STEM-based learning experiences?
3. What key insights emerged from preschool teachers' STEM implementation?

## **Literature review**

STEM education is an interdisciplinary approach that integrates science, technology, engineering, and mathematics through rigorous, relevant, and real-world learning experiences. It is an experiential pedagogy in which knowledge and skills are applied through integrated projects or real-world problem-solving contexts (National Science Teaching Association [NSTA], 2020; Vasquez, 2015; Vasquez et al., 2020). Related approaches in early childhood education include STEAM, which integrates the arts to support creativity, design, and multiple forms of expression (Berman, 2023; Bush & Cook, 2019; DeJarnette, 2018). Studies show that STEM education enhances children's learning outcomes and attitudes while fostering communication, problem-solving, critical thinking, social-emotional learning, life skills, collaboration, executive function, and interest in STEM-related careers (McClure et al., 2017; National Research Council [NRC], 2014; Peterson et al., 2018; Sarama

et al., 2018).

Across international contexts, early childhood educators value STEM education but report varying preparation and confidence, particularly in technology and engineering. Common challenges include limited content and pedagogical knowledge, difficulties in planning and adapting integrated activities, insufficient time and resources, and limited administrative and professional support (MacDonald et al., 2021; O'Neill et al., 2023; Park et al., 2017; Yildirim, 2021). These findings suggest that effective preschool STEM implementation requires not only teachers' STEM content knowledge but also an understanding of child development and developmentally appropriate pedagogy, including activity design, questioning, facilitation, classroom management, and assessment (McClure et al., 2017; National Association for the Education of Young Children [NAEYC], 2019; Sarama et al., 2018).

Research on STEM implementation and professional learning indicates that teachers benefit from hands-on experiences, model activities, curriculum materials, collaboration, expert guidance, and sustained support. Professional development can strengthen teachers' STEM understanding, instructional skills, confidence, and ability to connect learning with real-world problems. However, constraints related to time, workload, resources, and classroom composition often persist (Lo, 2021; Mesutoglu & Corlu, 2023; Yoon et al., 2018). In early childhood settings, particularly mixed-age classrooms, ongoing collaborative learning and opportunities to adapt STEM activities to children's developmental levels are important (Flanagan et al., 2024; Leung, 2023).

Taken together, previous studies show that early childhood STEM implementation is shaped by interactions among teacher competence, developmentally appropriate pedagogy, classroom conditions, professional learning, and institutional support. However, limited attention has been given to Thai preschool teachers' accumulated experiences of implementing STEM in real classrooms, including the values they perceived, the challenges they encountered, and the conditions they identified as supporting success across diverse school contexts. This study addresses this gap by examining teachers' experiences within the IPST project, with administrators' and parents' perspectives used to contextualize and corroborate teachers' accounts.

## Method

*A qualitative case study approach* was adopted to examine preschool teachers' experiences within the *bounded context* of the IPST's Early Childhood Learning Resources and Instructional Processes Development Project, using interviews as the primary data source.

### Research Context and Participants

The study was situated within the IPST's Early Childhood Learning Resources and Instructional Processes Development Project, implemented in 40 classrooms across six regions of Thailand during the 2022 academic year. The project served as the *bounded case*, while participating schools and participants provided embedded perspectives on STEM implementation. This bounded system (Creswell & Poth, 2018) enabled examination of diverse school contexts and instructional practices. Sixteen participants were included in the study. Ten preschool teachers were purposively selected as primary participants for their information-rich contributions (Hatch, 2007) across diverse professional backgrounds, qualifications, and geographic locations. To provide contextual and corroborating perspectives, six secondary participants were also included, comprising three administrators selected based on availability and willingness, and three parents identified through teacher nominations. Participants were classified as follows:

**The primary participants** were ten preschool teachers purposively selected based on their participation in the IPST project. Their background details are summarized in Table 1.

All teachers held bachelor's degrees in early childhood education, except Teacher B, a history major. Six also held master's degrees in related fields: educational psychology (Teacher A), educational research (Teacher E), early childhood education (Teacher F), elementary education (Teacher D), and educational administration (Teachers G and H). Contexts included suburban, medium- to large-sized, and mixed-age settings. Assignments varied: some taught one grade yearly, Teachers E and H moved with students, and Teacher B taught mixed-age groups. Curricula followed authority and school guidelines. STEM was implemented through discrete lessons, daily integration, and projects using IPST samples and teacher-designed lessons.

Table 1. *Background Information of primary participants*

| Teacher | Affiliation | Region    | Gender | Age<br>(Years) | Teaching<br>Experience<br>(Years) | Years<br>in IPST<br>Project | Student's<br>Age<br>(Years) | Number<br>of<br>Students |
|---------|-------------|-----------|--------|----------------|-----------------------------------|-----------------------------|-----------------------------|--------------------------|
| A       | OBEC        | West      | Female | 49             | 27                                | >10                         | 5–6                         | 18                       |
| B       | BPPB        | North     | Female | 37             | 10                                | 5                           | 3.5–9                       | 14                       |
| C       | OBEC        | South     | Female | 28             | 6                                 | 1                           | 4–5                         | 24                       |
| D       | DLA         | North     | Female | 53             | 30                                | 5                           | 5–6                         | 15                       |
| E       | OBEC        | Northeast | Female | 43             | 17                                | 1                           | 5–6                         | 30                       |
| F       | MHESI       | Central   | Female | 38             | 10                                | 1                           | 5–6                         | 28                       |
| G       | OBEC        | East      | Female | 37             | 12                                | 5                           | 5–6                         | 12                       |
| H       | OPEC        | North     | Female | 40             | 19                                | >10                         | 5–6                         | 25                       |
| I       | OBEC        | Central   | Female | 49             | 27                                | >10                         | 4–5                         | 25                       |
| J       | BPPB        | South     | Female | 51             | 27                                | 1                           | 5–6                         | 15                       |

*Note.* OBEC = Office of the Basic Education Commission; BPPB = Border Patrol Police Bureau; DLA = Department of Local Administration; MHESI = Ministry of Higher Education, Science, Research, and Innovation; OPEC = Office of the Private Education Commission.

**Secondary participants** comprised three administrators and three parents from primary participants' classrooms. The administrators, selected by availability and willingness, were two principals and one deputy principal from OBEC, DLA, and OPEC. All were female, aged 35-50, based in Northern and Western Thailand, with 4 to over 24 years of administrative experience and IPST involvement ranging from project inception to over 10 years. Parents were identified through teacher-nominated snowball referral and included two mothers and one aunt, aged 26-40.

At the time of data collection, the lead researcher was an IPST academic staff member and doctoral student in early childhood education with experience in preschool STEM teacher development. Involvement in the IPST project and prior relationships with some participants positioned the researcher as an insider, potentially influencing data collection and interpretation. The co-researcher, a university faculty member with expertise in early childhood education and qualitative research, reviewed the research process and interpretations. Member checking and peer debriefing were used to strengthen credibility.

### Research Instruments

Semi-structured interviews were the main data collection tool. The interview protocol

included background questions and open-ended questions designed to elicit participants' experiences without leading their responses. Questions were adapted for each participant group. The main question was: *"What happened during your participation in the IPST project to implement STEM-based learning experiences?"* Table 2 presents the sub-questions, objectives, and interview guidelines for each group.

Table 2. *Interview Protocol for participants*

| Sub-question                                                                      | Objective                                                                                                     | Interview Guidelines                                                                         | Primary participants | Secondary participants |         |
|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|----------------------|------------------------|---------|
|                                                                                   |                                                                                                               |                                                                                              | Teachers             | Administrators         | Parents |
| 1. What were preschool teachers' experiences with STEM implementation?            | To explore preschool teachers' experiences with STEM implementation.                                          | 1.1 How were STEM-based learning experiences implemented, and what were participants' roles? | •                    |                        |         |
|                                                                                   |                                                                                                               | 1.2 What challenges were encountered, and how were they addressed?                           | •                    | •                      |         |
|                                                                                   |                                                                                                               | 1.3 What support was needed or provided?                                                     | •                    |                        |         |
|                                                                                   |                                                                                                               | 1.4 How did administrators or parents support teachers?                                      |                      | •                      | •       |
| 2. What were preschool teachers' perspectives on STEM-based learning experiences? | To understand preschool teachers' perspectives on STEM-based learning experiences.                            | 2.1 What were your views on the STEM learning experience?                                    | •                    | •                      | •       |
|                                                                                   |                                                                                                               | 2.2 What challenges did you perceive in STEM implementation?                                 | •                    |                        |         |
|                                                                                   |                                                                                                               | 2.3 What value do you see in STEM education?                                                 | •                    |                        |         |
| 3. What key insights emerged from preschool teachers' STEM implementation?        | To identify key insights emerging from preschool teachers' implementation of STEM-based learning experiences. | 3.1 What changes did you observe after implementation?                                       | •                    | •                      | •       |
|                                                                                   |                                                                                                               | 3.2 What lessons or insights did you gain?                                                   | •                    |                        |         |
|                                                                                   |                                                                                                               | 3.3 What factors contributed to successful STEM implementation?                              | •                    | •                      |         |

## Data Collection

Prospective participants were contacted to explain the study and obtain consent. Official permission was sought from the researcher's affiliated institution and participating schools. After approval, interviews were scheduled at the participants' convenience.

Individual in-depth interviews with primary participants were conducted mainly online via Zoom, audio-recorded, and transcribed. One focus group interview was also conducted with three teachers available at the same time, using the same semi-structured protocol. Participants answered questions, elaborated on one another's responses, and provided additional examples from their STEM implementation experiences. One teacher responded in writing. Interviews lasted 30–50 minutes for primary participants and 10–30 minutes for secondary participants. Additional data included photos, videos, lesson plans, and portfolios. Table 3 summarizes data sources by group.

Table 3. *Participants and Data Sources*

| Participants           |                | Data Collection Methods/Data Sources |           |                   |                 |        |              |            |
|------------------------|----------------|--------------------------------------|-----------|-------------------|-----------------|--------|--------------|------------|
|                        |                | Interview                            |           |                   | Document Review |        |              |            |
|                        |                | Online meeting                       | Telephone | Written responses | Photos          | Videos | Lesson Plans | Portfolios |
| Primary participants   | Teachers       | •                                    |           | •                 | •               | •      | •            | •          |
| Secondary participants | Administrators | •                                    |           | •                 |                 |        |              |            |
|                        | Parents        |                                      | •         |                   |                 |        |              |            |

Each interview began with an explanation of the study and recording consent. Broad, open-ended questions were followed by probes to explore participants' experiences in greater depth. Transcripts were checked for accuracy and returned for member checking. This study was conducted with careful consideration of research ethics and participants' rights. Participants were informed about the study purposes, confidentiality, and their rights to decline participation, request data withdrawal, or withdraw from the study at any time. Pseudonyms were used in transcripts and data presentation, identifying information was removed, and all data were kept confidential and reported in de-identified form for academic purposes.

### Data Analysis

Data were analyzed using qualitative content analysis by segmenting, coding, and categorizing data from individual interviews and the focus group interview with teacher participants as the primary data sources. Interviews with secondary participants and documentary sources were used to contextualize and corroborate the teachers' accounts.

Open coding was used to identify and label transcript units. Related codes were compared, grouped, and organized into categories, themes, and subthemes. Coding was conducted manually using symbols, color codes, and abbreviations to organize and compare data. The analysis revealed three main themes and nine subthemes: (1) Value of Implementing STEM Learning Experiences; (2) Challenges in Implementing STEM Learning Experiences; and (3) Success Factors in Implementing STEM Learning Experiences. Secondary-participant and documentary data refined, contextualized, and corroborated the thematic structure.

To ensure trustworthiness, we conducted member checking by inviting participants to review and verify their transcripts. Direct quotations were included to represent each theme. Peer debriefing with an expert was conducted to enhance credibility and dependability of the analysis.

## Results

Analysis of individual interviews, a focus group interview, interviews with administrators and parents, and documentary data revealed three primary themes, as summarized in Figure 1. Teachers were the principal source of the findings, while administrators, parents, and documents provided contextual and corroborating evidence.

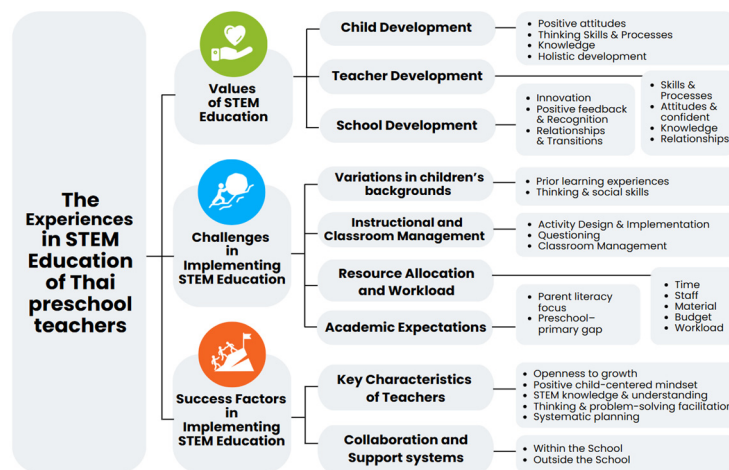


Figure 1. Preschool Teachers' Experiences in Implementing STEM Education

### Theme 1: Value of Implementing STEM Learning Experiences

**Child Development:** All teachers emphasized that STEM supports children's *holistic development*, including physical, emotional, social, linguistic, and cognitive development. They reported that STEM learning fostered positive attitudes, essential skills, and knowledge, while nurturing children's enthusiasm, confidence, perseverance, and self-expression:

*"STEM fosters holistic development: motor skills, emotional and social development, responsibility, collaboration, language, thinking, and curriculum-aligned knowledge." (Teacher A)*

*"The children are happy and eager to come to school... Sometimes they succeed, sometimes they fail, but they learn to change their mindset... When they succeed, they feel proud together." (Teacher I)*

*"...From my classroom research on positive attitudes toward learning science, mathematics, and technology through STEM... children's average scores improved after the intervention." (Teacher F)*

A parent's observation corroborated teachers' accounts of changes in children's confidence and self-expression:

*"One thing that changed is that my child became more confident to speak out." (Parent A)*

Teachers also reported that STEM enhanced children's *thinking and process skills*, including questioning, planning, problem-solving, creativity, critical thinking, and communication, as well as social-emotional skills such as collaboration, patience, and emotional regulation:

*"Creativity is the first thing children develop... Communication, planning together, controlling emotions, listening to others, and teamwork... fostered ethics, patience, and sharing." (Teacher J)*

*"They can work together, plan, and solve problems... showed significant cognitive development including EF (executive function)." (Teacher A)*

Parents' and administrators' observations corroborated these teacher accounts:

*"My child has improved greatly, especially in creativity and communication skills." (Parent B)*

*"My niece used to be shy and quiet. Group activities at school helped her open up and interact more*

*with friends and even at home. Teachers sometimes involve families too.” (Parent C)*  
*“Children have increased creativity and better judgment; they also became more confident.”*  
*(Municipal school administrator)*

Teachers from various school types observed that hands-on, interdisciplinary STEM activities promoted learning, *knowledge* integration, and understanding of core concepts:

*“Children learn more easily... because they get to experiment, design, and discuss.” (Teacher D)*

*“Children learn from their own and peers’ questions or problems through active participation, sharing ideas, and learning various subjects, including mathematics, Thai language, and arts. STEM fosters diverse skills and playful learning that motivates children.” (Teacher B)*

An administrator’s observation supported teachers’ accounts of integrated and meaningful learning:

*“STEM education enriches children’s thinking processes and deepens learning... knowledge is integrated in everyday life.” (Private school administrator)*

**Teacher Development:** Teachers reflected on improvements in planning, teaching strategies, questioning, attitudes, confidence, and professional relationships. They reported that implementing STEM enhanced their *systematic thinking and instructional skills*:

*“I learned to plan my work more systematically. Before, I thought teaching for ten years was enough, but STEM challenged me to change and plan in a structured way...” (Teacher D)*

*“My questioning has changed... I’m always thinking about what questions to ask next.” (Teacher H)*

Despite fatigue and preparation demands, teachers expressed *positive attitudes and growing confidence*:

*“I feel happy and successful when I see children eager to learn... It’s worth it.” (Teacher C)*

*“I enjoy implementing STEM. Hearing children laugh and seeing their smiles is rewarding. The first three months were tiring, but by the second semester, children gained solid foundations and progressed quickly. I hope STEM activities continue regularly.” (Teacher I)*

They gained *deeper understanding* of STEM activity planning, language use, questioning,

and integration, often learning alongside children:

*“I changed a lot. Previously, I mostly told children what to do without encouraging their own thinking or design. Now, I understood the process and gradually adapted to be more systematic.”*  
(Teacher H)

*“Some new teachers... didn’t know what STEM was... They changed their mindset and became more systematic in planning and question phrasing, and more confident...”* (Teacher I)

STEM implementation fostered *collaboration* among teachers, administrators, parents, and the community:

*“I developed myself, used teaching materials, and gained support from colleagues, administrators, and parents. Joining the IPST STEM training helped me connect with peers... we still share ideas to improve child development. It was very beneficial.”* (Teacher D)

**School Development:** Teachers reported that STEM enhanced school identity and innovation, strengthened community ties, and bridged preschool and primary levels. Administrators’ observations provided evidence for these accounts.

*“Our school gained a lot from STEM, developing innovations and representing the municipal schools in presentations and competitions, even winning awards.”* (Teacher D)

*“STEM has become a school achievement. The principal and primary teachers agreed and supported continuing STEM activities to prepare children for Grade 1.”* (Teacher G)

*“Parents appreciate the activities... we always receive praise from the school committee.”*  
(Municipal school administrator)

## Theme 2: Challenges in Implementing STEM Learning Experiences

**Variations in children’s backgrounds:** Six teachers noted variation in children’s STEM backgrounds, especially among beginners. Variations reflected prior STEM experience, school entry, and inconsistent attendance during COVID-19. Teachers reduced task difficulty, built foundational understanding, grouped children by ability, and assigned support teachers when available. They also noted COVID-19’s effects on learning continuity and social adjustment, requiring additional support and peer interaction.

*“When new children struggle to understand, one teacher works closely with those who grasp the*

*concepts, while another encourages those still learning to follow along with peers. For children with no prior STEM experience, activities are adjusted to suit younger age levels..." (Teacher H)*

*"Some children who did not attend online classes in the previous semester lacked the foundation. Compared with previous years, they needed more support in communication and understanding, and teachers had to rebuild basic concepts before moving forward." (Teacher I)*

**Instructional and Classroom Management:** Teachers faced challenges in *designing* age-appropriate STEM activities, using *open-ended questions*, and *managing diverse or large classrooms*. Novice teachers struggled to adapt lessons and grasp STEM concepts, while experienced ones emphasized modeling questioning techniques. Strategies like small groups, peer support, and home kits helped address mixed-age and online learning contexts.

*"In my mixed-age class, with children aged 3.6 to 8 years, it's hard to design one activity that fits all. So, we group older kids with younger ones to help explain and model." (Teacher B)*

*"Teachers sometimes answer too quickly, asking closed questions and not letting children think. We must learn to pause and encourage thinking." (Teacher A)*

**Resource Allocation and Workload:** Teachers faced challenges: *time constraints*, *staff shortages*, *limited materials*, *budget gaps*, and excessive non-teaching tasks. These issues affected STEM quality, prompting solutions like flexible scheduling, peer coaching, and small-group work. Teachers called for more staff, equitable resources, and reduced administrative burdens to support effective implementation.

*"Other tasks squeeze out STEM time... If authorities understood, they'd take non-teaching duties off our plate, but that hasn't happened." (Teacher G)*

*"There's only one teacher handling everything. We really need more hands..." (Teacher B)*

**Expectations and transition to primary school:** Parents' emphasis on reading and writing and disparities between preschool and primary curricula posed challenges. Teachers addressed these by increasing parental understanding through demonstrations and meetings:

*"It's a challenge to help parents understand these activities. After 20 years of teaching, they still focus on reading and writing... So, we share short videos or examples to show them what their*

*children can really do, and send homework so they see children's capabilities." (Teacher A)*

*"Policy and curriculum gaps mean preschool and primary expectations don't align. So, we meet with parents to explain that preschool already covers key skills for grade 1, such as observation, planning, inquiry, and experimentation." (Teacher I)*

Challenges varied by context. Mixed-age and small-school teachers emphasized classroom management and activity adaptation, whereas larger-school teachers cited coordination, workload, and resources. Experienced IPST teachers emphasized mentoring and questioning, while newer teachers focused on STEM concepts and activity design.

### **Theme 3: Success Factors in Implementing STEM Learning Experiences**

**Key Characteristics of Preschool STEM Teachers:** Teachers identified specific beliefs, attitudes, knowledge, and practical skills as important for effective STEM implementation. Administrators' accounts supported these teacher-identified characteristics. Five characteristics emerged:

1) *Openness to Learning and Continuous Self-Development:* Teachers emphasized the importance of a growth mindset and ongoing professional learning. Effective STEM teachers are open to new ideas, actively seek new knowledge, and are committed to continuous self-improvement.

*"Teachers must always seek new knowledge so that children can continuously engage in fresh and meaningful learning." (Teacher C)*

*"...Teachers are continuously developing themselves." (OBEC School Administrator)*

2) *Belief in Children's Potential and Positive Reinforcement:* Belief in children's abilities and positive reinforcement were foundational to quality STEM learning. Encouragement, affirmation, and avoiding premature judgment nurtured curiosity and motivation.

*"Don't rush to assess or judge children. Sometimes they can learn more than we expect. Use positive language, give encouragement, and praise their efforts. Let them try things on their own. Don't pressure them; they'll want to do it and want to learn." (Teacher B)*

*"Teachers need to reinforce children positively... praise them. If something doesn't work, offer*

*encouragement and help them think through the problem: 'Ah! Almost there, just a little more... Why do you think it's not moving? Where would you fix it? How can I help you?' And if they can't figure it out, we might guide them: 'Should we try fixing this part? Want to give it a go?'" (Teacher E)*

3) *STEM Knowledge and Understanding of Developmentally Appropriate Practices:* Effective STEM teaching requires both content knowledge and an understanding of child development. Teachers emphasized designing activities that match children's developmental levels and interests, and tailoring resources to their school context.

*"Teachers must understand the activities and plan well. STEM activities often require various materials, so resources must be sufficient and appropriate. We can adapt them flexibly to suit our context." (Teacher A)*

*"Teachers need to understand STEM in order to develop their students. Let children gain understanding through hands-on experience, not rote memorization. STEM should be usable in real-life situations." (Teacher J)*

4) *Facilitating Thinking and Problem Solving through Hands-on Learning:* Teachers facilitated independent problem solving through hands-on activities, thought-provoking questions, and materials that stimulated curiosity and critical thinking.

*"If we want children to be thinkers, we must let them do things themselves. At first, they're hesitant, afraid of making mistakes or failing. But once they try it, they start to become braver... We need to offer consistent activities for it to be effective." (Teacher E)*

*"Teachers play a key role by guiding children gently, not solving problems for them, but helping them see why something didn't work. Then we let them try again while supporting them..." (Teacher H)*

5) *Systematic Planning, Preparation, and Collaboration:* Systematic planning, preparation, collaboration with colleagues, administrators, and parents, and support from all parties increased implementation effectiveness.

*"Teachers must prepare before teaching, regardless of the topic. We need to understand the content clearly; otherwise, children will misunderstand too." (Teacher J)*

*"Preparation is essential, including steps and materials. We must have a process, resources,*

*communication, and support from all parties, including administrators, colleagues, and parents. Everyone's involvement is crucial." (Teacher A)*

### ***Collaboration and Support:***

#### ***Internal School Support***

Teachers across school affiliations identified *administrative support*, encouragement, resource provision, and cross-level collaboration between preschool and primary education as key to successful STEM implementation.

*"Our administrator values STEM from preschool to primary... Any materials we request for STEM are easily approved, and we receive support from parents and colleagues alike." (Teacher A)*

Teachers also highlighted how *internal collaboration among staff* helped streamline planning and improve teaching practices:

*"All teachers are involved... we plan together... administrators and teachers meet in our PLC to discuss daily activities, get feedback, and integrate everyone's input. We move forward as one." (Teacher H)*

*"All three early childhood levels work as a team. Senior teachers help junior ones, and they learn from each other. Our principal provides advice, supports events, and facilitates meetings. Parents and the community also collaborate." (Teacher J)*

Having an *on-site expert or advisor* was another key support factor:

*"We're fortunate that our administrator serves as an advisor, always providing new insights, sharing educational developments and ideas... which encourages us to seek and absorb knowledge continuously." (Teacher H)*

*"It really helps having a mentor (name of advisor) who guides us through areas we don't understand, observes our sessions, and gives constructive feedback." (Teacher E)*

Administrators' accounts corroborated teachers' emphasis on *continuous teacher development* and financial support:

*"We promote teacher competence through diverse development programs, including formal and informal training, direct experiences, regular PLCs, and reflective practices, to ensure continuous*

*learning.” (Private School Administrator)*

*“We support teacher growth through budget allocations and encourage effective STEM integration via the PLC process. The key is shared understanding between administrators and teachers, carried out with the PDCA cycle.” (OBEC School Administrator)*

### **External Support**

Teachers emphasized partnerships with parents, community members, experts, and educational organizations, which provided resources, shared knowledge, and enriched learning environments. Parents helped prepare materials, participated in activities, and sometimes served as guest speakers:

*“Parents cooperate a lot... for example, with homework involving design and construction. One parent even volunteered as a guest speaker after learning from YouTube when we couldn't find an external learning source on soap-making.” (Teacher H)*

*“Parents contribute knowledge, materials, and even help children reflect on their day, so they can share their learning with their families.” (Teacher E)*

Community members provided authentic STEM learning opportunities:

*“The key is collaboration among parents, administrators, and community experts to provide access to learning materials, environments, and knowledgeable guest speakers.” (Teacher C)*

*“When we did a project on trams, children got to ride one and learned from the staff how it worked. They then designed and built their own version to take their friends on a pretend trip to Udon Thani.” (Teacher E)*

External support, including equipment, manuals, training, and mentorship, was also critical. Networking with other schools further enhanced learning:

*“What really helped was: 1) the STEM guidebook and training from IPST, 2) expert guidance, 3) materials and equipment, 4) support from parents, administrators, and community, and 5) advice and supervision from the educational district office.” (Teacher E)*

*“We've received strong support from IPST through training, equipment, and answers to our questions, along with full backing from our school leadership.” (Teacher F)*

Teachers reported that *external training* enhanced their knowledge, confidence, and motivation. They recommended continuing such programs and providing age-specific activity plans to reduce content overlap across levels:

*“Training with IPST has empowered teachers. It gave us confidence and foundational knowledge to implement activities correctly. We’d love future trainings for new teachers too.” (Teacher I)*

*“We want more good activities like those from IPST. Some teachers aren’t confident in designing activities. If experts provide plans we can study, use, or adapt, that would be very convenient... Clear guidance and age-specific manuals help a lot.” (Teacher A)*

## Discussion

### The Value of STEM Education for Early Childhood Development

This study shows that STEM-based learning fostered *positive learning attitudes* among children, including engagement, enjoyment, persistence, confidence, and reduced fear of mistakes. This aligns with research emphasizing STEM’s role in curiosity, critical thinking, communication, collaboration, persistence, and interest in science, technology, and mathematics (IPST, 2020; Sarama et al., 2018). Engineering design stimulates curiosity and creative problem-solving (Estapa & Tank, 2017; Moore et al., 2018; NRC, 2014).

STEM activities supported *cognitive, social, and emotional* development through problem-solving, creativity, teamwork, emotional regulation, and ethical behavior. These findings are consistent with studies reporting gains in creativity, scientific thinking, and science process skills (Kitkrajang & Kongruang, 2019; Murcia & Oblak, 2022). Teachers’ observations of emotional regulation and collaboration also support research connecting STEM with social-emotional learning (Peterson et al., 2018). Hands-on, integrated problem-solving promoted learning, knowledge transfer, and language and literacy development (IPST, 2020; Sarama et al., 2018).

### The Key Characteristics of Preschool STEM Teachers

Analysis of lessons learned from successful STEM learning identified five characteristics of effective preschool STEM teachers, encompassing beliefs, knowledge, and skills. In terms

of *beliefs and attitudes*, effective teachers show confidence in children's abilities, openness to ideas, flexibility, and a commitment to continuous learning. This aligns with MacDonald et al. (2021), who reported that early childhood teachers hold favorable views of STEM and regard early STEM exposure as beneficial. Mesutoglu and Corlu (2023) found that positive teacher perceptions correlate with greater STEM teaching competence and support for interdisciplinary problem-solving. Such attitudes are crucial for effective STEM implementation (Thibaut et al., 2019).

Regarding *knowledge and understanding*, teachers demonstrated a grasp of child development and the ability to design and adapt STEM activities to children's interests and contexts. Their use of engaging, concrete materials aligns with Professional Standards and Competencies for early childhood educators (NAEYC, 2019) emphasizing core content knowledge and integrated learning. Research shows knowledgeable teachers foster children's STEM understanding and habits of mind through developmentally appropriate, play-based experiences (McClure et al., 2017).

In terms of *skills and abilities*, teachers systematically plan and manage activities, scaffold problem-solving, provide positive reinforcement, use effective questioning, and collaborate well. Structured planning is essential to successful STEM learning (Vasquez et al., 2020). Sarama et al. (2018) emphasize teaching strategies such as observing engagement, connecting STEM to children's experiences, encouraging articulation, and extending thinking through prompts.

### **Challenges, Support, and Collaboration in Implementing STEM Learning Experiences**

The findings indicate that preschool STEM implementation involved challenges, including children's varied readiness and prior experiences, difficulties in activity design and questioning, classroom management in diverse or mixed-age settings, limited resources, workload, and parental expectations. These challenges suggest that implementation is shaped by teacher competence and classroom and school contexts. This aligns with Yildirim (2021), who reported difficulties planning STEM activities due to limited content knowledge, and Leung (2023), who found that early childhood teachers needed support in STEM content knowledge, pedagogical strategies, resources, and expert guidance. Mixed-age challenges align with Flanagan et al. (2024), who highlighted difficulties implementing integrated

STEM with young children in multi-grade contexts.

Some teachers needed stronger knowledge and skills, indicating a need for continuous training and instructional guides across units and grade levels. Teachers new to STEM lacked confidence in their subject knowledge and teaching competence. This aligns with McClure et al. (2017), who found that early childhood educators may value STEM but lack confidence, content knowledge, and understanding of child development needed for effective instruction. Thus, targeted professional development should support both STEM content and pedagogy (Estapa & Tank, 2017). Activity design was another challenge. This is consistent with Kongkeaw and Jaruchainiwat (2020), who reported that preschool teachers struggle to design STEM experiences that engage children in novel problem-solving. Teachers lacked understanding of technology and engineering integration. Thammapruteep and Chartisathian (2018) similarly found that teachers perceived technology and engineering as difficult to incorporate into early childhood curricula. MacDonald et al. (2021) found that many early childhood educators lack confidence in STEM content, especially science, technology, and engineering, compared with mathematics. These findings indicate a need to strengthen teachers' knowledge, skills, and confidence in integrated STEM education.

Lessons from STEM implementation emphasize support and collaboration among administrators, staff, parents, communities, and external agencies. *Emotional support* includes recognition and encouragement from leadership and stakeholders. *Cognitive and practical support* includes ongoing professional development, professional learning communities, mentoring, coaching, and curriculum guides. *Organizational support* includes classroom staffing, reduced non-teaching duties, funding, accessible materials, local adaptation, and community resources. These findings align with the National Science Teaching Association (NSTA, 2020), which advocates a shared early childhood STEM vision, sustained teacher development, resources, and collaborative networks among educators, schools, and communities. However, because this study focused on teachers participating in the IPST project within the Thai early childhood education context, the transferability of the findings to other contexts may be limited.

## Recommendations

The findings suggest several recommendations for supporting early childhood STEM

implementation. First, *continuous professional development* should address STEM activity design, open-ended questioning, classroom management, and support for children with diverse learning backgrounds through practical examples, model activities, and local adaptation. Second, *school leaders and policymakers* should address teachers' constraints related to time, workload, materials, staffing, and non-teaching duties. Third, *schools* should communicate with parents about the value of STEM learning beyond reading, writing, and school readiness by sharing examples of children's learning processes and developmental outcomes. Finally, *schools and related organizations* should promote professional learning communities and partnerships with administrators, colleagues, families, communities, and external organizations to sustain STEM implementation.

Future studies should examine how school size, affiliation, resources, teacher experience, and classroom composition influence STEM implementation in preschool classrooms. Further research should develop and evaluate professional development models addressing teachers' needs in STEM activity design, questioning, classroom management, and mixed-age instruction. Comparative studies with non-IPST schools could provide broader insights into sustainable STEM implementation.

## Conclusion

This study highlighted the values, challenges, and success factors experienced by preschool teachers in implementing STEM-based learning experiences within the IPST project. The findings indicate that STEM education supported children's holistic development and promoted teachers' professional growth in planning, questioning, facilitation, and collaboration. At the same time, teachers faced challenges related to children's diverse backgrounds, activity design, classroom management, limited resources, workload, and parental expectations. Overall, the study suggests that effective STEM implementation in preschool classrooms depends on teacher competence, developmentally appropriate practices, and sustained support from schools, families, communities, and external organizations.

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