INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN PROGRESSIVE EDUCATION & DEVELOPMENT
OPEN ACCESS JOURNAL
Vol 14, Issue 01, (2025) E-ISSN: 2226-6348

Stages of Preschool Teacher Competence in Implementing STEM Learning

Michele May Yee Ng & Suziyani Mohamed
Faculty of Education Universiti Kebangsaan Malaysia
Email: michelemayyeeng@gmail.com & suziyanimohamed@gmail.com

To Link this Article: http://dx.doi.org/10.6007/IJARPED/v14-i1/24395 DOI:10.6007/IJARPED/v14-i1/24395

Published Online: 22 January 2025

Abstract
Early childhood education is a critical foundation for lifelong learning. In this context, the STEM (Science, Technology, Engineering, Mathematics) approach is a priority to enhance preschool education in Malaysia, aligned with the National Preschool Standard Curriculum (KSPK). This study aims to assess the competency level of preschool teachers in implementing STEM education, focusing on 21st-century skills knowledge, pedagogy, mathematics, science, engineering, and technology. This study used a quantitative survey design with a questionnaire based on the STEMPCK framework. The study population comprised preschool teachers in Melaka Tengah, with a sample size of 89 teachers determined using the Krejcie and Morgan table for a population of 97 teachers. Data were collected through an online questionnaire and analyzed using descriptive statistics to identify the teachers' competency levels. The findings revealed that teachers demonstrated strong competencies in mathematics and science, while engineering and technology required more attention. Pedagogical knowledge and 21st-century skills were at a satisfactory level, with moderate mean scores. The main challenges identified were integrating engineering concepts and effectively utilizing technology. These findings highlight the need for ongoing training and support for teachers, particularly in engineering and technology. The implications of this study are significant for policymakers and teacher training providers to deliver relevant support to enhance preschool teachers' STEM competencies. Interventions such as TPACK-based training could be considered to strengthen STEM teaching. Overall, investments in adequate training and resources are crucial to ensuring STEM education is holistically implemented at the preschool level.
Keywords: Preschool, Early Childhood Education, STEM, Teacher Competency

Introduction

Early childhood education is a critical phase in establishing the foundation for lifelong learning. According to Rahmatullah et al. (2021), the early childhood development period is a time of rapid growth, particularly in terms of brain development and neural structuring, which greatly influences children's cognitive and social abilities. Therefore, education at this stage plays a vital role in supporting their development. Globally, STEM (Science, Technology, Engineering, and Mathematics) education is increasingly recognized as essential for fostering innovation, critical thinking, and problem-solving skills among young learners. As nations strive to prepare future generations for an ever-evolving technological landscape, early integration of STEM learning has become a key priority.

In Malaysia, the implementation of STEM learning in preschools has been emphasized by the Ministry of Education (MOE), particularly through the revised National Preschool Standard Curriculum (NPSC) in 2017. These efforts aim to equip children with foundational skills aligned with the demands of the 21st century. However, despite these initiatives, challenges remain, particularly in equipping preschool teachers with the necessary competencies to deliver effective STEM instruction. Relevant literature indicates that the implementation of STEM education in early childhood education is not without challenges. For example, Simoncini and Lasen (2018) found that early childhood education professionals often do not view STEM as a primary learning domain and have a limited understanding of STEM as an integrated approach. Similarly, Muhammad Daud (2019) revealed that most science teachers have a low understanding of technology and engineering, which affects their implementation of STEM in teaching.

This study addresses a critical gap in understanding the competencies of preschool teachers in implementing STEM education. Preschool teachers play a pivotal role in shaping the learning environment, fostering creativity, collaboration, and critical thinking skills among children. Yet, limited research has examined their preparedness in terms of STEM-specific knowledge and pedagogical practices. By focusing on preschool teachers in the district of Melaka Tengah, this research aims to assess their competencies across six key domains: 21st-century skills, pedagogical knowledge, and subject-specific knowledge in mathematics, science, engineering, and technology. The findings will contribute to improving STEM education by identifying areas of strength and addressing gaps through targeted training and policy recommendations. Ultimately, this study seeks to enhance the quality of preschool education in Malaysia and provide valuable information to policymakers and teacher training providers.

Literature Review

Theory STEMPCK

While there are differing opinions on the content of Pedagogical Content Knowledge (PCK) in the literature, the model developed by Shulman (1986) has been widely accepted. Shulman (1986) defines PCK as the combination of pedagogical, contextual, and content knowledge developed by teachers to support children’s learning. Teachers develop their PCK through the interaction of content knowledge and pedagogical practices when teaching specific subjects to children. According to Grossman (1990), PCK consists of content knowledge, pedagogical knowledge, and contextual knowledge. Teachers use these three elements together in the teaching process to develop PCK for teaching specific subjects.

In the Technological Pedagogical Content Knowledge (TPACK) model by Mishra and Koehler (2006), PCK is the intersection of pedagogical knowledge (PK) and content knowledge (CK). They describe PCK as the understanding of how to structure teaching methods and tailor content characteristics to suit specific teaching contexts. PCK bridges the pedagogy teachers use, the curriculum design, and the evaluation processes in children's learning. Teachers generate innovative ideas by employing alternative teaching methods to teach specific subjects. By effectively utilizing PCK, teachers can enhance children's existing knowledge and awareness as they engage in creating diverse solutions to the same problems (Mishra & Koehler, 2006).

When examining PCK in STEM education, Saxton et al. (2014) defined STEMPCK as comprising three main elements:
Teachers' knowledge of STEM content.
Teachers' ability to guide children through STEM teaching processes.
Knowledge of integrating technology into the learning environment to enhance STEM content teaching.

Content knowledge is defined as "the amount and organization of knowledge itself in the teacher's mind" (Shulman, 1986). This knowledge encompasses various components, including knowledge of concepts (e.g., principles and definitions), theories, ideas, organizational structures, evidence and proofs, and knowledge construction processes (Shulman, 1986). Teachers with strong knowledge and skills in STEM disciplines can seamlessly integrate STEM education into their practices and develop effective STEM teaching strategies (Ball et al., 2008). Teacher effectiveness in teaching STEM subjects is closely tied to their competency in the respective subjects (Eckman et al., 2016). STEM educators must understand how STEM subjects interact and adapt to each other (Ostler, 2012). In addition to a strong foundation in STEM knowledge, teachers need to adopt modern integrated pedagogical models to align their practices with classroom instruction (Ostler, 2012).

Furthermore, the integration of science, technology, engineering, and mathematics (STEM) is associated with STEM-based professional knowledge (STEMPCK) and STEM teaching professional knowledge (PCK). Teachers with strong STEMPCK are more likely to confidently teach STEM subjects and integrate STEM disciplines into their classrooms (Yıldırım, 2016).

Pedagogical knowledge refers to understanding teaching methods, classroom conditions, assessment processes, and learning mechanisms (Shulman, 1986). Teachers with in-depth pedagogical knowledge understand how students construct knowledge, comprehend cognitive, social, and developmental learning theories, and apply these theories in classroom contexts. They are also aware of classroom dynamics and can manage various activities effectively. Overall, pedagogical knowledge encompasses aspects related to student learning, classroom management, assessment techniques, understanding student characteristics, and preparing and implementing lesson plans (Briscoe & Peters, 1997; Shulman, 1986).

Contextual knowledge refers to understanding internal and external resources influencing teaching and learning processes. Internal resources involve reflections on personal teaching experiences, while external resources include subject knowledge and government regulations on education and policies (Barnett & Hodson, 2001). The context defines the environment in which teaching and learning occur, including the content being taught. Factors such as classroom conditions, environmental characteristics, school culture, students' backgrounds, and school location influence the effectiveness and quality of STEM education (Harris & Hofer, 2011; Shulman, 1986; Yusof et al., 2012).

21st-Century Skills Knowledge

This encompasses the skills and knowledge all students must master for success in life and work. These skills should be taught alongside foundational academic knowledge, such as music, mathematics, and science, as well as critical skills like learning and innovation (e.g., critical thinking and problem-solving, creativity and innovation, communication, and collaboration); literacy (e.g., visual, scientific, and numerical literacy, interdisciplinary thinking, and basic literacy); information, media, and technology skills (e.g., proficiency in information, media, and technology); and life and career skills (e.g., flexibility and adaptability, initiative and self-direction, social and cross-cultural skills, productivity and accountability, and leadership and responsibility) (Binkley et al., 2012).

Effectively incorporating STEM content into learning environments requires teachers to have a deep pedagogical understanding of STEM education and content. Integrating science, technology, engineering, and mathematics into STEM content while ensuring alignment with STEM philosophy is challenging (Margot & Kettler, 2019). Additionally, rapid advancements in information and technology make it difficult for teachers to adapt PCK to learning processes. In this context, enhancing teachers' competencies in using information, communication, and technology (ICT) is essential (Silva et al., 2020). Teachers are expected to possess advanced 21st-century skills and understanding, closely tied to STEM education's nature and essential learning outcomes.

To deliver high-quality STEM education, the STEMPCK framework requires an interaction between STEM content's nature and the combination of various PCK elements. Yıldırım and Şahin Topalcengiz (2019), in their literature review on the theoretical framework of STEM, suggest that it includes content knowledge. This emphasizes that effective STEM education relies on a robust foundation of interdisciplinary knowledge and pedagogical integration.

Pedagogical Content Knowledge for Preschool Teachers (PCK) in STEM (STEMPCK)

Teachers need a deep understanding of STEM content to provide practical and effective STEM education for preschool children. According to Çorlu et al. (2014), teachers who lack a thorough understanding of STEM content and education will struggle to deliver effective STEM learning outcomes to children. Therefore, preschool teachers are expected to possess competencies in STEM content to integrate STEM disciplines and effectively teach them to children during instruction.

Integration knowledge is also critical in STEM education. Preschool teachers are expected to combine STEM content with pedagogy to effectively implement STEM activities in the learning environment (Ostler, 2012). This requires a combination of STEM and PCK. A preschool teacher with a solid understanding of STEM components is expected to use their pedagogical knowledge to integrate STEM at an early stage of children's learning. Pedagogical knowledge for teachers includes activity planning, execution, and evaluation. Teachers should also be skilled in classroom management and teaching methods tailored to child psychology (Shulman, 1986; Briscoe & Peters, 1997).

According to the National Research Council (NRC) (2014), the characteristics of STEM education are essential, and children's 21st-century skills are expected to grow with STEM education. STEM content knowledge and PCK for teachers are anticipated to improve through awareness of children's needs and objectives aimed at enriching their 21st-century skills, considering their developmental stages. These 21st-century skills include life and career skills such as global awareness, information and media literacy, leadership, responsibility, communication, efficiency, technological literacy, creativity, problem-solving, and critical thinking. Teachers should be able to integrate content while creating contexts relevant to regional characteristics, child backgrounds, and school locations when planning STEM activities (Harris & Hofer, 2011).

Sharapan (2012) suggests that preschool teachers' contextual knowledge should include selecting events, phenomena, and objects relevant to children's lives within their surroundings. This is important as relevant contexts can enhance children's learning. Items such as paints, toys, Legos, and gardens can be used to create meaningful contexts for STEM education. According to Allen (2016), STEM activity contexts at the preschool level should be concrete and closely aligned with children's experiences.

Preschool teachers’ knowledge in creating meaningful contexts is expected to positively influence STEM practices. STEMPCK integrates a teacher’s STEM knowledge, pedagogical knowledge, contextual understanding, and essential 21st-century skills to achieve quality STEM education at the preschool level. When teachers have a comprehensive understanding of content within STEM practice, this enhances their confidence in designing and implementing STEM activities (Bers et al., 2013). Teachers can enable multidimensional learning by integrating different disciplines within STEM content, forming connections between these disciplines (Smith & KarrKidwell, 2000). However, when preschool teachers face uncertainty regarding teaching STEM content, this can lead to anxiety and decreased confidence in implementing STEM activities (Hedlin & Gunnarsson, 2014). Therefore, in-service training supporting effective teaching methods and pedagogical skills is essential for teachers to effectively conduct STEM activities (Bers et al., 2013).

According to Chanunan (2021), STEMPCK-based training has had a positive impact on pre-service science and mathematics teachers. This research highlights the importance of teacher training in acquiring the necessary knowledge and skills to teach STEM effectively. Additionally, Faikhamta et al. (2020) developed pedagogical content based on STEM professional development programs and applied them to science teachers. Their study showed that the program had a positive contribution to teachers' STEM knowledge and practices, enhancing their awareness of STEM disciplines.

In conclusion, STEM training for preschool teachers can enhance their STEMPCK, which is essential for designing and implementing quality STEM activities. Teachers receiving STEM training are expected to have higher STEMPCK. Therefore, support for preschool teacher training in STEM fields is crucial to improving STEM education quality and providing sufficient support for children’s development in this area.

Methodology of the Study

This study employs a survey design with a quantitative approach to investigate preschool teachers' competencies in implementing STEM education. This design allows for data collection from a large population of teachers, providing a broader understanding of their competencies. Additionally, the survey collects standardized data through structured questionnaires, minimizing inconsistencies compared to open-ended methods, and is a time-efficient and resource-effective way to gather data from a diverse group of participants. To assess teachers' competencies, the survey will include sections evaluating their knowledge and skills in STEM, as well as their current practices in integrating STEM activities.

Study Location, Population, and Sample

The study was conducted in Melaka Tengah, a central district in the state of Melaka, Malaysia. Melaka Tengah covers an area of approximately 300 square kilometers and borders the districts of Alor Gajah, Jasin, and Melaka Tengah. This district is characterized by a mix of urban, suburban, and rural areas. The population of Melaka Tengah is diverse, primarily comprising Malays, Chinese, and Indians. Melaka Tengah was chosen as the study location due to its representative nature and the presence of government preschools offering STEM education.

The study population includes preschool teachers actively engaged in STEM education within the defined geographical area. According to Krejcie and Morgan's sample size table, the required sample size was determined based on the estimated population size. With a population of 97 preschool teachers obtained from the Melaka State Education Department, the recommended sample size was found to be 79. To account for potential non-responses, the target sample size was increased by 10%, resulting in a final sample size of approximately 89 teachers.

In terms of methodology, the majority of teachers (43.8%) fall within the age group of 40 to 49 years, followed by those aged 30 to 39 years (38.2%). Teachers aged 20 to 29 years account for 7.9%, and those aged 50 and above make up 10.1%. A significant portion of teachers holds a Bachelor's degree (83.1%), with 10.1% holding a Master's degree, and 6.7% holding a Diploma. No teachers in this study possess a Doctorate. Most teachers have more than 15 years of teaching experience (60.7%), followed by those with 11 to 15 years of experience (19.1%). Additionally, 12.4% of teachers have 6 to 10 years of experience, while 7.9% have less than 5 years of experience. A total of 51.7% of teachers have attended STEM courses or training, whereas 48.3% have not been involved in any STEM-related courses.

Table 1
Respondent Demographic Information

Code	Items		*n*	%
A1	Age	20 - 29 years	7	7.9
		30 - 39 years	24	38.2
		40 - 49 years	39	43.8
		50 years and above	9	10.1
A2	Gender	Male	5	5.6
		Female	84	94.4
A3	Highest Education Level	Diploma	6	6.7
		Bachelor's Degree	74	83.1
		Master's Degree	9	10.1
		Doctor of Philosophy	0	0
A4	Teaching Experience	Less than 5 years	7	7.9
		6 - 10 years	11	12.4
		11 - 15 years	17	19.1
		More than 15 years	54	60.7
A5	Number of Students in Class	Less than 10 students	2	2.2
		10 - 20 students	35	39.3
		21 - 30 students	51	57.3
		More than 30 students	1	1.1
A6	School Location	City	73	82
		Suburban	9	10.1
		Rural	7	7.9
A7	Type of School Teaching	National Schools (SK)	70	78.7
		Chinese National Type Schools (SJKC)	15	16.9
		Tamil National Type Schools (SJKT)	4	4.5
A8	STEM Courses Attended	Yes	46	51.7
		Never	43	48.3

Research Instrument

The main instrument for data collection in this study is a questionnaire designed to assess the competencies of preschool teachers in STEM instruction. The questionnaire will include sections on demographic information and STEM competencies of preschool teachers. The questionnaire consists of two parts: Part A (Demographic Information) and Part B (STEM competency of preschool teachers).

Part A collects data on personal factors, educational background, professional experience, and school-related information. Personal information includes age and gender to capture participant diversity. Educational background covers the highest level of education and field of study, reflecting the academic qualifications and STEM-specific training of teachers.

Part B of the questionnaire is structured around the STEMPCK framework, incorporating Shulman’s PCK model, which is the theoretical foundation used for the STEMPCK Scale (Yildirim & Sahin Topalcengiz, 2019). This section includes six main constructs: 21st Century Skills Knowledge, Pedagogical Knowledge, Mathematical Knowledge, Scientific

Knowledge, Engineering Knowledge, and Technological Knowledge. Each construct is designed to evaluate different aspects of a teacher's competency in STEM education. Part B uses a 4-point Likert scale: 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, and 4 = Strongly Agree to measure competencies.

Data Collection and Analysis Procedures

The questionnaire for this study was distributed electronically using an online survey platform, Google Forms. A link to the questionnaire was sent via WhatsApp by the PPD Officer to the targeted group communication of participants. The data collection process took place over a two-month period, from July 1, 2024, to September 1, 2024.

The questionnaire achieved a return rate of 91.8%. The structured data collected underwent a series of analyses to meet the study objectives. Descriptive statistics were calculated to identify the competency levels of preschool teachers in STEM teaching and learning. This involved calculating descriptive measures such as mean, standard deviation, frequency, and percentage for variables related to teacher competencies, including 21st Century Skills Knowledge, Pedagogical Knowledge, Mathematical Knowledge, Scientific Knowledge, Engineering Knowledge, and Technological Knowledge. These statistics provide a summary of the distribution and central tendency of teacher competency scores.

The study assumes that the sample of preschool teachers represents a broader population, with the data distribution not being overly skewed and each competency score being independent between respondents so that findings can be generalized.

Validity and Reliability

To ensure content validity, the questionnaire items were reviewed by an expert in STEM education—a lecturer in Science Education at the Institut Pendidikan Guru Kampus Darul Aman. This review process involved assessing the clarity of questions, relevance of items, and their alignment with the study's objectives. After revisions and improvements, the questionnaire was approved as a valid instrument for measuring preschool teachers' competencies.

A pilot study was conducted involving 30 preschool teachers selected based on demographic characteristics similar to those of the main study sample. The electronic questionnaire was distributed via WhatsApp, and respondents were given a two-week period to complete it. This pilot study aimed to ensure the questionnaire was appropriate and effective in evaluating preschool teachers' competency in STEM learning.

The reliability of the instrument was tested using Cronbach's Alpha, based on data from the 30 pilot respondents. The overall value obtained was 0.963, indicating a very high internal consistency. According to Nunnally (1978), a Cronbach's Alpha value above 0.70 is considered acceptable. Therefore, this questionnaire is confidently deemed suitable for the main study with a very high level of reliability.

Findings

This study aims to assess preschool teachers' competency in implementing STEM education, focusing on six main constructs: 21st-century skills, pedagogical knowledge, mathematical knowledge, scientific knowledge, engineering knowledge, and technological knowledge. Overall, the findings indicate that preschool teachers show varying levels of mastery across these constructs, with relatively high competency in science and mathematics. However, there is room for improvement in engineering and technology.

21st-century skills include abilities such as critical thinking, creativity, communication, and collaboration. In this study, the mean score for this construct was 7.33 (SD = 1.11), indicating a good level of mastery among teachers. Items within this construct reflect teachers' confidence in integrating these skills into STEM instruction. For example, for item B1, which states that teachers are confident in integrating critical thinking skills into STEM teaching, 60.7% of respondents agreed, and 25.8% strongly agreed. This highlights that the majority of teachers feel confident in fostering critical thinking among preschool students.

Table 2
Analysis of Survey Responses to 21st Century Knowledge and Skills

		n (%)					
Code	**Items**	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**	**Mean**	**Standard deviation**
B1	I am confident in integrating critical thinking skills into my STEM lessons.	0	12 (13.5)	54 (60.7)	23 (25.8)		
B2	I can encourage creativity among students through STEM activities.	0	10 (11.2)	55 (61.8)	24 (27.0)	7.33	1.11
B3	I can effectively incorporate communication skills into my STEM teaching.	0	11 (12.4)	54 (60.7)	24 (27.0)		

Pedagogical Knowledge is a fundamental component in education, especially in the preschool context where teaching methods must align with children's developmental stages. The findings indicate that preschool teachers' pedagogical knowledge has an average score of 7.05 (SD = 1.41), reflecting a moderate level of competency in this area.

In item B5, which assesses teachers' ability to adjust teaching strategies according to diverse learning needs, 31.5% of teachers strongly agreed that they can adapt their instruction effectively. However, 21.3% of respondents disagreed. This suggests that while some teachers are capable of flexible and responsive teaching, there is still a need for further support in understanding and implementing adaptable teaching methods that cater to the varied needs of students.

Table 3
Analysis of Study Responses to Pedagogical Knowledge

		n (%)					
Code	**Items**	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**	**Mean**	**Standard deviation**
B4	I know about the various teaching methods that are appropriate for STEM education.	0	22 (24.7)	49 (55.1)	18 (20.2)		
B5	I know how to adapt my teaching strategies to meet the diverse learning needs in STEM.	0	19 (21.3)	42 (47.2)	28 (31.5)	7.05	1.41
B6	I understand how to assess student learning in STEM subjects.	1 (1.1)	21 (23.6)	46(51.7)	21 (23.6)		

Mathematical knowledge among preschool teachers is a crucial element to ensure children develop a strong foundation in mathematics. The study results indicate that the mathematical knowledge construct has an average score of 7.90 (SD = 1.16), which is among the highest compared to other constructs. This reflects that preschool teachers generally possess a solid grasp of mathematical knowledge.

For example, in item B7, which assesses teachers' confidence in teaching basic mathematical concepts to children, 50.6% strongly agreed, while 47.2% agreed. This shows a high level of confidence among teachers in delivering fundamental mathematical concepts effectively.

Table 4
Analysis of Study Responses to Mathematics Knowledge

		n (%)					
Code	**Items**	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**	**Mean**	**Standard deviation**
B7	I can teach basic mathematical concepts to preschoolers.	0	2 (2.2)	42 (47.2)	45 (50.6)		
B8	I can effectively integrate mathematical thinking into daily activities.	0	10 (11.2)	47 (52.8)	32 (36.0)	7.90	1.16
B9	I understand the early childhood mathematics curriculum.	0	6 (6.7)	31 (34.8)	52 (58.4)		

Scientific knowledge is also a crucial component in STEM education, and the findings indicate that preschool teachers have a strong grasp of this area, with an average score of 7.93 (SD = 1.17). Items related to science, such as teaching basic scientific concepts (B10) and creating engaging science activities (B11), show high levels of agreement. Specifically, 44.9%

of teachers strongly agreed that they can effectively teach basic scientific concepts, and another 44.9% strongly agreed that they create science activities that foster students' curiosity.

Table 5
Analysis of Study Responses to Science Knowledge

		n (%)					
Code	**Items**	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**	**Mean**	**Standard deviation**
B10	I teach basic science concepts to preschoolers.	0	3 (3.4)	40 (44.9)	46 (51.7)	7.93	1.17
B11	I create engaging science activities that foster curiosity.	0	10 (11.2)	39 (43.8)	40 (44.9)		
B12	I have a strong understanding of early childhood science curriculum..	1 (1.1)	8 (9.0)	40 (44.9)	40 (44.9)		

The engineering knowledge construct shows a lower level of mastery among preschool teachers, with an average score of 6.72 (SD = 1.61). This suggests that engineering aspects are a challenge faced by teachers in implementing STEM education at the preschool level. Items B13 to B15 indicate that most teachers agree moderately with their ability to teach basic engineering concepts and create engineering activities. For instance, only 21.3% strongly agreed that they could introduce basic engineering concepts to students, while 22.5% disagreed that they could design engineering activities for preschool children (item B14).

Table 6
Analysis of Survey Responses to Engineering Knowledge

		n (%)					
Code	**Items**	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**	**Mean**	**Standard deviation**
B13	I can introduce basic engineering concepts to preschoolers.	2 (2.2)	19 (21.3)	49 (55.1)	19 (21.3)	6.72	1.61
B14	I can design practical engineering activities for children.	6 (6.7)	20 (22.5)	47 (52.8)	16 (18.0)		
B15	I understand how to integrate engineering principles into my teaching.	5 (5.6)	21 (23.6)	48 (53.9)	15 (16.9)		

Lastly, technological knowledge recorded an average of 7.04 (SD = 1.19), indicating a moderate level of competence among preschool teachers in integrating technology into STEM education. Item B16, which focuses on the use of technological tools, shows that 65.2% of teachers agree that they can effectively use technology to support STEM learning. This suggests that while technology still requires improvement, it has started to be embraced by teachers as a valuable tool in teaching.

Table 7
Analysis of Study Responses to Technological Knowledge

		n (%)					
Code	**Items**	**Strongly Disagree**	**Disagree**	**Agree**	**Strongly Agree**	**Mean**	**Standard deviation**
B16	I use a variety of technology tools to support STEM learning.	1 (1.1)	14 (58)	58 (65.2)	16 (18.0)		
B17	I can effectively integrate technology into my STEM lessons.	1 (1.1)	13 (14.6)	60 (67.4)	15 (16.9)	7.04	1.19
B18	I have a strong understanding of the role of technology in early childhood education.	1 (1.1)	14 (15.7)	48 (53.9)	26 (29.2)		

Overall, the findings of this study indicate that preschool teachers have a strong level of competence in science and mathematics, but still require additional support in engineering knowledge. Meanwhile, pedagogical knowledge, 21st-century skills, and technology are at a satisfactory level but with room for improvement. These findings highlight the importance of continuous training and support for preschool teachers, especially in the areas of engineering and technology, to ensure that STEM education can be delivered in a more holistic and comprehensive manner.

Discussion

This study aims to evaluate the competence of preschool teachers in implementing STEM education through the analysis of six main constructs: 21st-century skills, pedagogy, mathematics, science, engineering, and technology. The findings indicate significant variation in teachers' mastery of these constructs, with strong performance in mathematics and science, while engineering and technology require more focused attention.

The study reveals that preschool teachers generally have a high level of competence in STEM education. Teachers demonstrate a strong confidence in integrating STEM elements into their teaching, particularly in encouraging critical thinking and creativity among students. This aligns with previous studies that emphasize that teachers' knowledge and positive attitudes toward STEM education contribute to their preparedness in implementing it (Fatahiyah, Hata & Nur, 2020).

Teachers recorded the highest scores in mathematics and science knowledge, reflecting their confidence in teaching these areas. This aligns with earlier research by Baltsavias and Kyridis (2020), which asserts that in the context of STEM education, foundational knowledge is primarily built through mathematics and science instruction. This process involves developing complex knowledge, emphasizing a deep understanding of mathematical and scientific concepts. This foundation enables teachers to create more meaningful and in-depth perceptions of technology and engineering, which are often abstract and broader in scope. Teachers demonstrate the ability to grasp basic mathematical and scientific concepts, which are essential for supporting STEM education at the preschool level.

However, despite high confidence, findings also indicate areas requiring further attention. For example, many teachers reported limited confidence in introducing basic engineering concepts and designing engineering activities for young children. This highlights that engineering remains a major challenge in STEM education at the preschool level. Similarly, Adam and Halim (2019) noted that barriers to integrating STEM education into the Malaysian curriculum include limited exposure of Science and Mathematics teachers to engineering elements and design processes. These findings suggest that although preschool teachers exhibit strong competence, significant attention must be given to engineering and STEM assessment to ensure a more holistic STEM learning experience. Thus, there is an urgent need to enhance training and support for teachers in engineering to facilitate a more comprehensive STEM education.

Meanwhile, the findings also reveal that the majority of preschool teachers believe they can effectively integrate technology into STEM education. With most teachers expressing confidence in using technological tools, this indicates that technology is increasingly being embraced as a crucial component in STEM education. As technology continues to advance rapidly, the study suggests that continuous support should be provided to teachers in integrating technology into STEM instruction. Today's children will be future creators and users of digital technology, hence they need appropriate access for their development. However, access to technology must be balanced and tailored to the child’s age and developmental stage (Niki Buchan, 2021). Therefore, teachers should be continuously supported to strengthen their ability to effectively integrate technology into STEM education.

The findings of this study have significant implications for policymakers and teacher training providers. The impact on preschool education practices is substantial. Firstly, it highlights the need for more in-depth training, particularly in engineering and technology. Such training can boost teachers' confidence and help them design engaging and relevant activities for preschool students. Secondly, the deficit in pedagogical knowledge suggests the need for more targeted guidance in implementing flexible and responsive STEM teaching strategies tailored to diverse learning needs. Thirdly, to overcome limitations in technology use, institutional support is necessary to ensure fair access to technological tools and infrastructure across all schools.

Moving forward, future studies could focus on the effectiveness of specific training interventions, such as the TPACK framework, in improving teachers' competence. Additionally, broader studies involving various geographic areas could provide a more comprehensive understanding of teachers' competence levels across Malaysia.

Overall, this study highlights that while preschool teachers excel in mathematics and science, there is an urgent need to enhance competence in engineering and technology. Investment in training, resources, and curriculum development is essential to ensure effective STEM implementation at the preschool level. Limitations, such as a focus on specific geographic areas and the use of perception-based surveys, should be considered to ensure future research provides more robust insights.

Conclusion

In conclusion, this study shows that preschool teachers exhibit high confidence in mathematics, science, and 21st-century skills. However, weaknesses in engineering and technology indicate the need for additional intervention through professional training and institutional support. By ensuring teachers have access to adequate training and infrastructure, STEM education at the preschool level can be strengthened to provide a solid foundation for students to meet the challenges of the 21st century.

References

Adam, N. A., & Halim, L. (2019). Cabaran Pengintegrasian Pendidikan STEM Dalam Kurikulum Malaysia. *Seminar Wacana Pendidikan 2019*, *SWAPEN 2.0*. https://www.researchgate.net/publication/335909086_Cabaran_Pengintegrasian_Pendidikan_STEM_Dalam_Kurikulum_Malaysia

Ball, D. L., Thames, M. H., and Phelps, G. (2008). Content knowledge for teaching: what makes it special? *J. Teach. Educ.* 59, 389–407.

Baltsavias, A., & Kyridis, A. (2020). Preschool Teachers' Perspectives on the Importance of STEM Education in Greek Preschool Education. *Journal of Education and Practice*, *11*(14). https://doi.org/10.7176/jep/11-14-01

Barnett, J., & Hodson, D. (2001). Pedagogical context knowledge: Toward a fuller understanding of what good science teachers know. Science Teacher Education, 85(4), 426–453. doi:10.1002/sce.1017

Bers, M. U., Seddighin, S., and Sullivan, A. (2013). Ready for robotics: bringing together the T and E of STEM in early childhood teacher education. *J. Technol. Teach. Educ.* 21, 355–377.

Binkley M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In P. Griffin P., B. McGaw, & E. Care (Eds.), Assessment and teaching of 21st century skills (pp. 17–66). Dordrecht, the Netherlands: Springer. doi:10.1007/978-94-007-2324-5_2

Briscoe, C., & Peters, J. (1997). Teacher collaboration across and within schools: Supporting individual change in elementary science teaching. Science Education, 81(1), 51–65. doi:10.1002/(SICI)1098-237X(199701)81:13.0.CO;2-0

Chanunan, S. (2021). Enhancıng preservıce STEM teachers' STEM PCK and teachıng self-effıcacy through stem pck-based course wıth the uses of experıentıal learnıng coupled wıth worked example ınstructıonal prıncıples. *J. Educ. Naresuan Unıv.* 23, 45–73.

Corlu, M. S., Capraro, R. M., & Capraro, M. M. (2014). Introducing STEM education: Implications for educating our teachers for the age of innovation. Education and Science, 39(171), 74–85.

Eckman, E. W., Williams, M. A., & Silver-Thorn, M. B. (2016). An integrated model for STEM teacher preparation: The value of a teaching cooperative educational experience. Journal of STEM Teacher Education, 51(1), 71–82. Retrieved from http://ir.library.illinoisstate.edu/jste/vol51/iss1/8/

Faikhamta, C., Lertdechapat, K., and Prasoblarb, T. (2020). The impact of a PCK-based professional development program on science teachers' ability to teaching STEM. *J. Sci. Math. Educ. Southeast Asia* 43, 1–22.

Fatahiyah, N., Hata, M., & Nur, S. (2020). Kesediaan Guru Sains dan Matematik dalam Melaksanakan Pendidikan Stem dari Aspek Pengetahuan, Sikap dan Pengalaman

Mengajar. *Akademika*, *90*(Khas 3), 85–101. https://doi.org/10.17576/akad-2020-90IK3-07

Gözüm, A. I. C., Papadakis, S., & Kalogiannakis, M. (2022). Preschool teachers' STEM pedagogical content knowledge: A comparative study of teachers in Greece and Turkey. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.996338

Grossman, P. L. (1990). *The Making of a Teacher: Teacher Knowledge and Teacher Education.* New York: Teachers College Press.

Harris, J. B., & Hofer, M. J. (2011). Technological pedagogical content knowledge (TPACK) in action: A descriptive study of secondary teachers' curriculum-based, technology-related instructional planning. Journal of Research on Technology in Education, 43(3), 211–229. doi:10.1080/15391523.2011.10782570

Hedlin, M., and Gunnarsson, G. (2014). Preschool student teachers, technology, and gender: positive expectations despite mixed experiences from their school days. *Early Child Dev. Care* 184, 1948–1959.

Margot, K. C., and Kettler, T. (2019). Teachers' perception of STEM integration and education: a sySTEMatic literature review. *Int. J. STEM Educ.* 6, 1–16. doi: 10.1186/s40594-018-0151-2

Mishra, P., and Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108, 1017–1054.

Daud, K. (2019). Cabaran guru prasekolah dalam menerapkan Pendidikan Stem. *Jurnal Pendidikan Sains Dan Matematik Malaysia*, *9*(2), 25–34. https://doi.org/10.37134/jpsmm.vol9.2.4.2019

National Research Council [NRC]. (2014). *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research*. Washington, DC: National Academies Press.

Buchan, N. (2021, September 5). *How to get the "T" in STEM*. Essential Resources Educational New Zealand. https://www.essentialresources.co.nz/2021/09/how-to-get-technology-within-stem/?srsltid=AfmBOoq1q1Y425PMvJY1uWmYAbrxTposdTpd-b9lf4sITg14prCqJcxi

Nopiyanti, I., Adjie, N., & Putri, S. (2019). STEAM-PBL in Early Childhood Education: Optimization Strategies for Developing Communication Skills. *Advances in Social Science, Education and Humanities Research*, *503*, 81–86.

Ostler, E. (2012). 21st century STEM education: A tactical model for long-range success. International Journal of Applied Science and Technology, 2(1), 28–33. Retrieved from http://www.ijastnet.com/ journals/Vol_2_No_1_January_2012/3.pdf

Rahmatullah, B., Muhamad Rawai, N., Mohamad Samuri, S., & Md Yassin, S. (2021). Overview of early childhood care and education in Malaysia. *Hungarian Educational Research Journal*, *11*(4). https://doi.org/10.1556/063.2021.00074

Saxton, E., Burns, R., Holveck, S., Kelley, S., Prince, D., Rigelman, N., et al. (2014). A common measurement system for K-12 STEM education: adopting an educational evaluation methodology that elevates theoretical foundations and systems thinking. *Stud. Educ. Eval.* 40, 18–40.

Sharapan, H. (2012). From STEM to STEAM: how early childhood educators can apply Fred Rogers' approach. *YC Young Child.* 67, 36–40.

Shulman, L. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher*, *15*(2), 4–14.

Silva, R., Bernardo, C. D. P., Watanabe, C. Y. V., Silva, R. M. P. D., and Neto, J. M. D. S. (2020). Contributions of the internet of things in education as a support tool in the educational management decision-making process. *Int. J. Innov. Learn.* 27, 175–196.

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

Smith, J., and Karr-Kidwell, P. (2000). The Interdisciplinary Curriculum: A Literary Review and a Manual for Administrators and Teachers. Retrieved from ERIC Database. (ED443172). https://files.eric.ed.gov/fulltext/ED443172.pdf

Sukri, N. H., & Mahmud, S. N. D. (2022). Preschool Teachers' Competency in Stem Education Implementation. *International Journal of Academic Research in Progressive Education and Development*, *11*(2). https://doi.org/10.6007/ijarped/v11-i2/12242

Yıldırım, B. (2016). An analyses and meta-synthesis of research on STEM education. Journal of Education and Practice, 7(34), 23–33. Retrieved from http://www.iiste.org/Journals/index.php/JEP/article/view/34597/35577

Yusof, Y. M., Zakaria, E., & Maat, S. M. (2012). Teachers' general pedagogical content knowledge (PCK) and content knowledge of algebra. The Social Sciences, 7(5), 668–672. doi:10.3923/sscience.2012.668.672